सत्यमेव जयते
Ministry of Housing and Urban Affairs
Government of India

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

प्रधान मंत्री आवास योजना
Pradhan Mantri Awaas Yojana

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

RACHNA 2.0

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

CLIMATE SMART BUILDINGS

Training #43 (RACHNA 2.0) : 2 Day Training Program at Gurugram, Haryana

DAY 1

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

01

INTRODUCTION

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

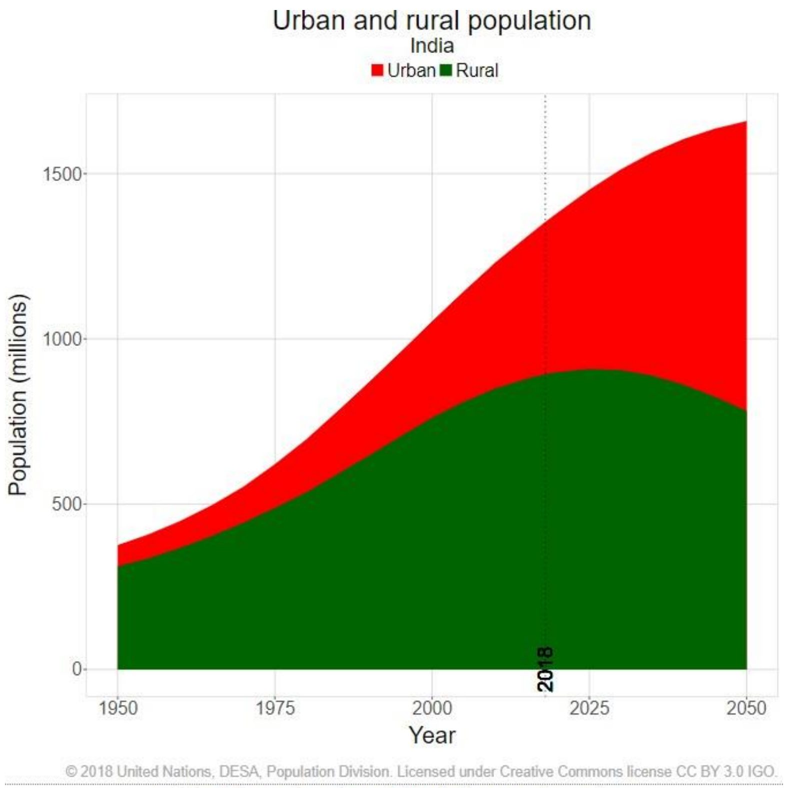
प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

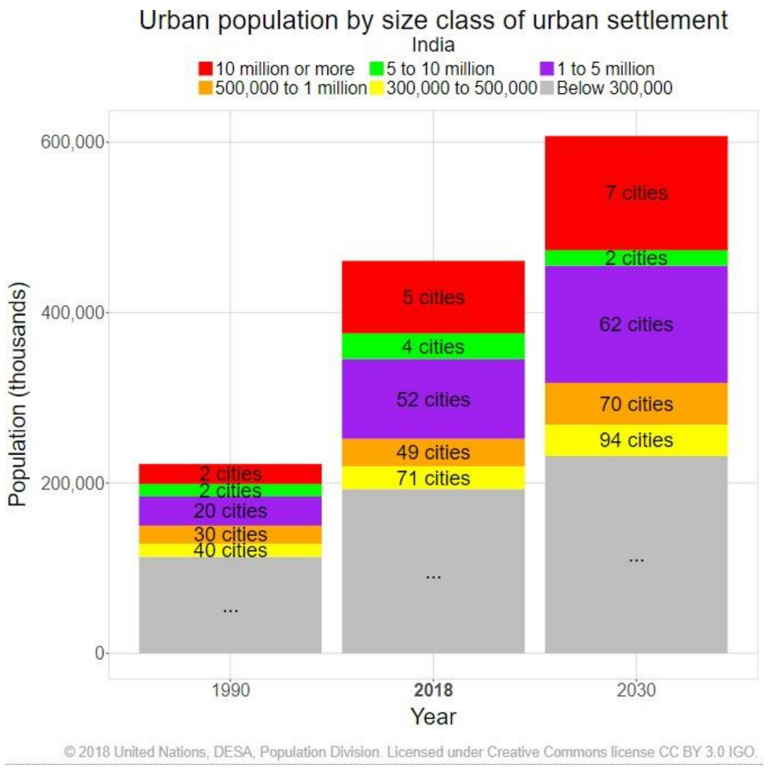
Azadi Ka Amrit Mahotsav

giz

Growing Opportunities with Rapid Urbanization

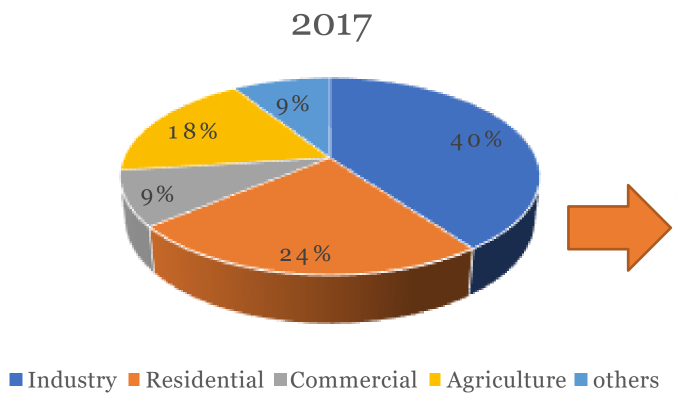


Note: Urban and rural population in the current country.

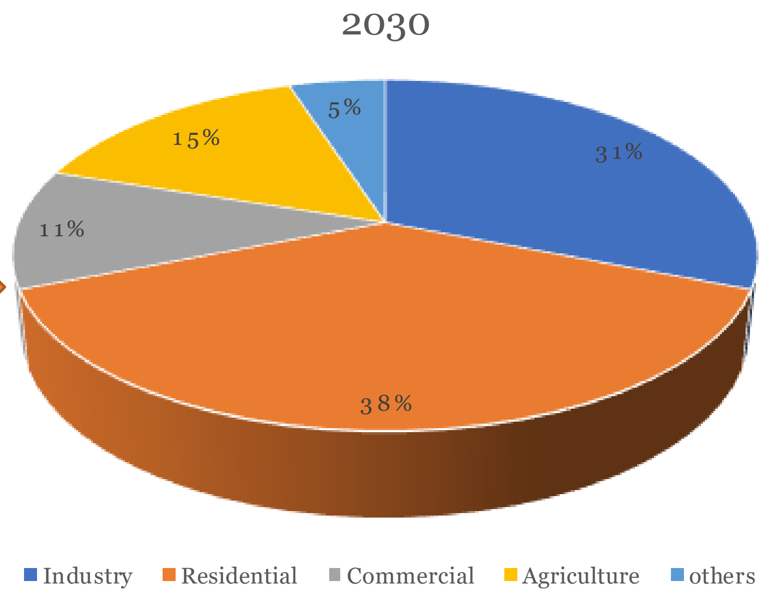


Cities, which will contribute over 80% to GDP by 2050, need to be Receptive, Innovative, and Productive to foster sustainable growth and ensure a better quality of living

Energy demand with Rapid Urbanization



1066 Twh



2239 Twh

Residential Buildings: Fast Growth in Electricity Consumption.
*IESS, NITI Aayog

- Residential buildings consumes around 255 TWh electricity in 2017, the electricity consumption in residential buildings is expected to multiply by **more than 3X** and reach around 850 TWh by 2030. Increased penetration of **air-conditioning / HVAC** in residential building is the key reason for this growth.

- Residential buildings will become the **largest end-user of electricity** in the country accounting for 38% of the total electricity consumption.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

MoHUA Initiates for Urban Transformation

1. RAY
2. PMAY (U)
3. DAY - NULM
4. HRIDAY
5. AMRUT
6. Smart Cities Mission
7. JNNURM

Flagship Missions under the Ministry of Housing & Urban Affairs (MoHUA) aim to achieve Transformative, Inclusive and Sustainable development through planning, development and reforms for achieving Urban Transformation.

Affordable Housing in India

Affordable housing, as defined by the National Planning Policy Framework, is housing for sale or rent for those whose needs are not met by the market.

The provision of affordable housing is a key element of the Government's plan to end the housing crisis, tackle homelessness and provide aspiring homeowners with a step onto the housing ladder

Pradhan Mantri Awas Yojna – Urban

- PMAY-U, launched in 2015, aims to provide houses for homeless. The Government is offering this scheme to all UT's and states. It also offers interest subsidy for Home loans for first time buyers in urban areas
- The residential buildings expected to increase by 2 times in terms of floor area by 2030
- 12 million new affordable homes in Urban areas under PMAY by 2022.

A significant percentage is in the form of high density, multi-storey residential blocks

Very low penetration of air conditioning though majority have ceiling fans

Ensuring Thermal comforts to occupants through design is of prime importance.

PMAY U Features

- All weather housing units with water, kitchen, Electricity & Toilets
- Adequate Physical and Social Infrastructure
- Women Empowerment
- Security of Tenure
- Better quality of life for Urban Poor's

Pradhan Mantri Awas Yojna – Urban

The mission is addressing the affordable housing requirement in Urban areas through following program verticals:

Subsidiary for beneficiary led individual house construction/enhancement. In-Situ Slum Redevelopment (ISSR) for Slums	Affordable housing in partnership with Public & Private Sectors
Promotion of Affordable Housing through Credit linked subsidy	Beneficiary-led Individual House Construction/ Enhancement (BLC-N/ BLC-E)

Project Objectives

Pradhan Mantri Awas Yojana - Urban

11.2 million dwelling units are being constructed

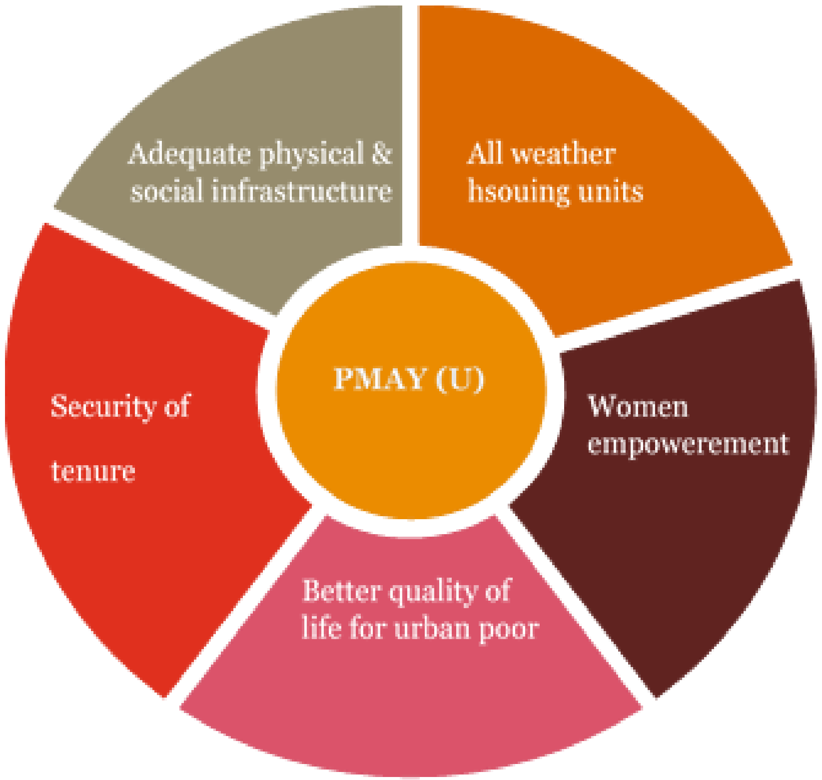
\+

7.35 lakh crores investment

→

10 lakh occupants in the EWS/LIG category benefitting

- **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/enhancement. (ISSR)**



Key features of PMAY-U projects

Global Housing Technology Challenge- India (GHTC-India)

MoHUA has initiated the GHTC-India to identify and mainstream a basket of innovative construction technologies from across the globe for the housing construction sector that is sustainable, eco-friendly, and disaster-resilient.

GHTC-India → 54 Innovative Construction Technologies Shortlisting → Light House projects with 6 selected technologies

AGARTALA, TRIPURA
Light Gauge Steel Structural System & Pre-Engineered Steel Structural System

CHENNAI, TAMIL NADU
Precast Concrete Construction System-Precast Components Assembled at Site

INDORE, MADHYA PRADESH
Prefabricated Sandwich Panel System

LUCKNOW, UTTAR PRADESH
Stay-in-place Formwork System

RAJKOT, GUJARAT
Monolithic Concrete Construction System

RANCHI, JHARKHAND
Precast Concrete Construction System-3D Pre-Cast Volumetric

Components of GHTC India

1

- Grand Expo and Conference on Alternative and Innovative Construction Technologies

2

- Identifying and Mainstreaming Proven Demonstrable Technologies for the Construction of Light House Projects

3

- Identifying Potential Future Technologies for Incubation and Acceleration Support through ASHA – India (Affordable sustainable Housing Accelerators)

Events organized by MoHUA w.r.t. GHTC India Challenge

GHTC-India Launch: 14th Jan 2019



Indian Housing Technology Mela, Lucknow: 5th Oct 2021



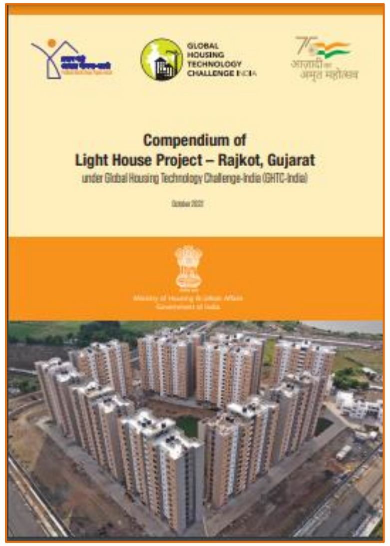



Indian Urban Housing Conclave, Rajkot: 19th Oct 2022

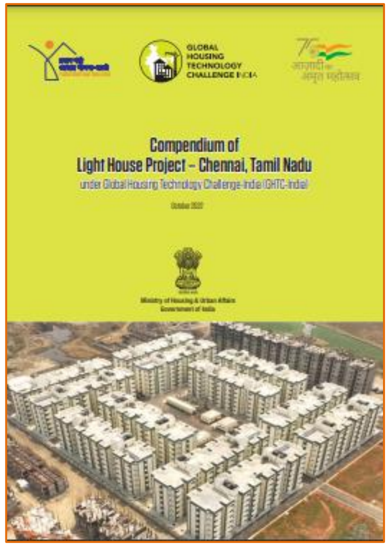


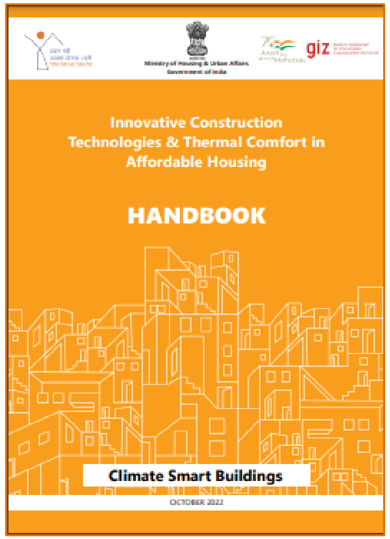
Book Launches by MoHUA under GHTC India Challenge

Compendium of Light House Project Rajkot

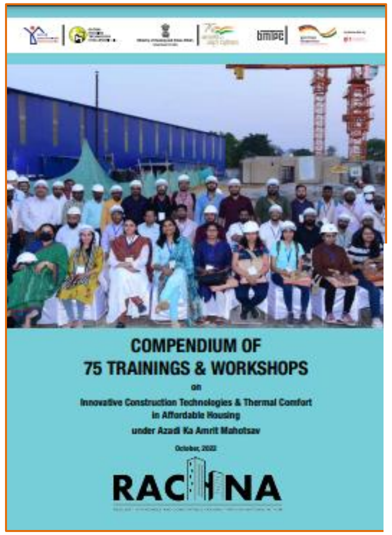


Compendium of Light House Project Chennai





Handbook on Innovative Construction Technologies & Thermal Comfort in Affordable Housing



Compendium of 75 Trainings & Workshops under RACHNA

Climate Smart Buildings Programme (IGEN-CSB)

Government of India/ MoHUA

+

The Federal Ministry of Economic Cooperation(BMZ), Germany/ GIZ

→ IGEN-CSB

Affordable

Climate Smart Building

Climate Resilient

Thermally Comfortable

Key features of a Climate Smart Building

Reduce the demand for air-conditioning by 30-40%	Curtail 30 metric tonnes of CO2
Improve health and wellbeing of people	Support the commitment of GoI towards reducing CO2 emissions

Results of a Climate responsive building design

About the project-"Climate Smart Buildings (CSB): Establishment of the Cluster Cell in Rajkot, Gujarat under Global Housing Technology Challenge-India (GHTC-India)"

Chandigarh	Dadar & Nagar Haveli, Daman & Diu	Gujarat	Haryana	Punjab	Rajasthan

The climate smart building 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 as 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.

Project Objectives

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 in West Cluster

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

WP 4: Capacity development of Govt officials and private stakeholders on thermal comfort in the West Cluster

DAY 1

Tea Break

DAY 1

Session 1: Innovative Construction Technologies of Light House Projects, LHP Study and Observations

02

New Age Innovative Construction Technology & LHPs

Light House Projects

- The aim of the assignment is to introduce thermal comfort into the foray of affordable housing, a critical design & thus usability aspect which unfortunately has been missing from the current nature of affordable housing in India.

- Although studies & policies like the green guidelines for PMAY projects, Eco-Niwas Samhita Part-1, Star Labelling of energy efficient homes etc have been around but what the sector really needs is specific, easy to comprehend provisions which can be mandated & enforced in a steadfast way which is exactly what this project intends to do

Light House Projects

Strategic Intent

- Seamless implementation of LHPs
- Assist in knowledge transfer through documentation of technologies used & implementation of LHPs
- Technical assistance to achieve thermal comfort in demonstration projects
- Support the implementation of thermal comfort provision in state legislature
- Capacity buildings around thermal comfort & sustainable construction

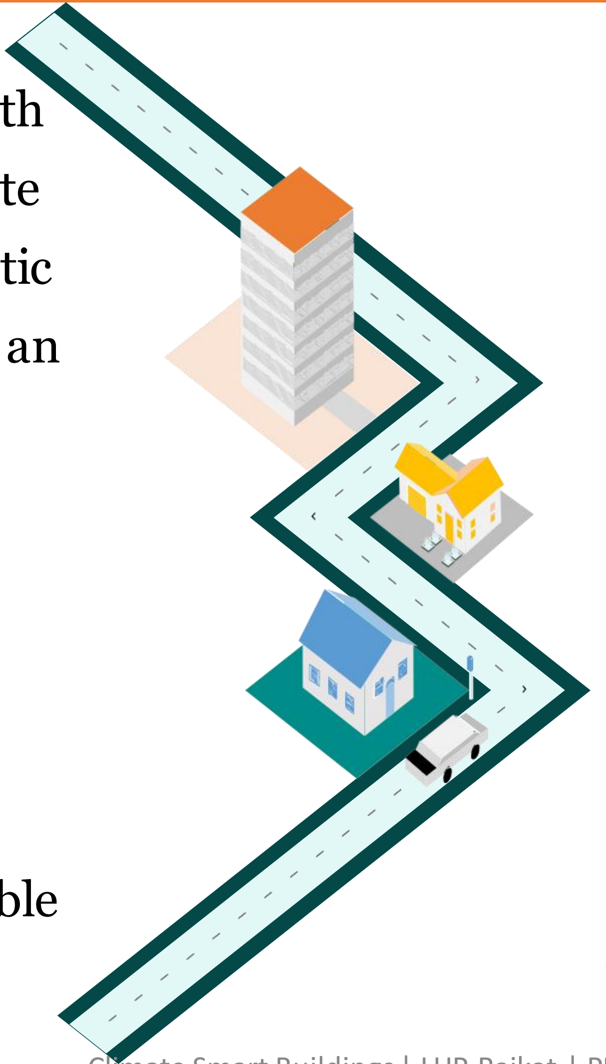
Outcome

- Successful model for the implementation & documentation of LHPs
- Databank of technologies , relevant materials in the state analyzed around various relevant parameters
- Replicable models for thermally comfortable affordable houses in Gujarat (climate sensitive to 3 climatic conditions in the state)
- Thermal comfort provisions mandated by the law
- Better grasp of thermal comfort & sustainability in general among the concerned stakeholders & general public too

What are we working on?

LHPs are model housing projects with houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region, an initiative under the Climate Smart Building Programme.

These projects demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner.



Currently the LHPs' are being implemented in six states (Uttar Pradesh, Gujarat, Madhya Pradesh, Gujarat, Jharkhand, and Tripura) of India under Global Housing Technology Challenge (GHTC) – India. 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.

Details of LHP Projects along with construction Technology Used

LHP Location	TECHNOLOGY SELECTED	NUMBER OF HOUSES TO BE CONSTRUCTED
Rajkot, Gujarat	Monolithic Concrete Construction using Tunnel Formwork	1144
Indore, Madhya Pradesh	Prefabricated Sandwich Panel System	1024
Chennai, Tamilnadu	Precast Concrete Construction System – Precast Components Assembled at Site	1152
Ranchi, Jharkhand	Precast Concrete Construction System – 3D Volumetric	1008
Agartala, Tripura	Light Gauge Steel Structural System & Pre-engineered Steel Structural System	1000
Lucknow, Uttar Pradesh	PVC Stay in Place Formwork System	1040

Features of LHP

Definition

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

Minimum Size of houses

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

Available on-site facilities

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

Design

- Designed as per the dimensional requirements mandated in the National Building Code (NBC) 2016.
- Design in concurrence with existing centrally sponsored schemes and Missions such as Smart Cities, AMRUT, Swachh Bharat (U), National Urban Livelihood Mission (NULM), Ujjwalla, Ujala, Make in India, etc.
- Structural details designed considering durability and safety requirements of applicable loads including earthquakes and cyclone and flood as applicable confirming to applicable Indian/International standards.
- Design of Cluster involves the possibility of innovative system of water supply, drainage and rainwater harvesting, renewable energy sources with special focus on solar energy.

Construction Period

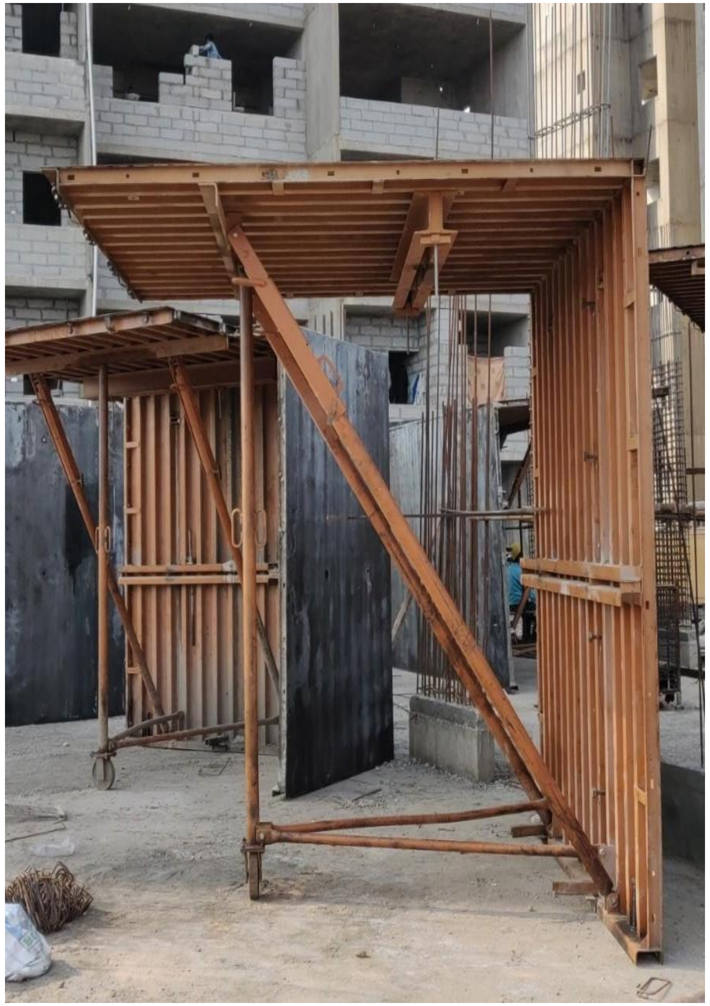
A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

Construction Methodology of LHP Rajkot

Monolithic Concrete Construction using Tunnel Formwork

Tunnel formwork is a mechanised cellular structure construction system. It is made up of two half shells that are joined to make a room or a cell. An apartment is made up of several cells.

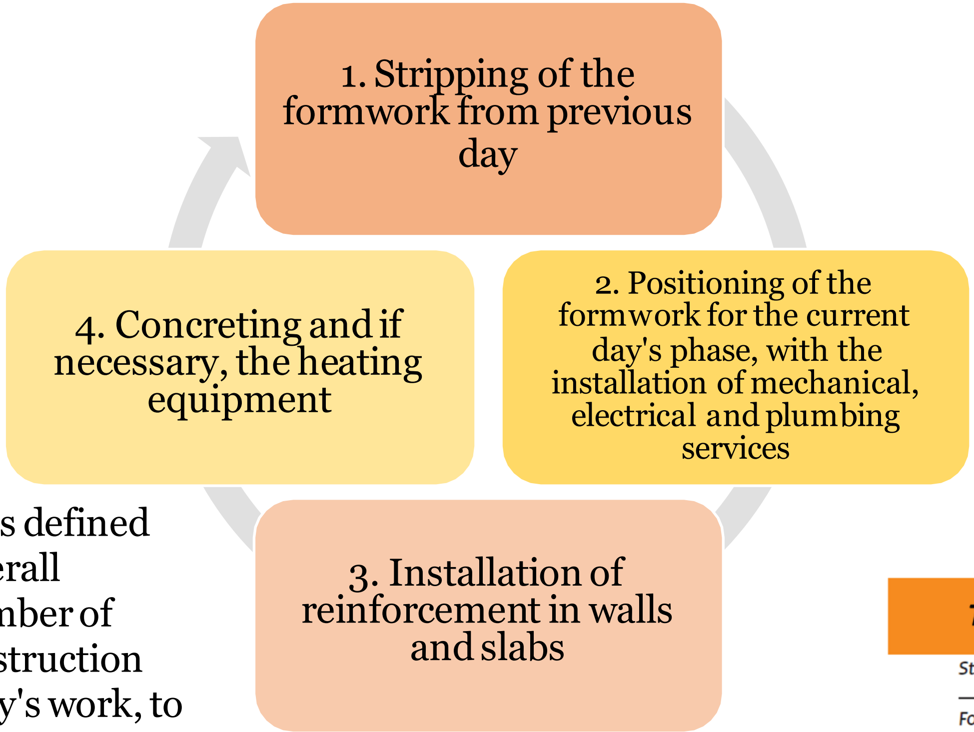
Tunnel forms allow walls and slabs to be cast in one day through several phases to the structure. The programme and the amount of floor area that can be poured in one day define the phasing. The task to be done each day is defined by the 24-Hour cycle. In the morning, the formwork is set up for the day's pour. In the afternoon, the reinforcement and services are installed, and concrete is poured. Concrete for walls and slabs must be poured in one operation once reinforcing has been installed. Early in the morning, the formwork is removed and positioned for the next phase.



The assembly-line approach of the system to construction provides developers and contractors with benefits relating to the certainty of their site schedule, efficient time management and an overall reduction in cost. This enables companies to develop a better quality, monolithic structure that is more acoustically and thermally efficient. The repetitive nature of tunnel form tasks ensures high productivity, and optimum use of labour and these are of considerable benefit to the project manager.

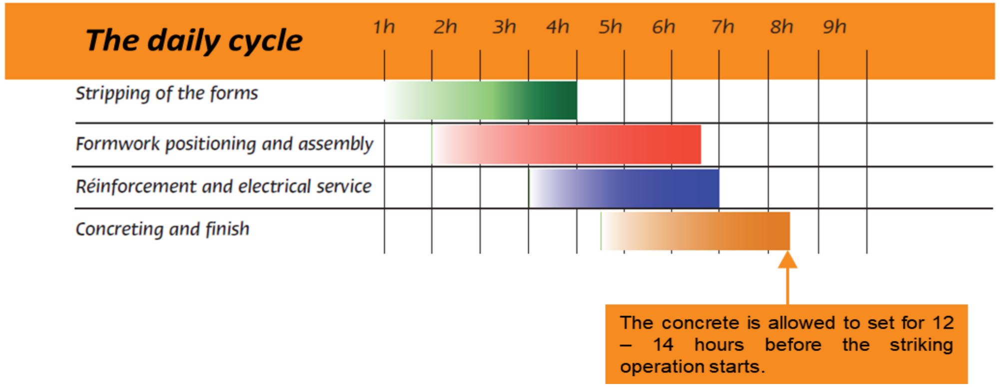
This formwork is manufactured in a completely automated facility in France and there is no manufacturing plant in India.

Construction Methodology – 24 Hour Cycle



The implementation of 24-Hour Cycle shall be in accordance with IS 456:2000 – Code of practice for plain and reinforced concrete. However, the structural engineer shall furnish details about the actual process of removal of formwork after casting of concrete

The task to be done each day is defined by the 24-Hour cycle. The overall structure is divided into a number of more or less comparable construction phases, each matching to a day's work, to establish this cycle. The amount of labour and equipment required is then calculated based on the magnitude of these phases. Every day, the phases are similar to achieve optimal efficiency.



Light House Projects

Following are the details of Construction Technologies being employed at the Light House Projects shortlisted 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 SystemAgartala, Tripura

- 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'. An already established System for building construction in many countries, this system intends to replace the conventional RCC Beam-Column structure which uses steel/plywood shuttering. '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

- An already established System for building construction in China, Australia, African and Gulf countries, this 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. These replace conventional brick & mortar walling construction practices and can be used as load-bearing and non-load bearing walling for residential and commercial buildings. For buildings higher than single storey, the system can be used either with RCC or steel framed structure.
- 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 Assembeled 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 requited 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 Assembeled 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 with 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

An already established System for building construction in Europe, Singapore, Japan & Australia, this 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. These Modules are transported, erected & installed using cranes and push-pull jacks and are integrated together in the form of complete building unit.
Subject to the hoisting capacity, building of any height can be constructed using the technology.

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

An already established System for building construction in Japan, Australia & North America; 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 up to G+3 building. LGSF is used in combination with pre-engineered steel structural system for buildings above G+3 for longevity, speedier construction, strength and resource efficiency.

Under this Light House Project, houses are being constructed using Light Gauge Steel Frame System (LGSF) with Pre-Engineered Steel Structural System.

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 by 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

- Already in use in Canada & Australia, the plant manufactured rigid poly-vinyl chloride (PVC) based polymer components serve as a permanent stay-in-place finished form-work for concrete walls. The formwork System being used acts as pre-finished walls requiring no plaster and can be constructed instantly.
  This System is suitable for residential and commercial buildings of any height from low rise to high rise. 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.

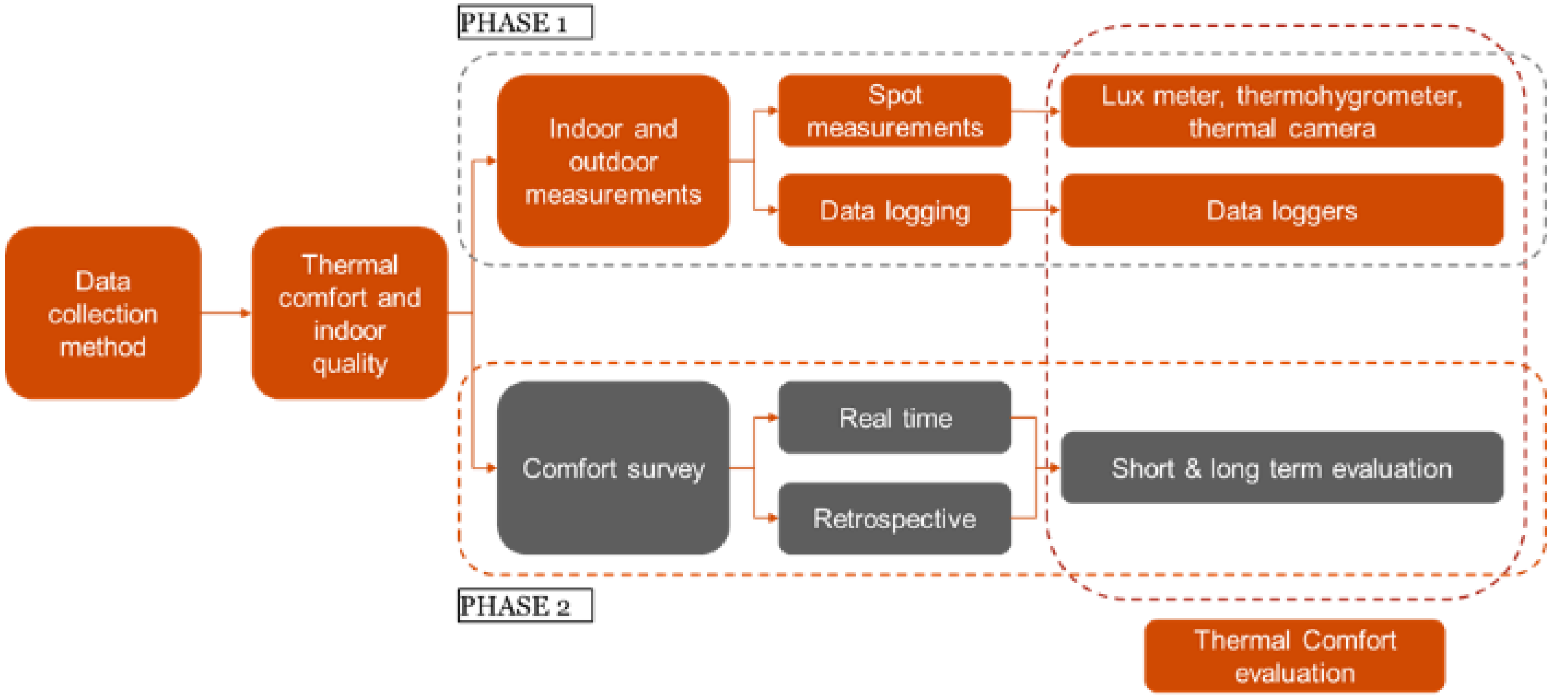
03

Thermal Comfort Analysis & Recommendations on LHPs and Demo Projects

CASE STUDY OF LHP RAJKOT

Thermal comfort study of the Light House Project- Rajkot

The LHP in Rajkot constructed with Monolithic Tunnel formwork technology has been planned and constructed with such specification and layout which would give better thermal comfort compared to conventional construction. GIZ was assigned the task of studying aspect of thermal comfort in LHP project.



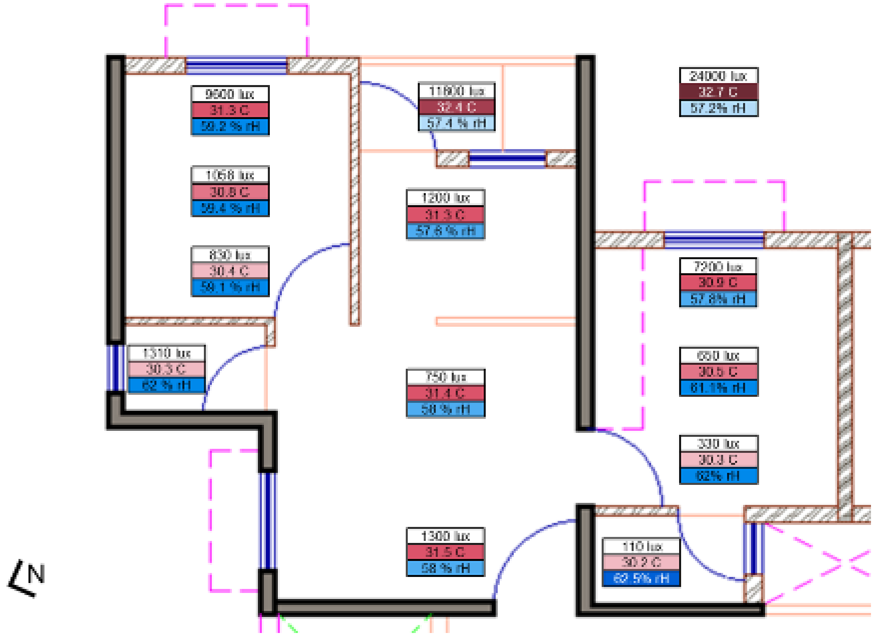
Methodology for monitoring and evaluation

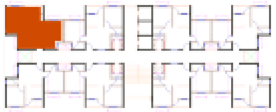
- On-site spot measurements
- dataloggers,
- comparative graphs, and
- a comfort chart

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Thermal comfort study of the Light House Project- Rajkot

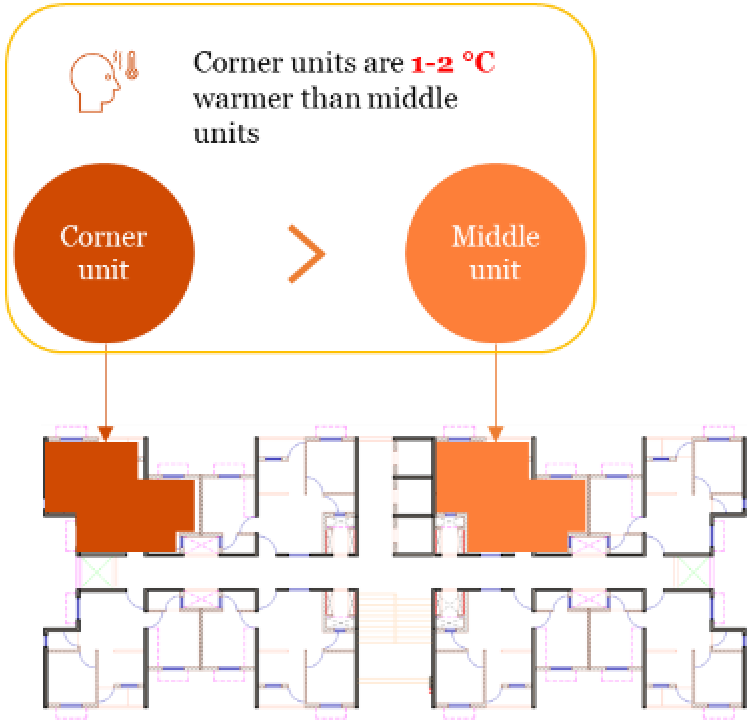
On-site spot measurements





Key Plan

Findings

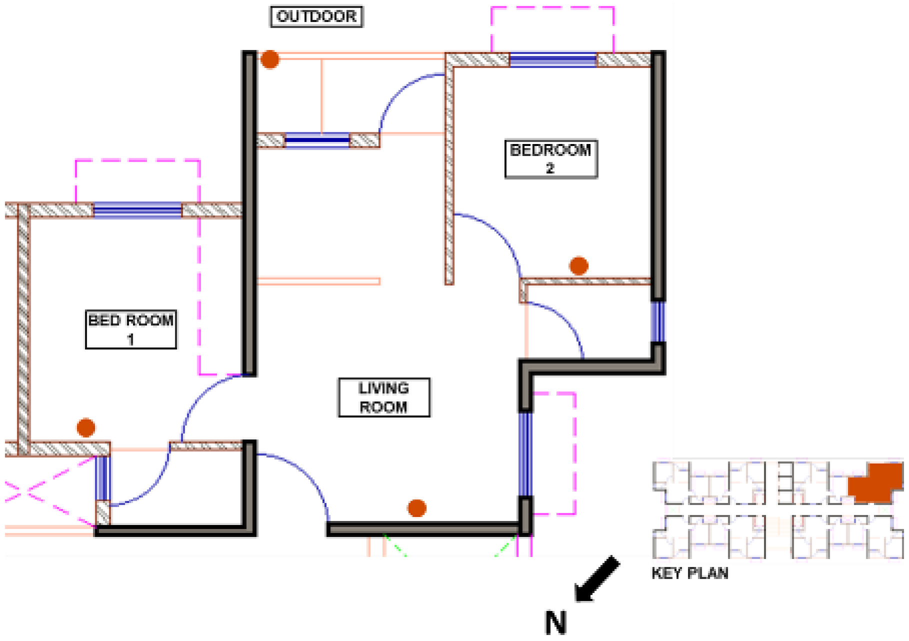


Thermal comfort study of the Light House Project- Rajkot

Findings (Cont.)

Thermal comfort study of the Light House Project- Rajkot

Datalogger placement

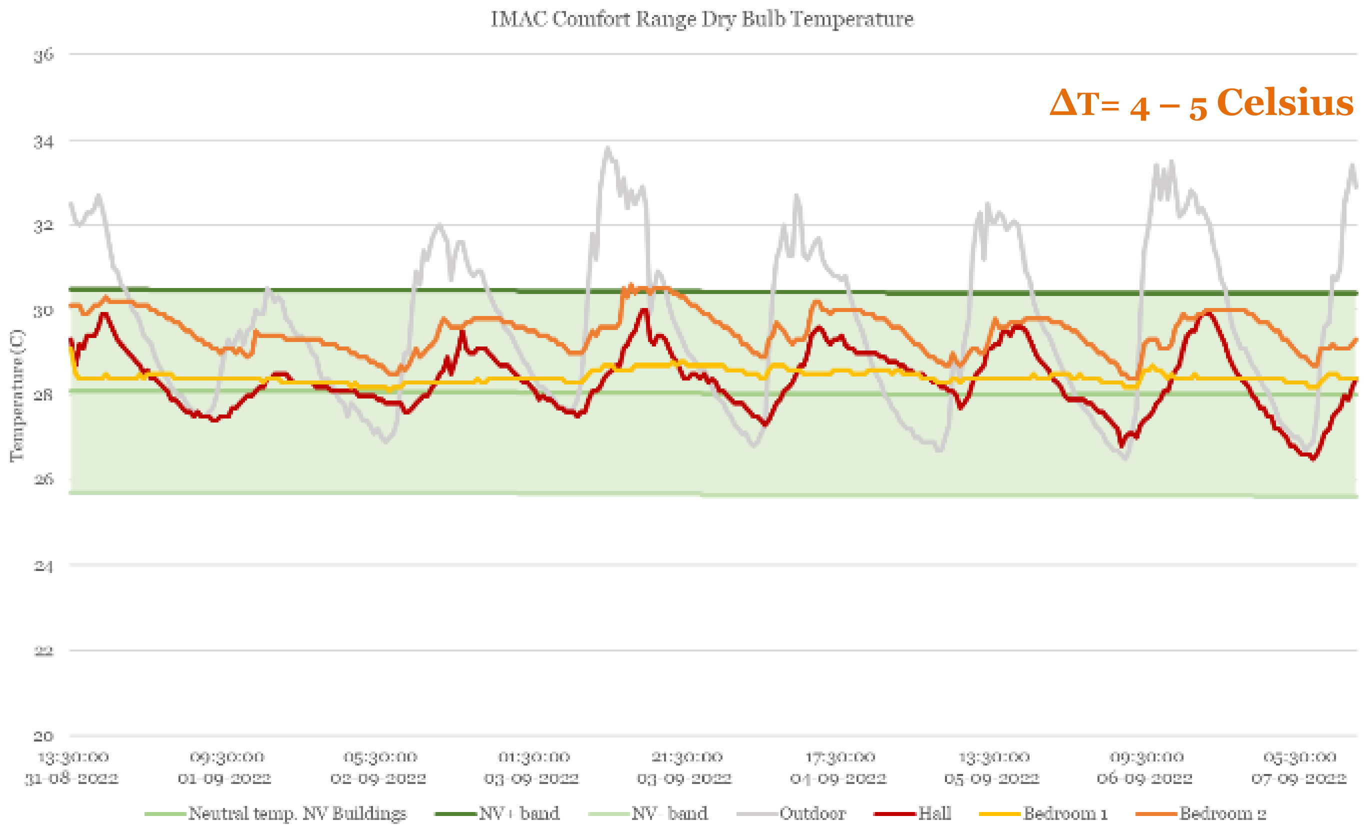


Location: Tower 8 | 1st floor | Corner unit

Occupancy: 9 am to 5 pm

Operation mode: No comfort system, No lighting, Natural Ventilation

Findings



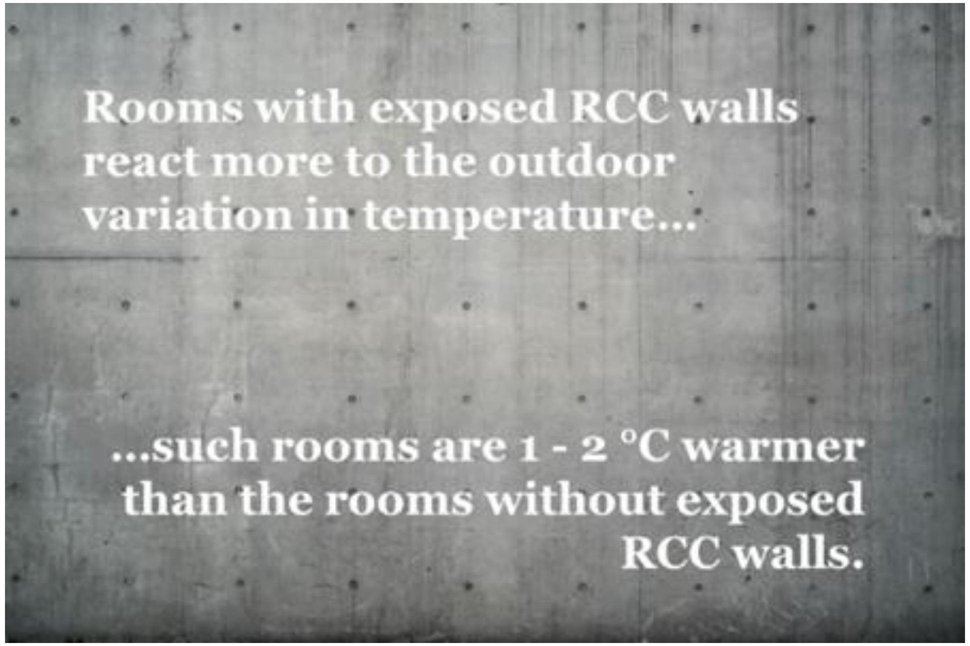
The data loggers readings from Wednesday, 31st August to 7th September 2022.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Thermal comfort study of the Light House Project- Rajkot

Findings (Cont.)

98% of the time the indoor temperatures stayed within the IMAC comfort band



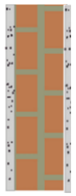
RCC walls have no insulation properties, and they heat and cool more rapidly based on outdoor conditions

Key performance features of the Light House Project- Rajkot

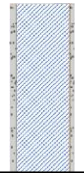
Saved kWh of Power due to reduction in construction time]	**215051 kWh** saved. Typical saving is **4.72 kWh/Sq. mtr** compared to building construction using conventional method.
% reduction in cost of construction	**10%** [Faster construction speed leading to reduction in construction cost]
% reduction in water use	**26.67%** (For Concrete), Approx 70% (For Masonary Work)
% reduction in Construction waste	**10%** Approx.[Usage of Tunnel Formwork causing reduction in construction waste]
% Reduction in use of energy	**16.67%**
% Reduction in embodied energy	**25%**

Comparation between building envelope of conventional building vs LHP, Rajkot

Conventional Construction Envelope Details

Envelope Type	Conventional Case - Construction Configuration	Section	U Value*
Wall	Interior Surface Film resistance + Internal Cement Mortar (12 mm) + Brick Wall (230mm) + External Cement Mortar (12 mm) + Exterior Surface film resistance		1.97 W/m2K
Roof	Interior Surface Film resistance + External Cement Mortar (18mm) + RCC slab (150mm) + Internal Cement Mortar (12mm) + Exterior Surface film resistance		2.78 W/m2K
Fenestration & Glazing	Steel framed Single Glazing Unit (SGU) with 5mm glass, SHGC = 0.84, VLT = 0.89		6.2 W/m2K
Void	Assumed SHGC = 1, VLT = 1		7W/m2K
RETV	Residential Envelope Transmittance Value (North-South Blocks)		16.64 W/m2

LHP Rajkot Construction Envelope Details

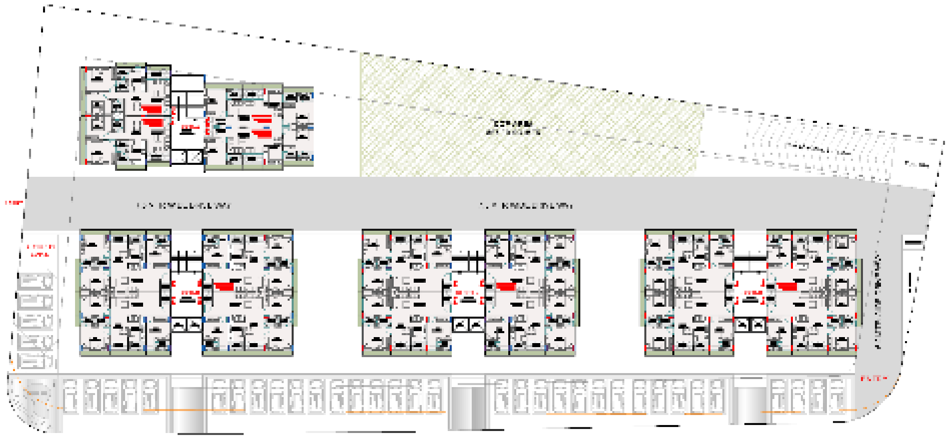
Envelope Type	LHP Case - Construction Configuration	Section	U Value*
Wall	Interior Surface Film resistance + Internal Cement Mortar (10 mm) + AAC Block (200mm) + External Cement Mortar (30 mm) + Exterior Surface film resistance		0.68 W/m2K
Roof	Interior Surface Film resistance + RCC slab (160 mm) + screeding (55 mm) + External Cement Mortar (50mm) + China mosaic + Exterior Surface film resistance		2.74 W/m2K
Fenestration & Glazing	uPVC framed SGU with 5mm glass thickness, SHGC = 0.83, VLT = 0.89		5.9 W/m2K
Void	Assumed SHGC = 1, VLT = 1		7W/m2K
RETV	Residential Envelope Transmittance Value (North-South Blocks)		14.32 W/m2

CASE STUDY OF DEMO PROJECTS

The Demonstration Housing Projects

Under the Climate Smart Buildings Project in Western Cluster, the CSB Cell have identified and are supporting 2 no. of upcoming affordable housing projects in Ahmedabad to achieve minimum Thermal Comfort standards of MoHUA – GoI.

Zundal, AUDA Project, Ahmedabad

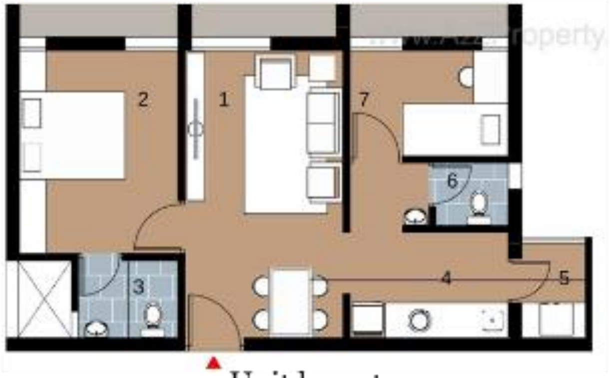


Re-anand, Ahmedabad

Assessment reports on Demonstration Housing Project's performance have been made that highlight on results, conclusions, and recommendations for enhanced thermal comfort and energy efficiency.

ENS compliance and improvemnets for Demonstration Housing Project

Zundal, AUDA AHP project, Ahmedabad



Unit layout

It is recommended to provide roof insulation in order to comply with max. thermal transmittance value for roof and to increase the comfortable hours with in the units.

As designed

Element	U value $W/m^2.k$	RETV W/m^2	ENS Part 1 Compliance	ENS Score
WALL ACC 150mm + plaster	0.86	11	✓	132
WINDOW Aluminium + single glazed	5.8			
ROOF 120mm concrete slab	2.94	-	✗	

With improvements

Element	U value $W/m^2.k$	RETV W/m^2	ENS Part 1 Compliance	ENS Score
WALL ACC 150mm + plaster	0.86	11	✓	140
WINDOW Aluminium + single glazed	5.8			
ROOF 150mm concrete slab + EPS Insulation	0.7	-	✓	

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

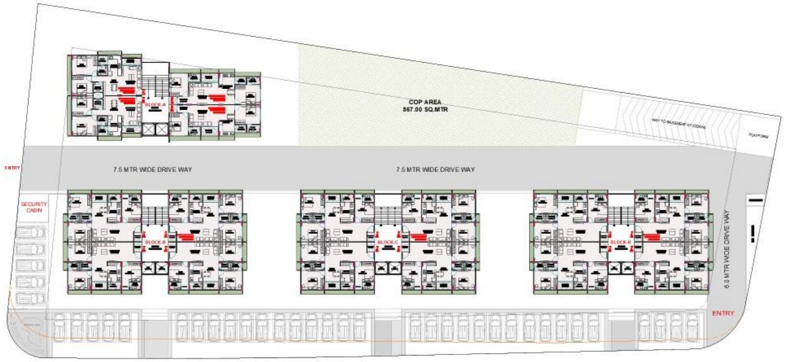
Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ENS compliance and recommendations for Demonstration Housing Project

Re-anand, Private APH project, Ahmedabad



Site layout

Unit layout

It is recommended to provide roof insulation in order to comply with max. thermal transmittance value for roof and to increase the comfortable hours with in the units.

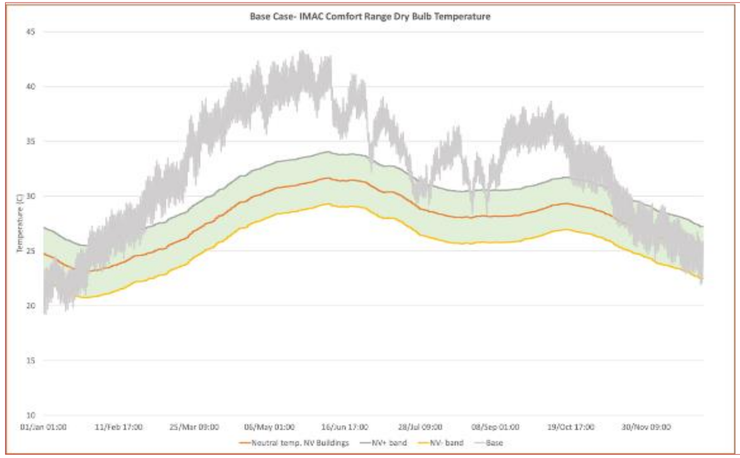
As designed

Element	U value $W/m^2.k$	RETV W/m^2	ENS Part 1 Compliance	ENS Score
WALL: ACC 200mm + plaster	0.68	11.2	✓	132
WINDOW: Aluminium + single glazed	5.8			
ROOF: 150mm concrete slab	2.8	-	✗	

With improvements

Element	U value $W/m^2.k$	RETV W/m^2	ENS Part 1 Compliance	ENS Score
WALL: ACC 200mm + plaster	0.68	11.2	✓	140
WINDOW: Aluminium + single glazed	5.8			
ROOF: 150mm concrete slab + EPS Insulation	0.6	-	✓	

Thermal Performance of the Demonstration Housing Project



ROOF

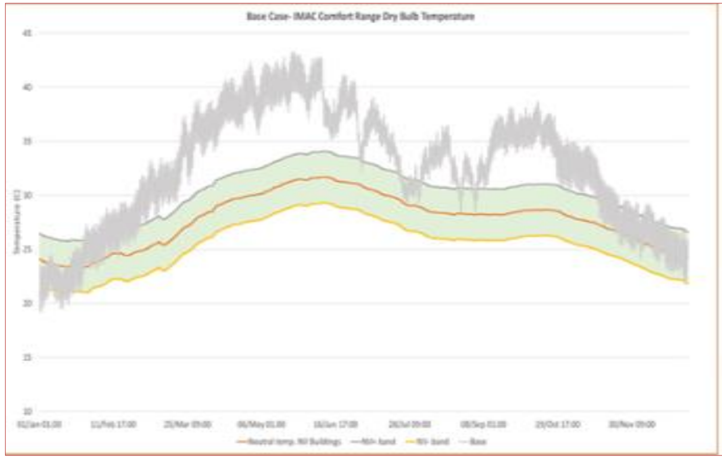
150mm concrete slab

ANNUAL DISCOMFORT HOURS

6539 hours

74% of the time in a year the units in the top floor remain uncomfortable

Re – anand Project - Thermal Performance of the top floor unit – without insulation.



ROOF

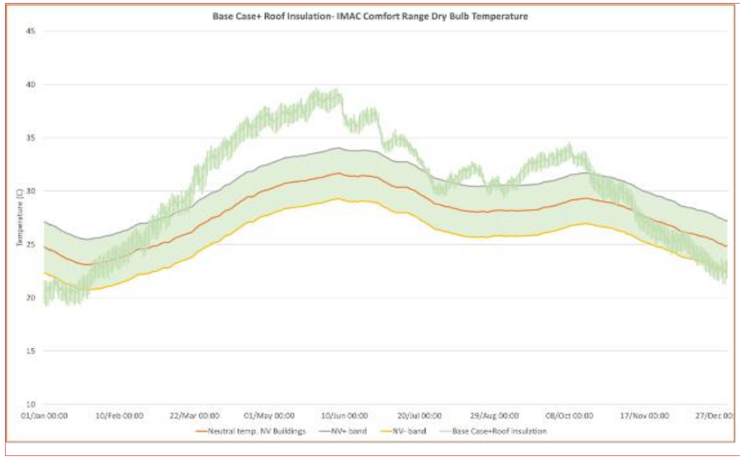
150mm concrete slab

ANNUAL DISCOMFORT HOURS

6606 hours

75% of the time in a year the units in the top floor remain uncomfortable

Zundal AHP Project - Thermal Performance of the top floor unit – without insulation.



ROOF

150mm concrete slab + 50mm EPS insulation

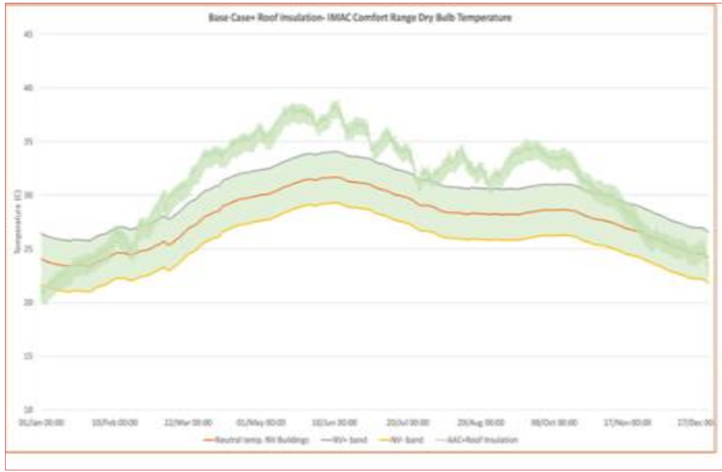
ANNUAL DISCOMFORT HOURS

5614 hours

64% of the time in a year the units in the top floor remain uncomfortable

Roof insulation provides 14% less discomfort hours when compared to roof without insulation

Re – anand Project - Thermal Performance of the top floor unit – with insulation.



ROOF

150mm concrete slab + 50mm EPS insulation

ANNUAL DISCOMFORT HOURS

6008 hours

68% of the time in a year the units in the top floor remain uncomfortable

Roof insulation provides 9% less discomfort hours when compared to roof without insulation

Zundal AHP Project - Thermal Performance of the top floor unit – with insulation.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs, Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Recommendations

- Proper orientation of Buildings, this reduce the impact of unfavorable weather conditions like solar radiation, driving rain and thunderstorm
- Proper Ventilation – Proper positioning the windows and opening them create air movement in the house. 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.
- Using Shading Device – use of overhangs or horizontal projections over windows. Double pane windows with tinted glass and glass coated with reflective film should be used for windows instead of steels, wood and zincs.
- Creation of Microclimate – trees can be planted to create micro – climate that is, small-scale climatic condition at a spot or area or site
- Preventing Infiltration – 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, etc.

Recommendations

- To align with GHG reduction targets and other government activities, make "Thermal Comfort for All" a government priority, and relate it to India's ambition to give a better quality of life to all of its residents.
- Create market momentum for smart cooling through public awareness campaigns, information access, and technical support.
- Consistent testing and rating processes, as well as market communication initiatives, can help to mainstream the use of energy efficient building materials and equipment.
- Take significant steps to phase out HFCs and encourage the industry to switch to renewable refrigerants.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

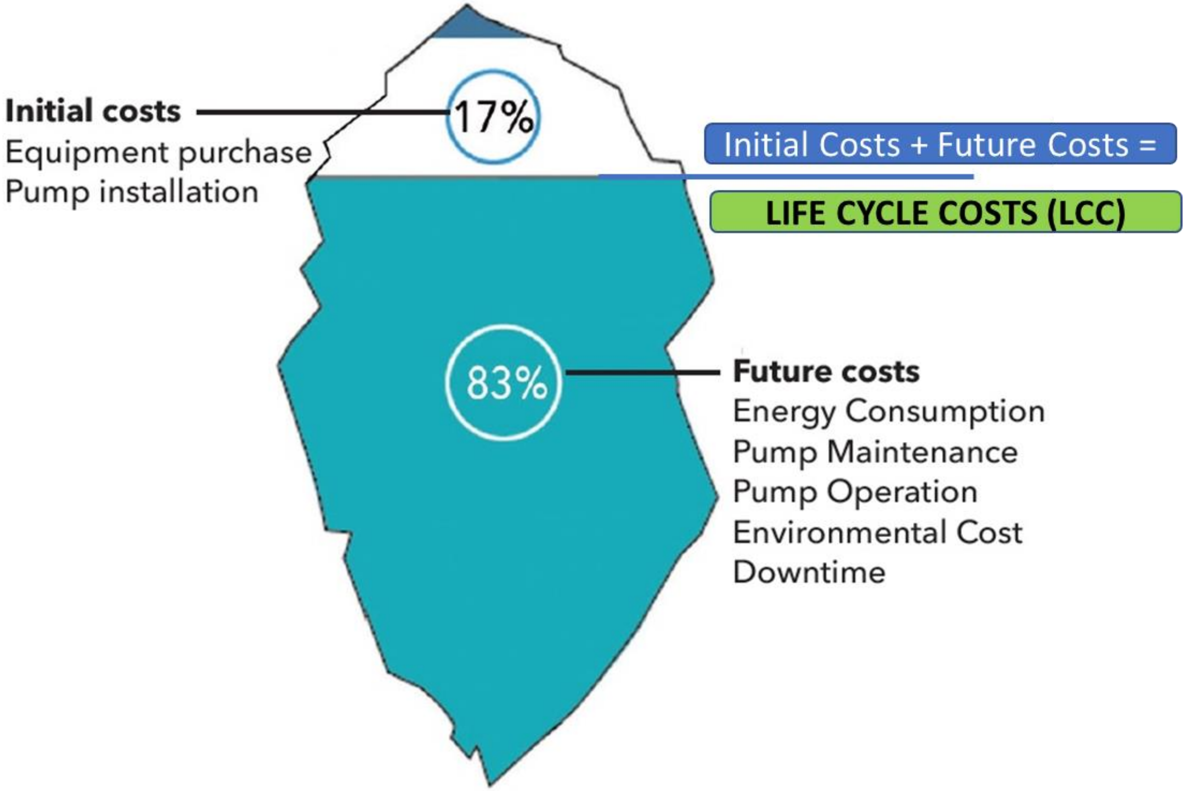
04

Life Cycle Cost and its impact on Carbon Emission

Concept of life cycle cost and its impact on carbon emission

Life Cycle Cost

Life cycle costing is a method of economic analysis directed at all costs related to constructing, operating, and maintaining a construction project over a defined period of time.



Concept of life cycle cost and its impact on carbon emission

Why LCC matters in sustainable building

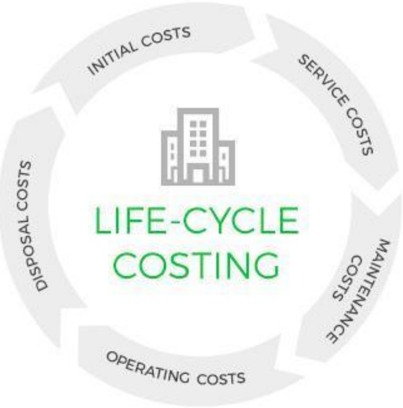
Sustainable/green technology in building in commonly more expensive than its traditional counterpart. However, it is more energy efficient, lower operation and maintenance cost. The Energy saving, O&M feature occur over the life-time of the building. Therefore,

It is essential to use the analysis which recognizes the cost saving which spread over the life-time – the Life Cycle Cost (LCC) analysis

Concept of life cycle cost and its impact on carbon emission

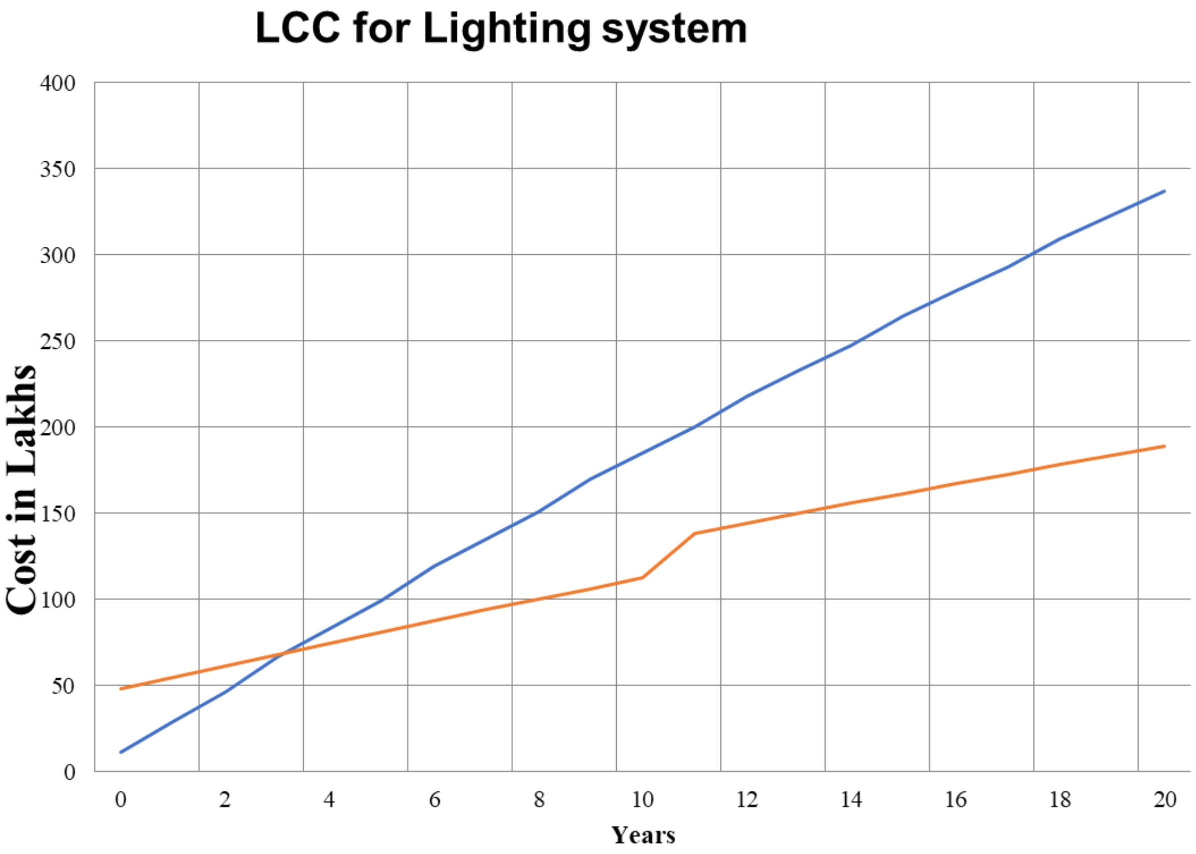
Why LCC matters in sustainable building

Total LCC = (Investment cost + operation cost + Maintenance + Replacement cost + Disposal cost) – Salvage Value



Concept of life cycle cost and its impact on carbon emission

LCC of CFL vs LED



DAY 1

Q&A Session on New & Innovative technologies and Thermal Comfort

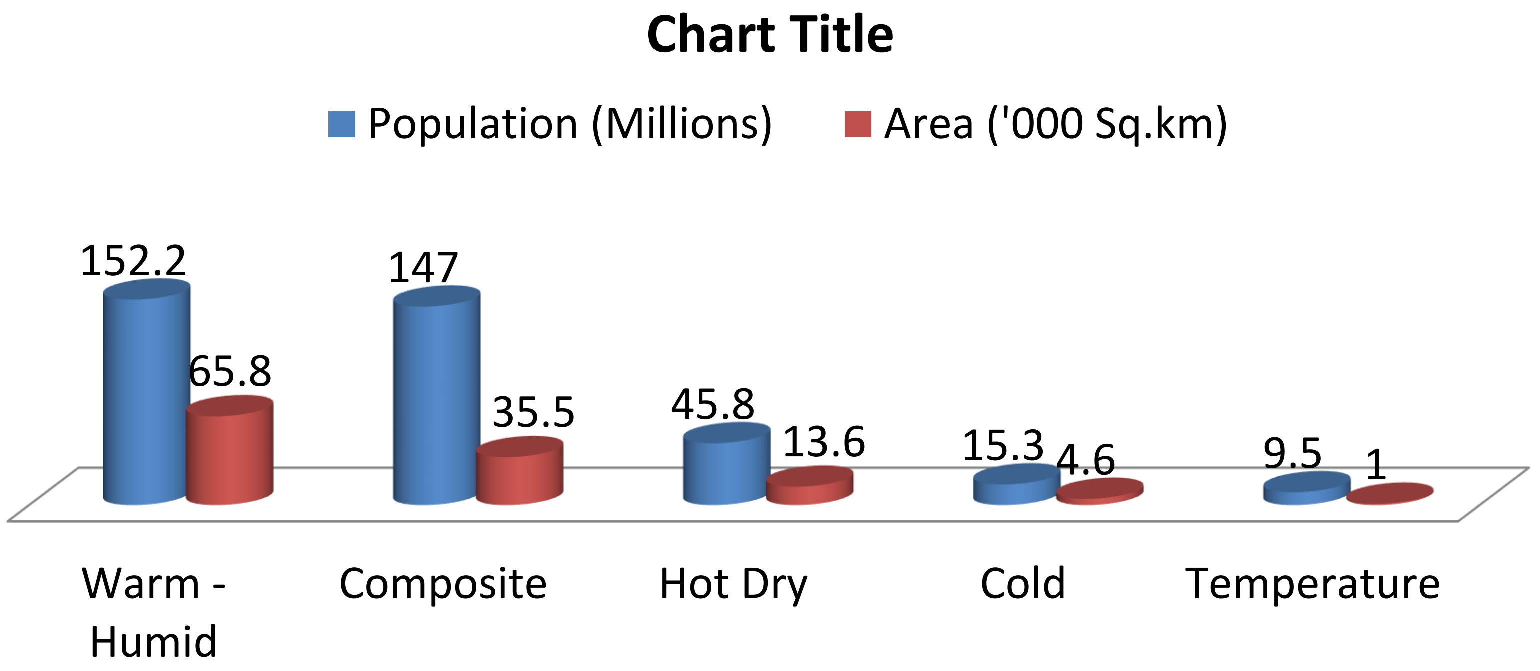
DAY 1

Session 2: Importance of Thermal Comfort

05

Thermal Comfort and Cooling Demand

Thermal Comfort & Cooling Demand

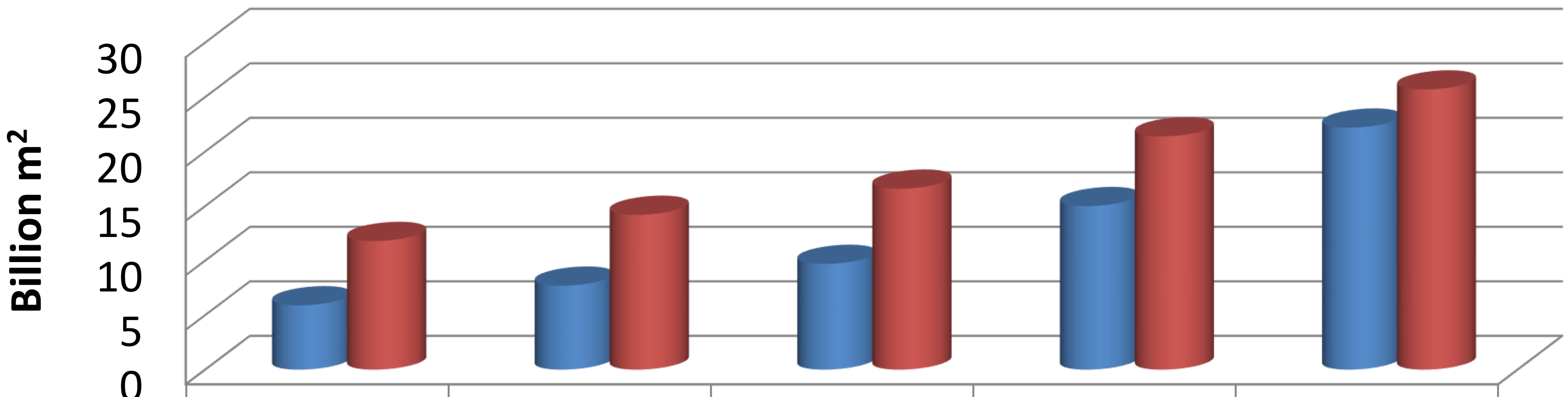


Population and area distribution in the five climate zones of India. Source: “Census 2011”, Government of India, (2011), available at: http://www.censusindia.gov.in/2011census/ dchb/DCHB.html

- According to the graph, the major Indian metropolitan areas with urban populations (which make up 35% of the country's total population) are located in warm, humid, and mixed climates.
- Every year, high cooling degree days are experienced by residents of the cities located in these climate zones and the hot, dry climate.

Thermal Comfort & Cooling Demand

Residential Build – Up Area (Billion m^2)



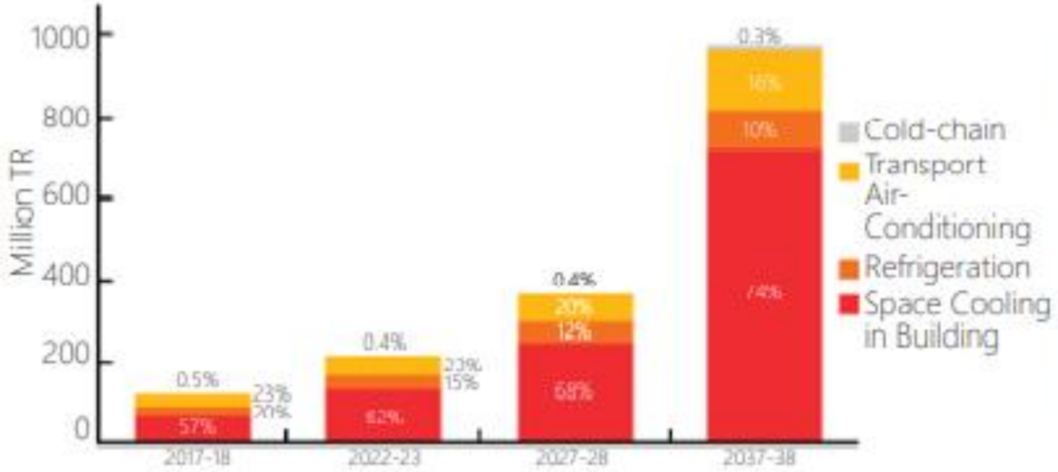
	2020	2025	2030	2040	2050
Urban	5.9	7.7	9.7	15	22.2
Rural	11.8	14.2	16.6	21.4	25.7

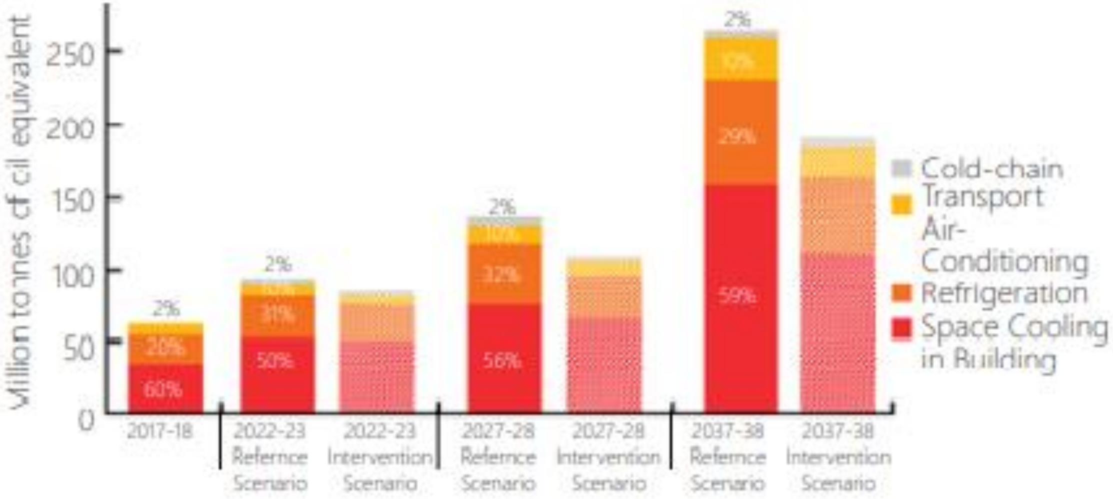
Projected increase in residential built-up area in urban and rural India. Source: ICAP

- Projections of residential built-up area expansion in both urban and rural India are shown in Graph.
- Between 2020 and 2050, it is predicted that the total area of built-up urban residential space will rise by a factor of more than three.
- Over three decades, it is anticipated to increase from 5.9 billion square metres to 22.2 billion square metres (2020-2050).
- In addition, over the same period, the per capita residential built-up area in Indian cities will rise from 12.6 sq. m. to 24.2 sq. m. (MOEFCC, 2019).

Thermal Comfort & Cooling Demand

By 2050, only around two-thirds of our metropolitan building stock will have been constructed. Consequently, our new development must take into account both our current and future cooling needs. To make this happen, it is essential to comprehend how our cooling demand is changing. According to the India Cooling Action Plan, the demand for cooling is expected to increase eight times between 2017–2018 and 2037–2038. In just two decades, the demand for the building sector alone will increase by up to 11 times from the baseline.





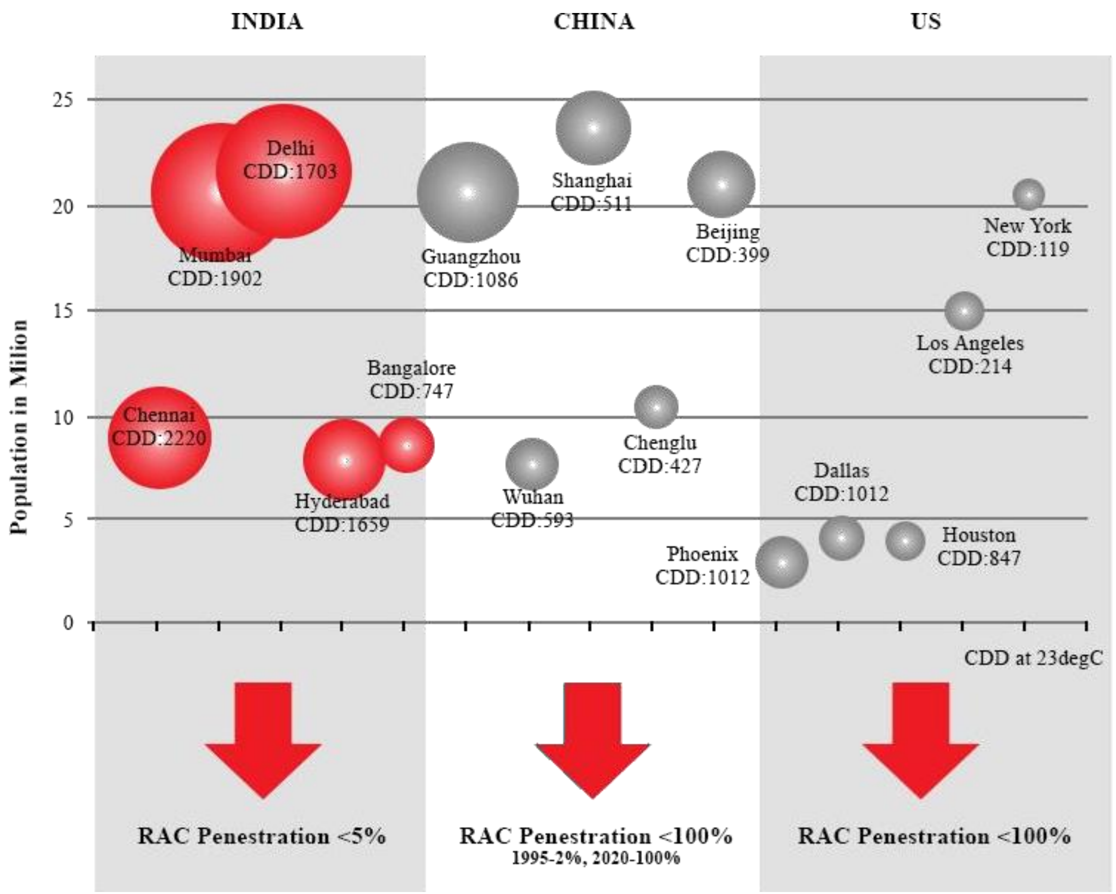
Above: Sector-wise growth in cooling demand; Below: India's Total Primary Energy Supply (TPES) for cooling. Source: India Cooling Action Plan (redrawn)

Need for Thermal Comfort in Buildings: India Cooling Action Plan

1. 20-25% reduction of cooling demand across various sectors by 2037-2038
2. 25-40% reduction in cooling energy requirements by 2037-2038
3. 25-30% reduction in refrigerant demand by 2037-2038
4. Training and certification of 1,00,000 service technicians by 2022-2023
5. Recognizing “cooling and related areas” as a thrust area of research

Source: Ministry of Environment, Forest & Climate Change, Government of India. (2019, March). India Cooling Action Plan. Retrieved from http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

Need for Thermal Comfort in Buildings: International Perspective

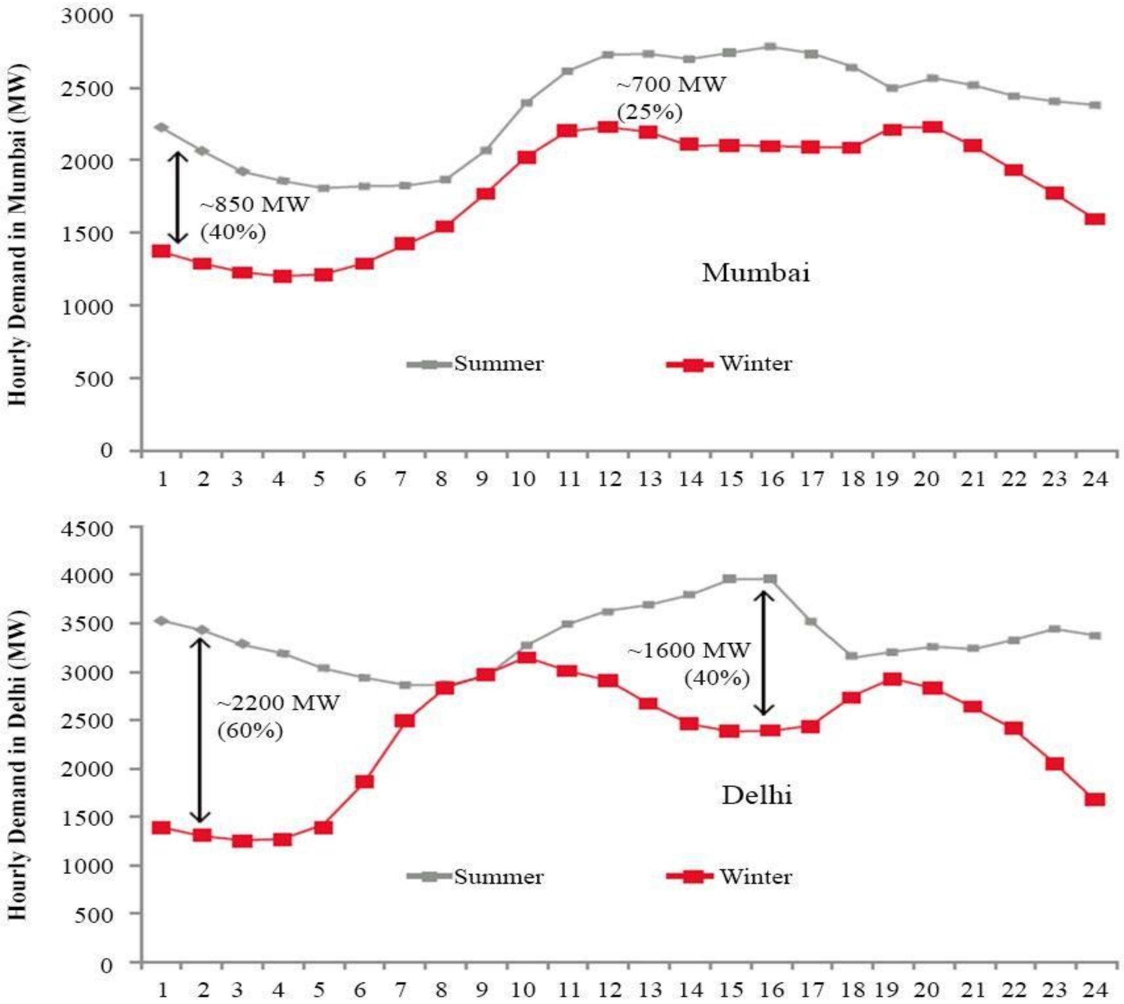


Cooling Demand in India, China, and the US

- To combat uncomfortable conditions
- Leads to increased peak
- Leads to higher consumption

Source: Sustainable and Smart Space Cooling Coalition (2017). Thermal Comfort for All – Sustainable and Smart Space Cooling. New Delhi: Alliance for Energy Efficient Economy

Need for Thermal Comfort in Buildings: Peak Demand



- Summer and Winter Day Profile of Electricity use
- Mumbai and Delhi Comparison
- Leads to higher consumption

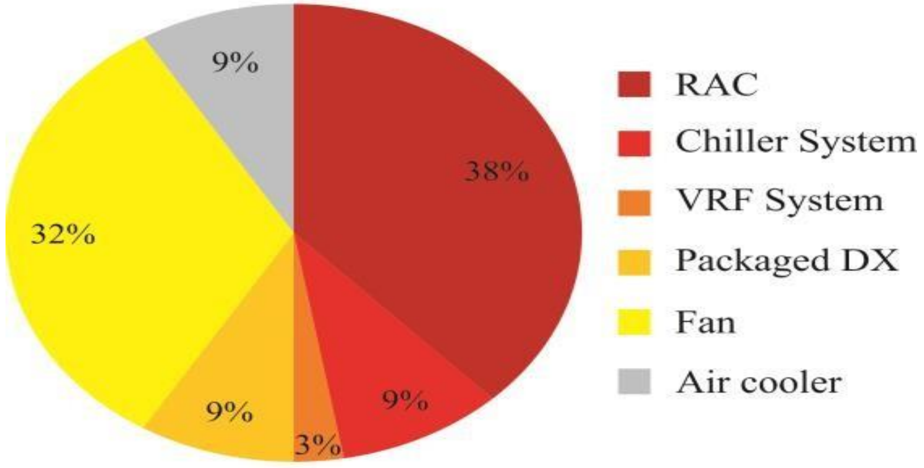
Late-night 850 MW to late afternoon 700 in Mumbai
Late-night 2200 MW to late afternoon 1600 in Delhi

Source: Phadke, A., Abhyankar, N., & Shah, N. (2014). Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges.

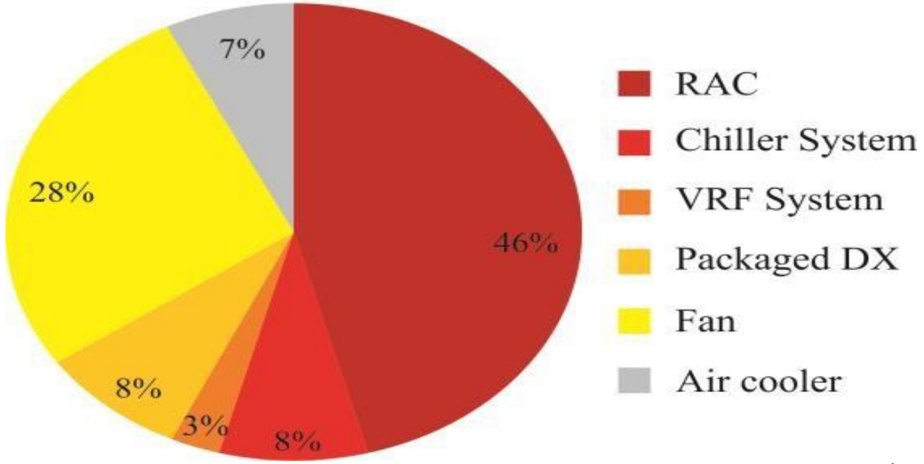
https://international.lbl.gov/publications/avoiding-100-new-power-plants

Need for Thermal Comfort in Buildings: Consumption & Emission

2017 Annual Energy Consumption = 126TWh



2017 Annual Carbon Emission = 124 mtCO2e



- Total Consumption 126 TWh and 124 $MTCO_{2e}$
- Room Air Conditioners 48.8 TWh (38%) consumption
- Room Air Conditioners 57.0 $MTCO_{2e}$ (46%) Carbon Emission

Source: Ministry of Environment, Forest & Climate Change, & Government of India. (2019, March). India Cooling Action Plan. Retrieved from http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

Need for Thermal Comfort in Buildings: Consumption & Emission

- In 2017, approximately 272 million
- households were estimated in India
- Expected to increase to 328 by 2027
- 386 million by 2037

- In 2017, approximately 8% of the households were estimated to have room air conditioners
- Anticipated to rise to 21% by 2027-28
- And 40% by 2037-38

- In 2017, the estimated commercial floor was around 1.2 million sqft
- Is expected to grow about 1.5 to 2 times by 2027-2028
- 2.5 to 3 times by 2037-38, respectively

Source: Ministry of Environment, Forest & Climate Change, & Government of India. (2019, March). India Cooling Action Plan. Retrieved from http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

06

Factors affecting Thermal Comfort and Cooling Demand

Factors affecting Thermal Comfort

PHYSIOLOGICAL FACTORS

The factors which are independent from weather and surrounding environment of the building. And are very subjective and depend on person to person

PHYSICAL FACTORS

The factors which are dependent on weather and surrounding environment of the building. Some of which can be managed

PHYSICAL FACTORS

•01

•Air Temperature

•02

•Mean Radiant Temperature

•03

•Radiant Temperature Asymmetry

•04

Floor Surface Temperature

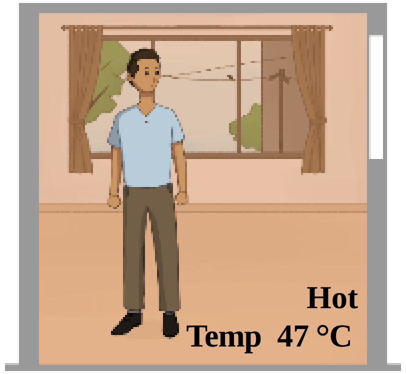
•05

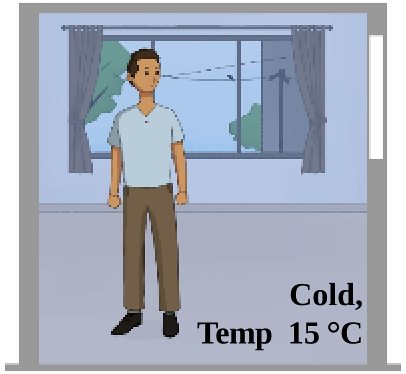
•Relative Humidity

•06

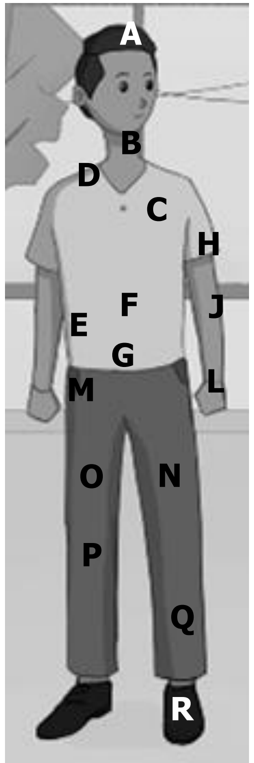
•Air Speed

Thermal Comfort – Cold – Neutral - Warm



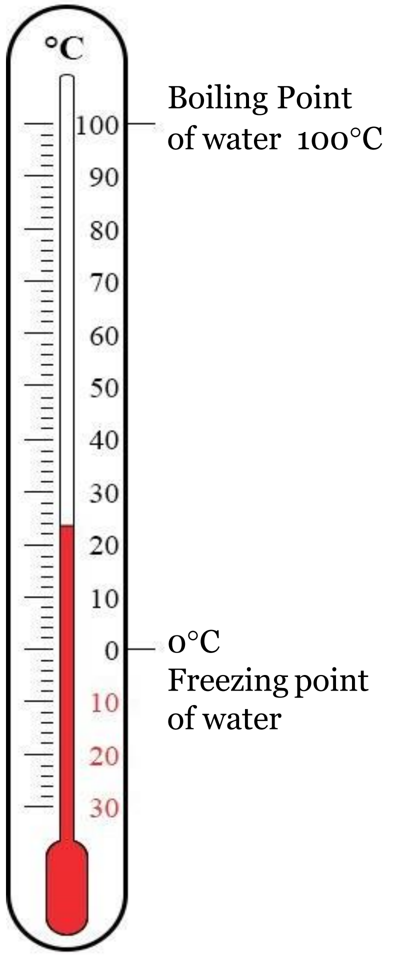


Air Temp 27 °C



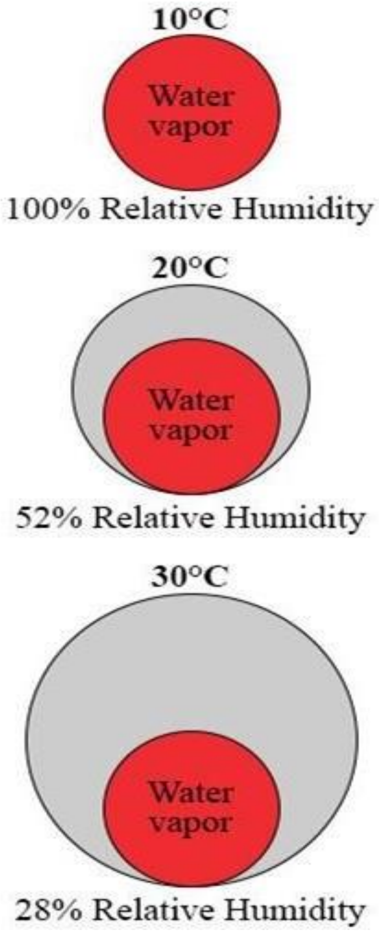
Body Part	Skin Location	Cold (15 °C)	Neutral (27°C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37
L	Hand	23.7	33.8	36.7
M	Hip	26.5	32.2	36.8
N	Side thigh	27.3	33	36.5
O	Front thigh	29.4	33.7	36.7
P	Back thigh	25.5	32.2	36
Q	Calf	25.1	31.6	35.9
R	Foot	23.2	30.4	36.2

Factors Affecting Thermal Comfort – Air Temperature



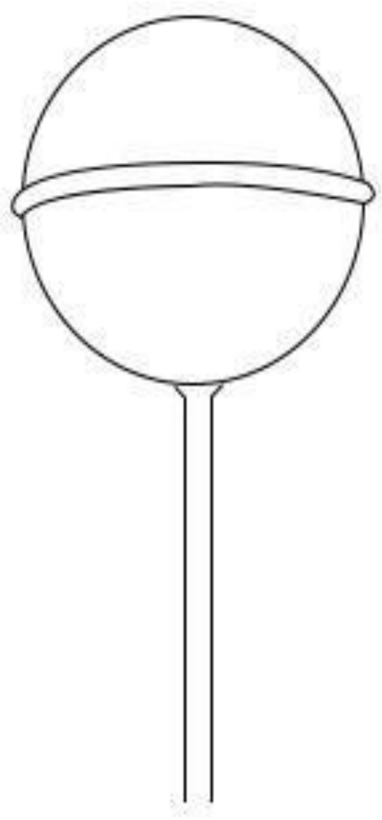
- Temperature of the air surrounding the Environment (Dry Bulb Temperature) – DBT)
- Measured in Degrees Celsius (°C), by a thermometer freely exposed to the air, but shielded from radiation and moisture.
- Affects the rate of Evaporation on skin surface of building occupants.

Factors Affecting Thermal Comfort – Relative Humidity [RH]



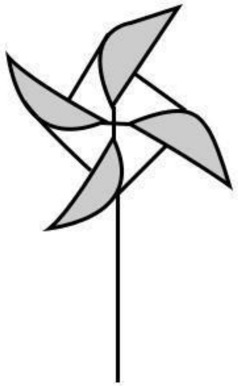
- It is defined as %ge of Amt. of water vapour present in air to max. amount of water vapour that air can hold at specific temperature and pressure.
- Affected by DBT and Pressure of Air.
- Higher the RH of the air, hotter it will feel for Building Occupants.

Factors Affecting Thermal Comfort – Mean Radiant Temperature [MRT]



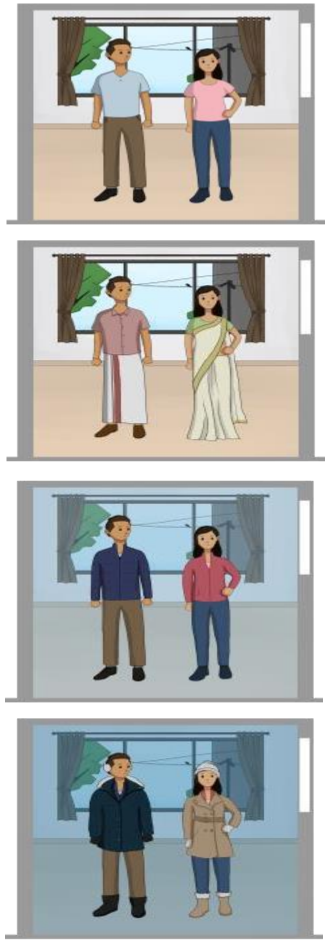
- MRT is defined as uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.
- Depends on ability of a surface to emit the incident heat, also known as emissivity of the material
- Calculated using Globe Temp. (T_g) & Air Temp.(T_a).

Factors Affecting Thermal Comfort – Air Speed



- Air Speed is defined as the average speed of the air surrounding an occupant, with respect to location, and time.
- Measured in Meter per second (m/s)
- Elevated air speeds can be used to improve thermal comfort beyond the maximum limit of temperature established by codes and standards (ASHRAE, 2021)

Factors Affecting Thermal Comfort – Clothing Value

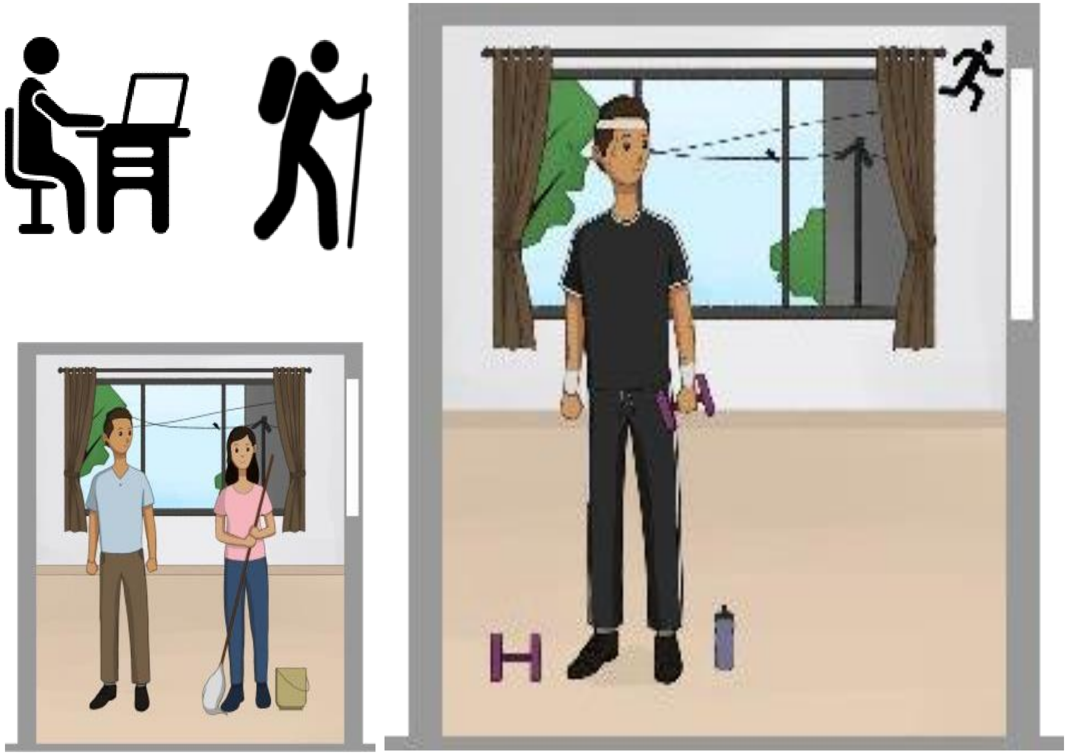


- Can be defined as "The resistance to sensible heat transfer provided by clothing ensemble".
- The insulation provided by an individual garment includes effective resistance of the garment material and the thermal resistance of the air layer trapped between the garment and the skin (CIBSE, 2015).
- Clothing Insulation Value (clo - I_{cl}).

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

Factors Affecting Thermal Comfort – Metabolic Rates



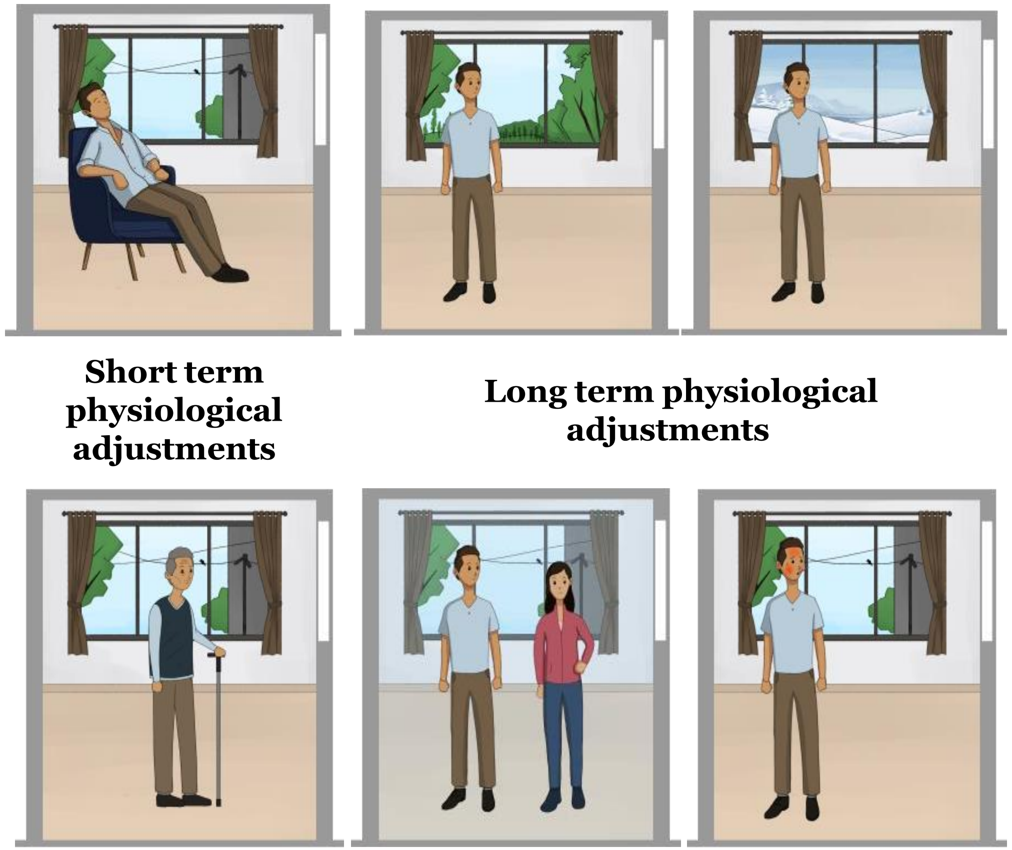
- Metabolic Rate can be defined as level of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism.
- Expressed in met units where 1 met = 58.2 W/m2.
- Depends on activity level, age, fitness level, etc. of a person.

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

Factors affecting Thermal Comfort - Others

- **Acclimatization**
  - Short-term physiological adjustments
  - Long-term endocrine adjustments
- **Body shape and fat**
- **Age and gender**
- **Status of health**



Short term physiological adjustments

Long term physiological adjustments

Age

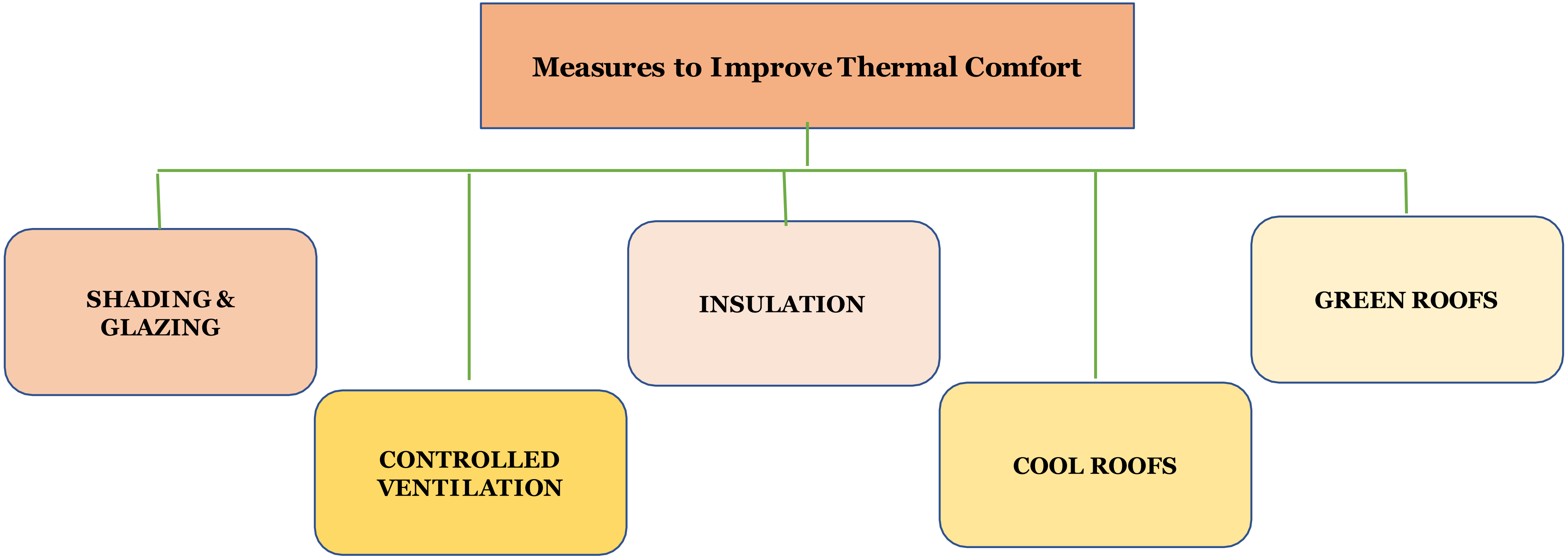
Gender

Health & Wellbeing

07

Contemporary Approaches for achieving Thermal Comfort in buildings

Measures to Improve Thermal Comfort



Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

VARIOUS METHODS TO SHADE WINDOWS					
Overhangs	Awnings	Louvers	Vertical Fins	Light Shelves	Natural Vegetation

These can reduce cooling energy consumption by 10-20%

The shading mechanism can be fixed or movable (manually or automatically) for allowing varying levels of shading based on

1. **the sun's position and**
2. **movement in the sky**

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Shading & Glazing

Thermal Comfort

SHADING

In combination with high-performance glass with low solar heat gain coefficient (SHGC), can reduce energy consumption even further by cutting down or heat gain through radiation

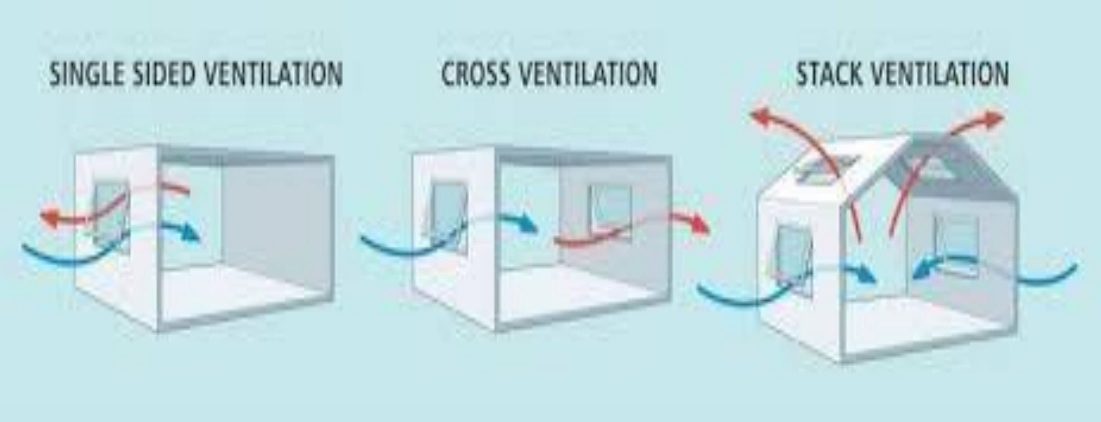
GLAZING

Refers to the glass windowpanes that make up the building envelope. Conduction and radiation are the primary sources of heat gain via a window. radiation, which can be regulated by defining the parameters correctly. SHGC and U-value, respectively.

Controlled Ventilation

BUILDING CAN BE DESINED AS

- **CROSS VENTILATION**
- **STACK VENTILATION**
- **SINGLE-SIDED VENTILATION**



Controlled Ventilation

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

Air Velocity range between 0.5 to 1 m/s	**Drops temperature at about 3 ^{O}C at 50% relative Humidity**

AIR VELOCITY OF 1 m/s	
Office Environment	Too High
Home Environment	Acceptable (Especially if there is no resource to active air conditioning.)

Controlled Ventilation

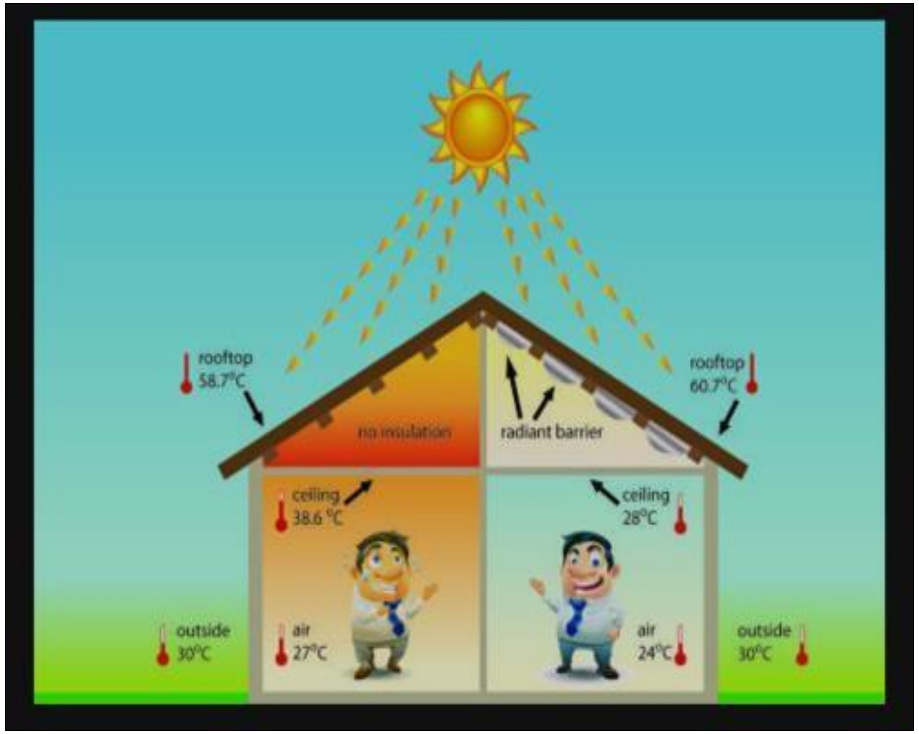
Natural ventilation takes advantage of the differences in air pressure between warm air and cool air, as well as convection currents, to remove warm air from an indoor space and allow fresh cooler air in.

This also has the added advantage of cooling the walls and roofs of the buildings that hold significant thermal mass, further enhancing the thermal comfort of the occupants

NATURAL VENTILATION	
With Breeze Air	Works Best
Absence of natural breeze	Fans can be used to improve the flow of cool air
Natural ventilation promotes the occupants' adaptation to external temperature, called adaptive thermal comfort	

Even in hot-dry and warm-humid climate zones where some air-conditioning may be required during peak Thermal Comfort for All summer, buildings can be designed to operate in a mixed mode to enable **night ventilation** and **natural ventilation** during cooler seasons

Insulation



Heat Conduction takes place through

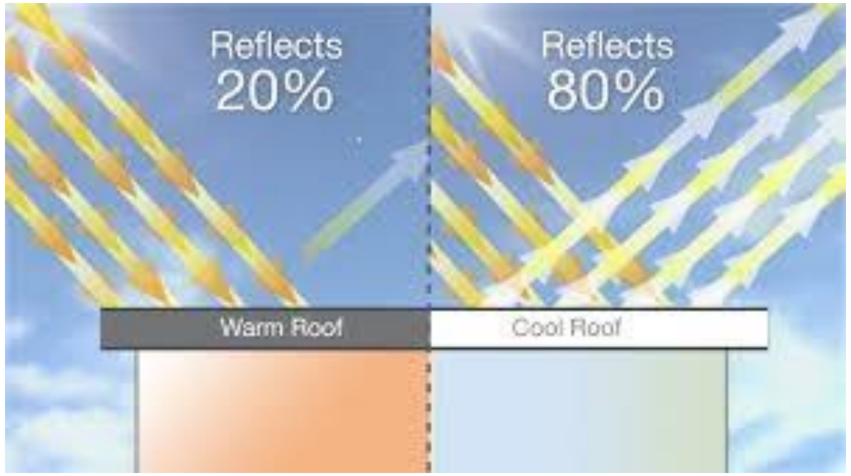
- Roof
- Walls
- Windows

An insulating material can resist heat transfer due to its low thermal conductivity. Insulating walls and the roof can reduce cooling energy loads by up to 8%

Cool Roofs

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

When sunlight is incident on a dark roof	When Sunlight is incident on a cool roof
38% heats the atmosphere	10% heats the environment
52% heats the city air	8% heats the city air
5% is reflected	80% is reflected
	1.5% heats the building



Cool Roofs

In the summer, a typical cool roof surface temperature keeps 25-35°C cooler than a conventional roof, lowering the internal air temperature by roughly 3-5°C and improving the thermal performance.

The comfort of the inhabitants is improved, and the roof's lifespan is extended.

Cool roofs increase the durability of the roof itself by reducing thermal expansion and contraction.

Apart from helping enhance the thermal comfort in the top floor and helping reduce air-conditioning load, cool or white roof or pavements also offer significant reduction in urban heat island effect

The cities of Jodhpur and Jaipur are from extremely hot state of Rajasthan, where most of the city homes are painted in light blue and light pink colours, are examples of practical application of this age-old traditional design style.

Green Roofs

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

GREEN ROOFS PURPOSE

- Absorbing Rain Water
- Providing Insulation
- Helping lower urban air temperatures
- Mitigating the urban heat island effect

Green Roofs

Reduction in Energy use is an important feature of Green Roofing

GREEN ROOFS IN BUILDINGS ALLOWS	
During cooler Winter Months	Retain their heat
During hotter Summer Months	Reflecting and absorbing solar radiations

08

Thermal Comfort Metrics

Thermal Comfort Metrices – Preference, Comfort and Acceptability

Metabolic Rate

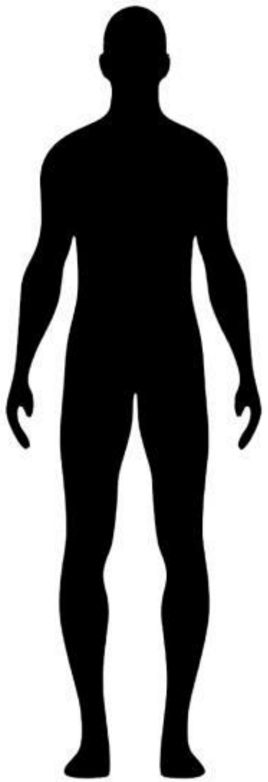
Clothing Insulation

Air Temperature

Air Velocity

Mean Radiant Temperature

Relative Humidity



Storage = Production - Loss

PMV Balance

- +3 Hot
- +2 Warm
- +1 Slightly Warm
- 0 Neutral (Comfort)
- -1 Slightly Cool
- -2 Cool
- -3 Cold

Thermal Comfort Metrices

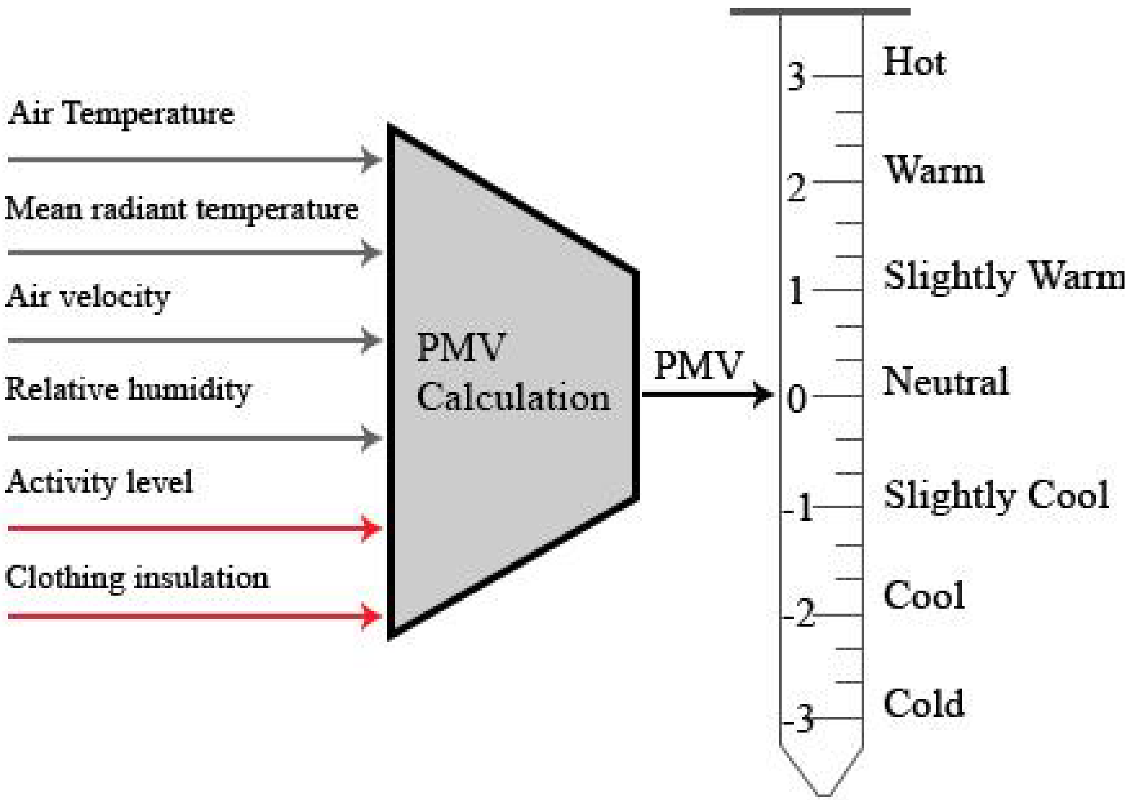
- Thermal Sensation
- Thermal Acceptance (Thermal Comfort)
- Thermal Preference
- Thermal Satisfaction

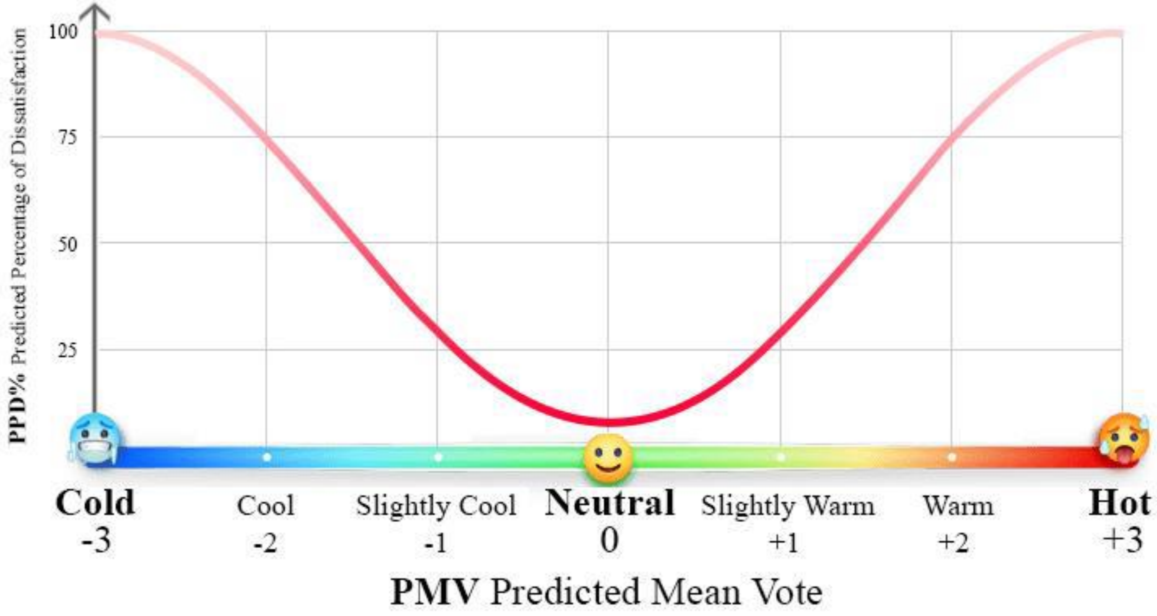
Thermal Comfort Metrices – Preference, Comfort and Acceptability

PMV	Sensation Value	Acceptance Value	Preference Value
-3	Cold	-	-
-2	Cool	Very Unacceptable	Want Cooler
-1	Slightly Cool	Unacceptable	Want Slightly Cooler
0	Neutral	-	No Change
+1	Slightly Warm	Acceptable	Want Slightly Warmer
+2	Warm	Very Acceptable	Want Warmer
+3	Hot	-	-

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

Thermal Comfort Metrices – PMV





Acceptable thermal comfort bands listed in ISO 7730:2005

Band	PMV Range
A	-0.2 < PMV < +0.2
B	-0.5 < PMV < +0.5
C	-0.7 < PMV < +07

Source: Guenther, S. (2021). What Is Pmv? What Is Ppd? The Basics of Thermal Comfort. Simscale. Simscale. Retrieved from https://www.simscale.com/blog/2019/09/what-is-pmv-ppd/

Thermal Comfort Metrices – PPD

Predicted Percentage of Dissatisfied occupants (PPD) refers to the percentage of occupants likely to experience thermal dissatisfaction out of the total number of occupants. ISO 7730:2005 defines the hard limit as ranging between -2 and +2, for existing buildings between -0.7 and +0.7, and new buildings ranging between -0.5 and +0.5.

PPD ranges corresponding to acceptable PMV ranges as defined in ISO 7730:2005

Band	PMV Range	PPD%	Temperature (◦C)
A	-0.2 < PMV < +0.2	< 6	24.5 ± 1
B	-0.5 < PMV < +0.5	< 10	24.5 ± 1.5
C	-0.7 < PMV < +07	< 15	24.5 ± 2.5

Thermal Comfort Metrices – Degree Discomfort Hours

- Calculated based on India Model for Adaptive (thermal) Comfort (IMAC).
- Summation of difference of hourly operative temperature and IMAC band acceptable temperature only for hours when temperature goes outside IMAC temperature band with 80% or 90% acceptability range.

Formula for DDH (Annual)

$$DDH\,(annual) = \sum_{i=1}^{8760} |(T_i - T_{acceptable})|$$

$$T_{acceptable} = T_{lower} \text{ when } T_i < T_{lower}$$

$$T_{acceptable} = T_{upper} \text{ when } T_i > T_{upper}$$

- T_i – Measured or Achieved Operative Temp. at i^{th} hour
- $T_{acceptable}$ - Either the lower (T_{Lower}) or the upper limit (T_{Upper}) of the targeted operative temperature based on IMAC comfort model.

Basis of Eco Niwas Samhita RETV value

Same as Discomfort Degree Hours

Total discomfort degree hours across the year against the comfort definition*

*National Building Code 2016 (India Model for Adaptive Comfort)

Source: vecteezy. (n.d.). Hot weather thermometer. vecteezy. Retrieved from https://www.vecteezy.com/vector-art/583489-hot-weather-thermometer-icon-vector

DAY 1

Lunch Break

DAY 1

Session 3: Building Physics and Fundamentals of Thermal Comfort

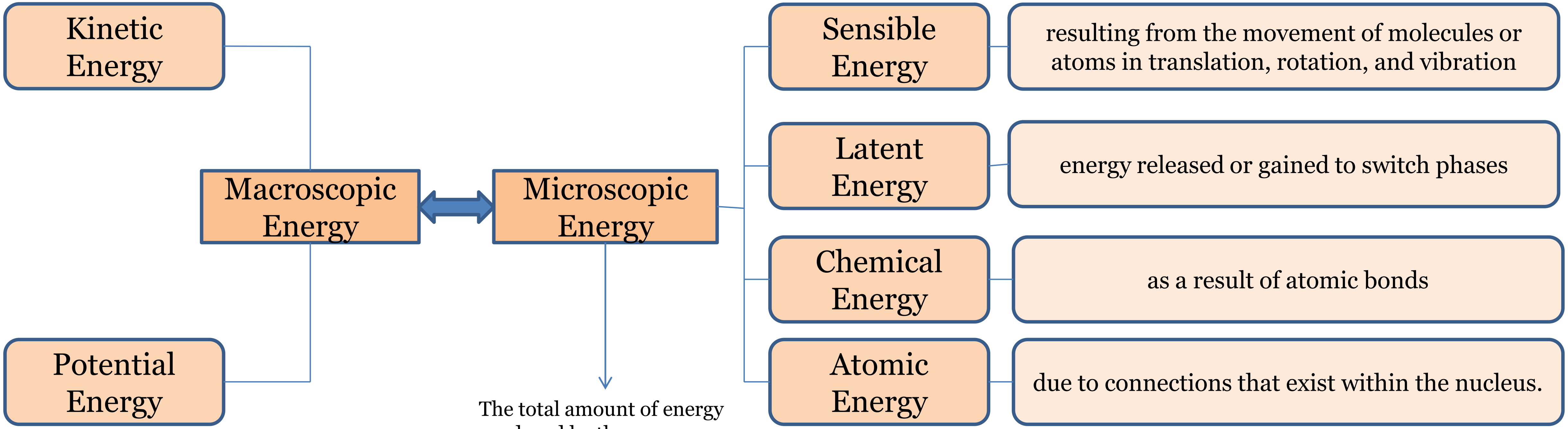
09

Building Physics Affecting Thermal Comfort

Building Physics Affecting Thermal Comfort

Energy & Heat

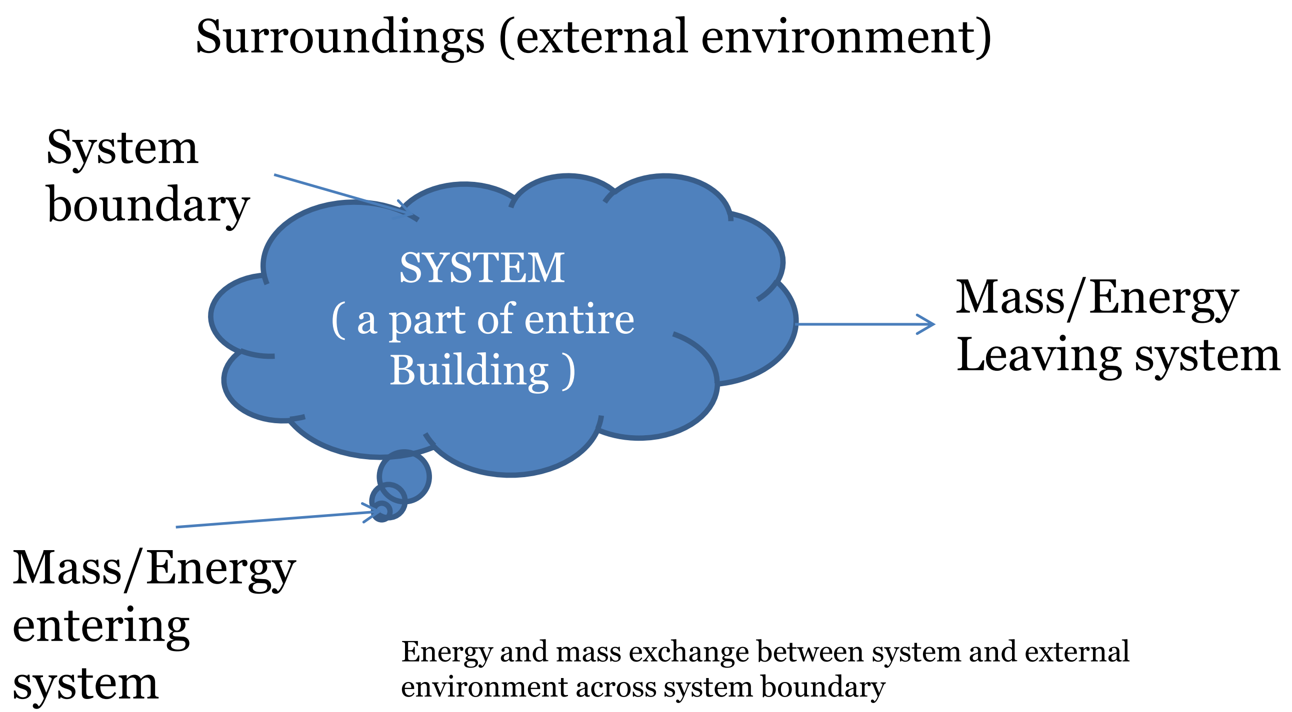
As chemical and atomic energy are not relevant in the context of buildings, the phrase "internal energy" is limited to perceptible and latent energy.



The total amount of energy produced by the configurations, forces, and motion of its molecules and/or atoms is known as its internal energy.

Building Physics Affecting Thermal Comfort

Energy & Heat



Energy and mass exchange between system and external environment across system boundary

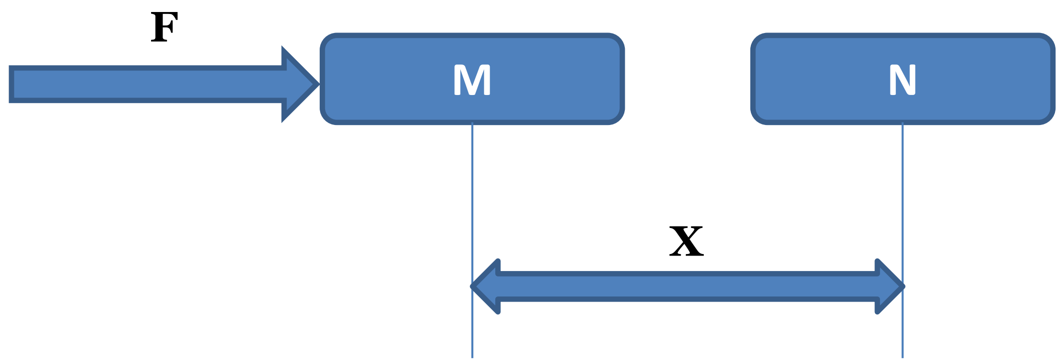
The envelope is regarded as the boundary when a building is viewed as a system in order to comprehend its thermal interactions with the surrounding environment.

A system, in terms of thermodynamics, is an area that is being studied, such as a room, floor, or building. A system border establishes the region's size, while elements outside of that boundary make up the external environment. As a result, a thermodynamic system is defined as a space-bound area or a volume of matter enclosed by a closed surface (ASHRAE, 2021). Over this system boundary, mass and/or energy are exchanged.

An open system is one that enables both energy and mass exchange with its surroundings, whereas a closed system only permits the exchange of energy and excludes mass. However, it is important to note that in order to distinguish between the system and its surroundings in both systems, a real or hypothetical, fixed or moveable boundary must be established (ASHRAE, 2021) This line may be rigid or flexible.

Building Physics Affecting Thermal Comfort

Energy & Heat



Work 'W' is done when Force 'F' moves a body of mass 'm' over distance 'x'

What is Energy ?

Energy of a system is its potential to do work.

Mechanical work (W) is defined as when a force (F) moves a mass (m) over a distance (x), as shown in Figure. An organism uses its internal energy to change its environment.

Similar to how heat is lost from a system at a higher temperature to a cooler environment, internal energy is also lost.

Thermal energy is caused by the motion of molecules and/ or intermolecular forces (ASHRAE, 2021).

Building Physics Affecting Thermal Comfort

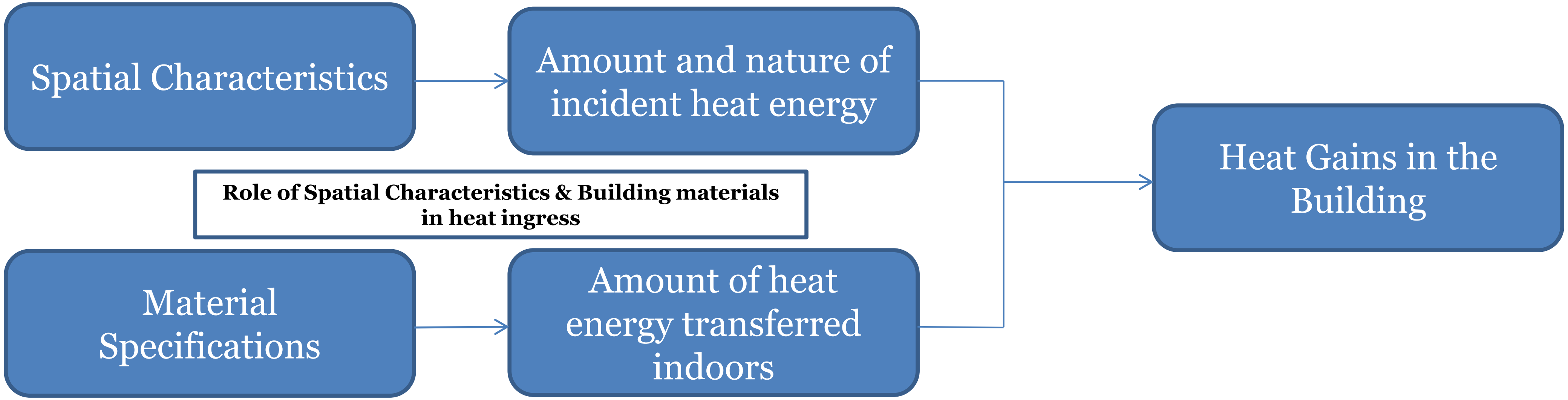
the amount of heat transferred inside a building is a function of the following

- building envelope characteristics
- operation patters of the openable elements of the building envelope
- climate of the place where building is situated.

Building Physics Affecting Thermal Comfort

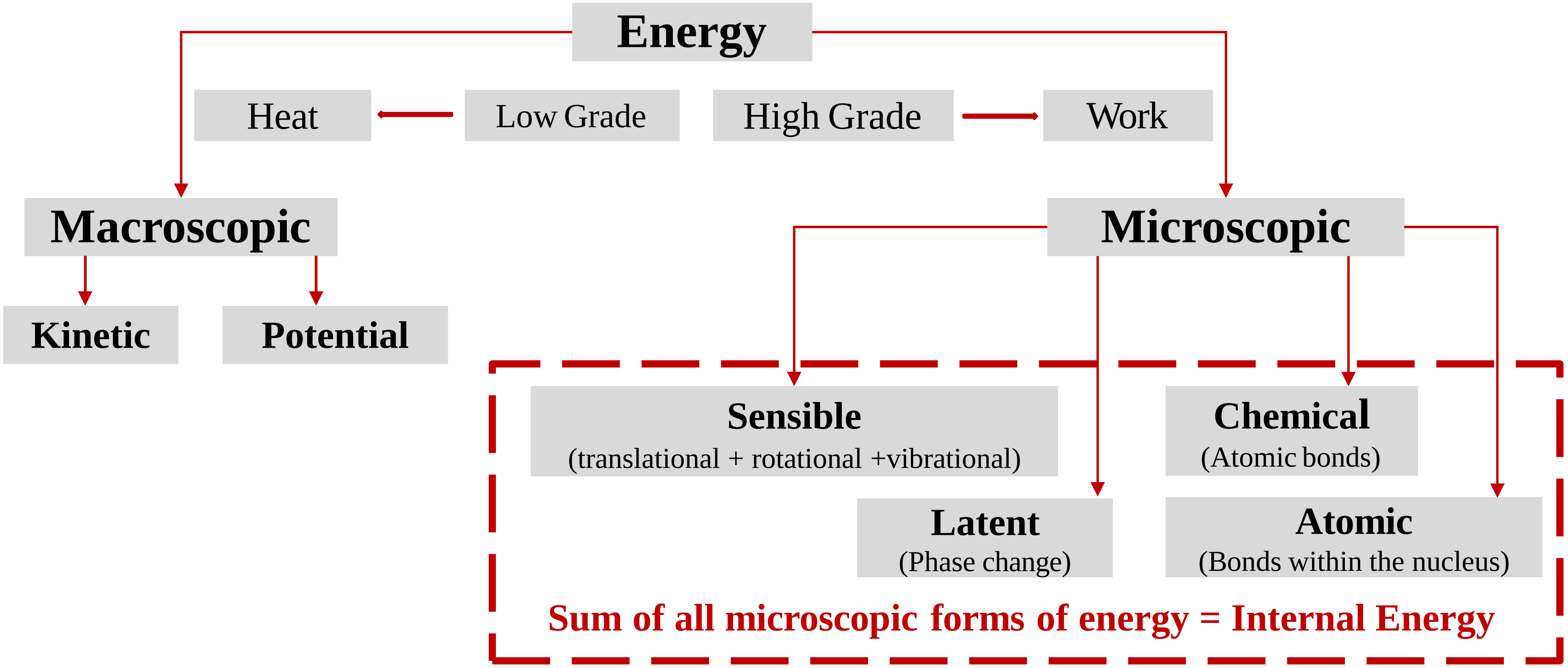
Factors Influencing Heat Transfer

- The amount of thermal energy on the surface of various building elements is visible in thermography images of buildings and people in various built environments.



- Figure demonstrates that the distribution of thermal energy among its users and in any indoor or outdoor environment is not uniform. This implies that heat is constantly being transferred between the surfaces of different items, people inside, and the air inside. Building heat transmission occurs at the building envelope, much as how heat transfer between a human body and the air around it occurs at the skin's surface.

Building Physics Affecting Thermal Comfort



Forms of Energy

Building Physics Affecting Thermal Comfort

1st Law of Thermodynamics

$$\Delta U = Q - W$$

ΔU - change in internal energy

Q - heat added to the system

W - work done by the system

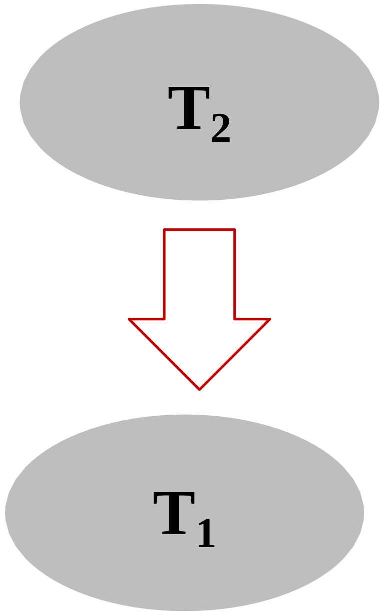
Establishes a relationship between a system's

- Internal energy
- The work performed by (or to) the system, and
- The heat removed from (or added to) the system

The internal energy of a system performing work or losing heat decreases, whereas a system's internal energy rises if it gains heat or is subjected to work.

Building Physics Affecting Thermal Comfort

2nd Law of Thermodynamics



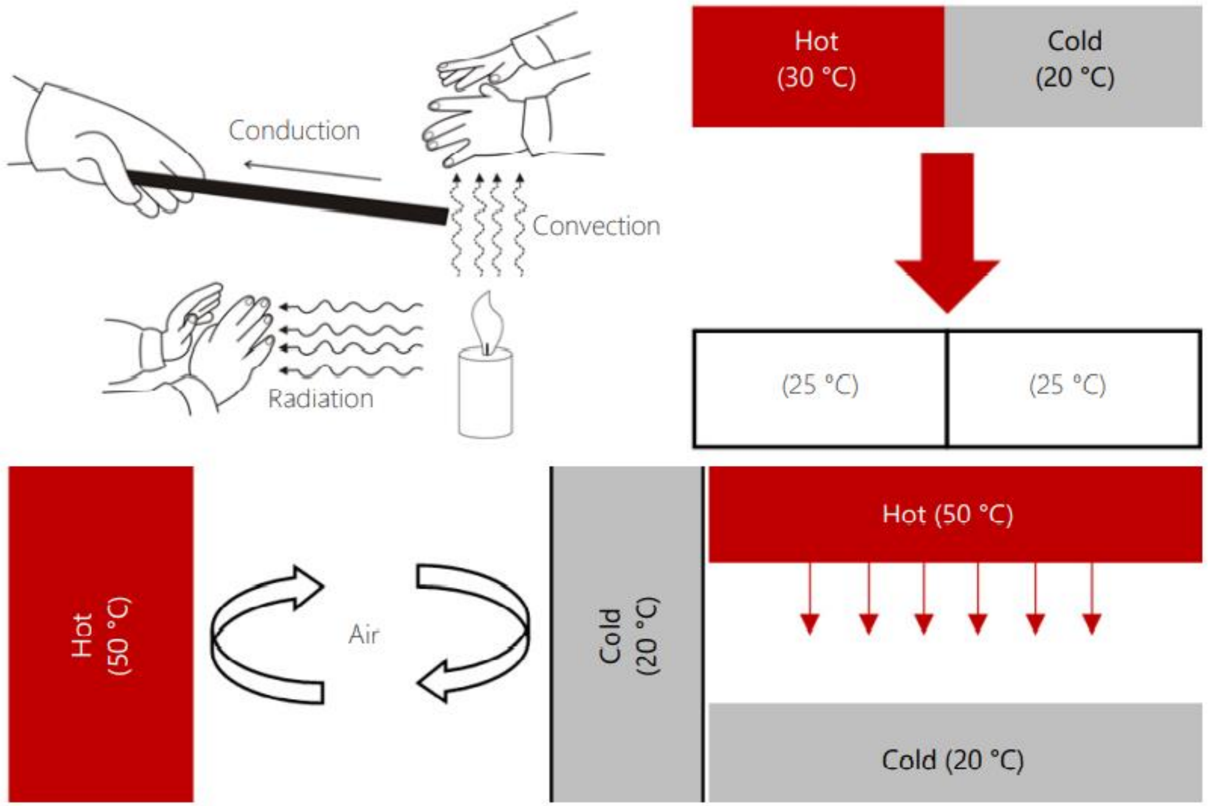
$(T_2 > T_1)$

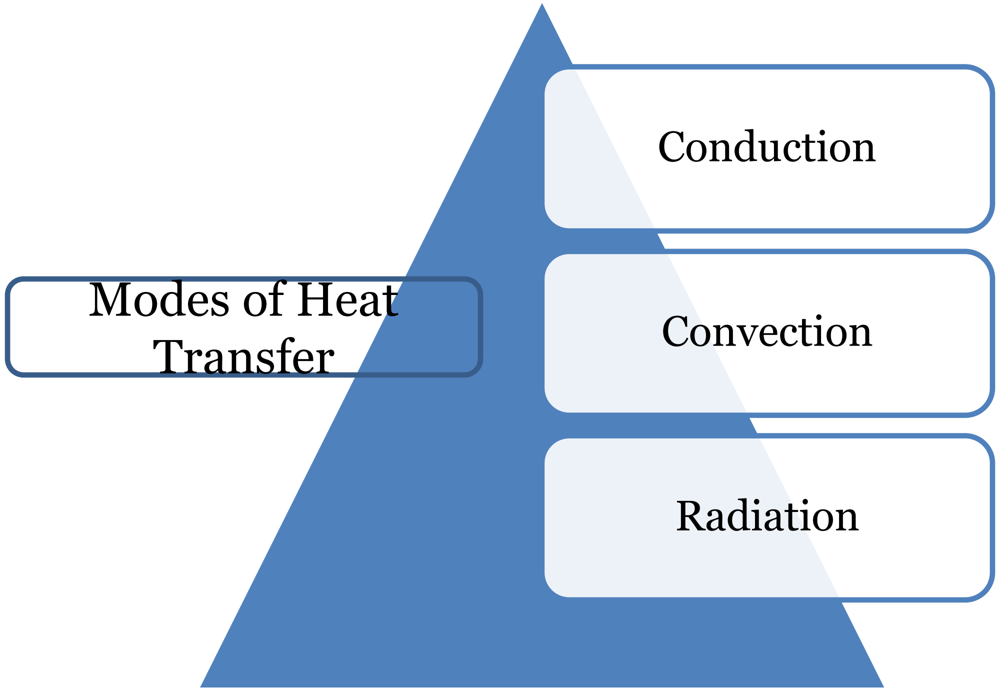
- The natural (spontaneous) direction of heat flow between bodies is from hot to cold.

- Heat moves from higher temperature to lower temperature

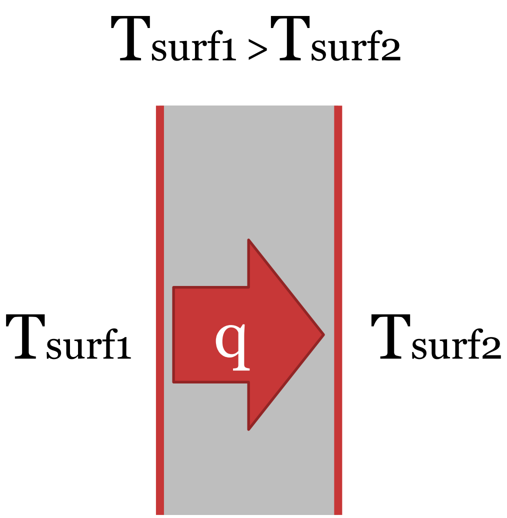
Building Physics Affecting Thermal Comfort

Modes of Heat Transfer





Heat Transfer in Buildings – Conduction Principles



Conduction

Occurs in a stationary medium

Hot objects with higher energy

(due to intense random molecular motions)

transfer heat to

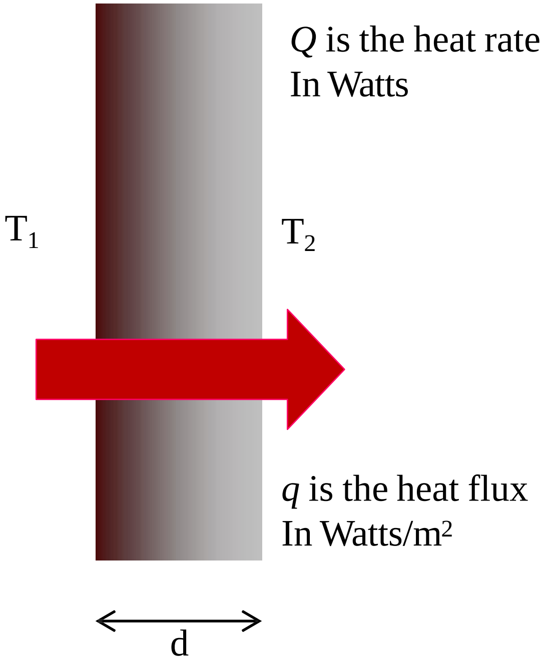
Cool objects with lesser

energy (due to lower

molecular motions)

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

Heat Transfer in Buildings – Conduction Principles

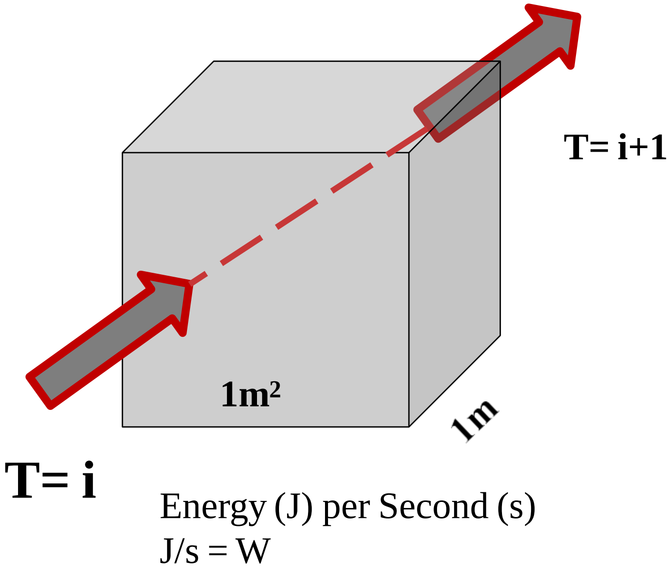


Steady-state (**time-independent**) heat conduction through a layer (thickness d, thermal conductivity k) with surface temperatures T_1 and T_2

$$Q = k\,A\,\frac{T_1 - T_2}{d}\ (W)$$

$$q = k\,\frac{T_1 - T_2}{}$$

Heat Transfer in Buildings – Conduction Principles



q depends on?

- Temperature difference
- Thickness of the layer (d)
- Thermal conductivity (k) which is a property of the material

Thermal conductivity (k)

- property of the material
- function of moisture and temperature
- $W \cdot m^{-1} \cdot K^{-1}$

Heat Transfer in Buildings – Conduction Principles

Energy & Heat

Thermal conductivity, density and specific heat capacity of common building materials and surface finishes

MATERIALS	DENSITY (kg/m³)	THERMAL CONDUCTIVITY (W/m.k)	SPECIFIC HEAT CAPACITY (J/kg.K)
Walls			
Autoclaved Aerated Concrete Block (AAC)	642	0.184	0.794
Resource Efficient Bricks (REB)	1520	0.631	0.9951
Concrete block (25/50)	2427	1.396	0.4751
Concrete block (30/60)	2349	1.411	0.7013
Calcium Silicate Board	1016	0.281	0.8637
Cement Board	1340	0.438	0.8113
Sandstone	2530	3.009	1.5957
Stone (Jaisalmer Yellow)	3006	2.745	2.0954
Stone (Kota)	3102	3.023	2.0732
Bamboo	913	0.196	0.6351

Source: Thermo-Physical-Optical Property Database of Construction Materials, U.S.-India Joint Center for Building Energy Research and Development (CBERD) and Ministry of New and Renewable Energy (MNRE)

Heat Transfer in Buildings – Conduction Principles

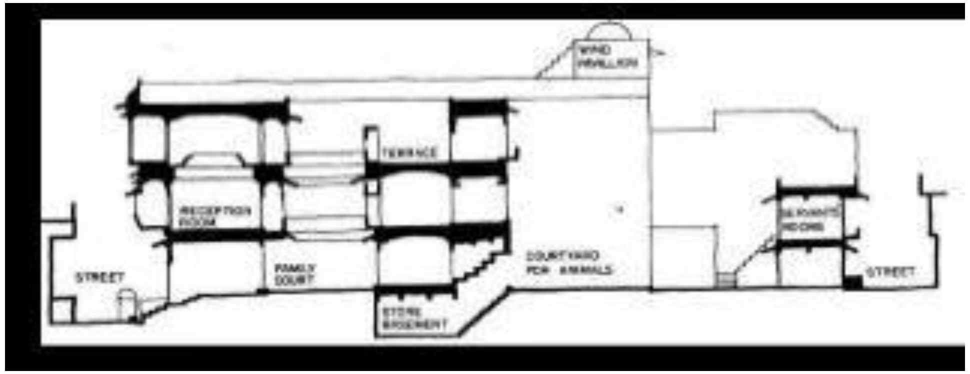
Energy & Heat

Thermal conductivity, density and specific heat capacity of common building materials and surface finishes

Source: Thermo-Physical-Optical Property Database of Construction Materials, U.S.-India Joint Center for Building Energy Research and Development (CBERD) and Ministry of New and Renewable Energy (MNRE)

MATERIALS	DENSITY (kg/m³)	THERMAL CONDUCTIVITY (W/m.k)	SPECIFIC HEAT CAPACITY (J/kg.K)
Surface Finishes			
Plaster of Paris (POP) powder	1000	0.135	0.9536
Cement Plaster	278	1.208	0.9719
Plywood	697	0.221	0.7258

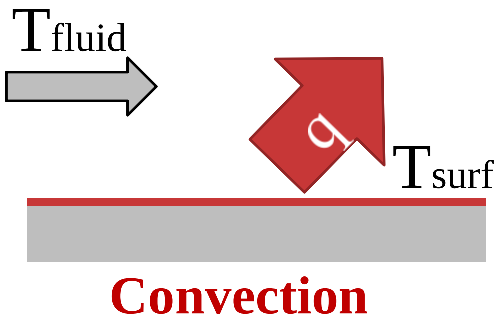
Heat Transfer in Buildings – Conduction Principles



Conduction through walls

Heat Transfer in Buildings – Convection Principles

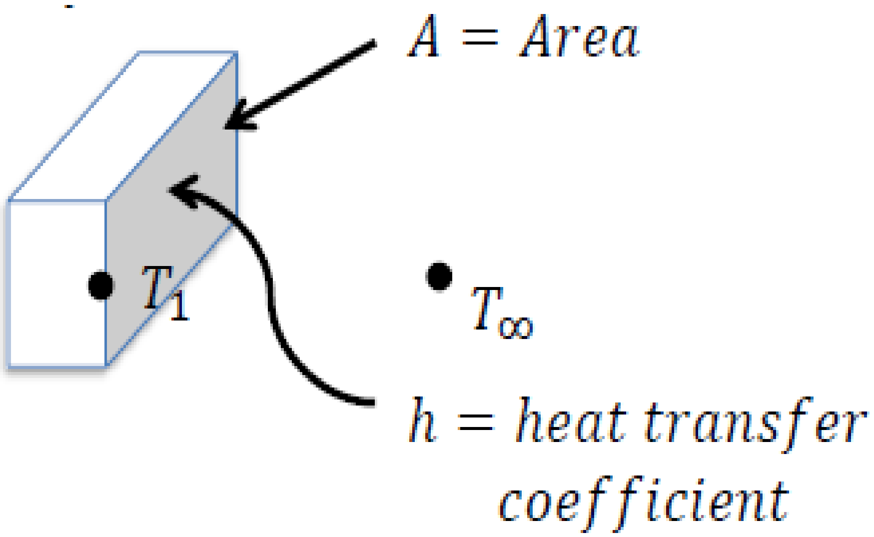
$T_{surf} > T_{fluid}$



- Convection heat transfer needs a fluid (gas or liquid) medium and involves bulk fluid motion
- The heated fluid moves away from the source of heat, carrying energy with it causing convection currents that transport energy

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

Heat Transfer in Buildings – Convection Principles



Convective heat transfer (Q) between a fluid and a surface is
Q a temperature difference
Q a area of the surface in contact

Q= **h** A **ΔT**

Q = heat transfer by convection, W
A = surface area, m2
ΔT = T∞ – T1 at some specified location, K
h = heat transfer coefficient, W·m-2·K-1

Heat Transfer in Buildings – Convection Principles

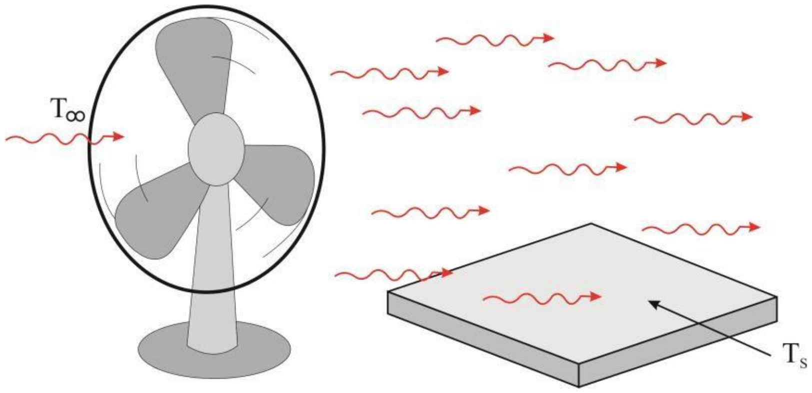
Surface resistance (ISO 6946)		
Heat flow direction	R_{si} [$m^2 \cdot K \cdot W^{-1}$]	R_{so} [$m^2 \cdot K \cdot W^{-1}$]
Horizontal (±30°)	0.13	0.04
Up	0.10	0.04
Down	0.17	0.04

Surface conductance

Conductance of the thin film of air at the surface of the material/body

- h = surface/film conductance
- $W \cdot m^{-2} \cdot K^{-1}$
- Surface/film resistance $R_s = 1/h$

Heat Transfer in Buildings – Convection Principles



Heat transfer coefficient

Surface conductance = Surface film conductance = Equivalent conductance = Heat transfer coefficient = h

$h = h_c + h_r$

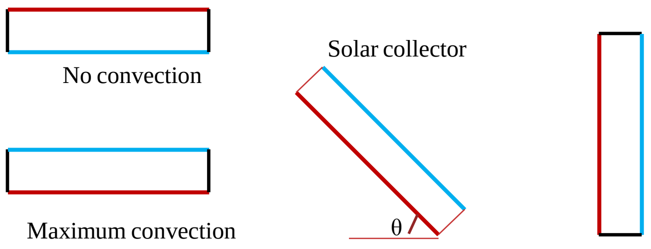
h_c = convective heat transfer coefficient

h_r = radiative heat transfer coefficient

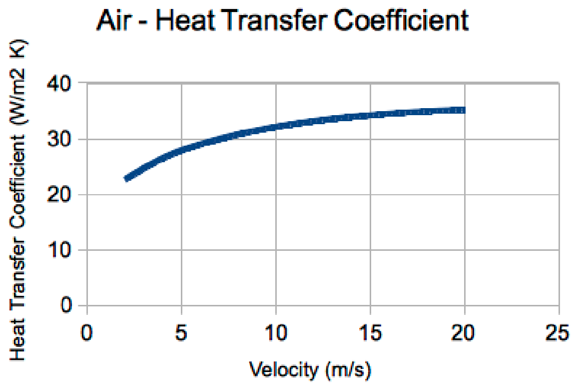
Natural Convection – Forced Convection

Source: Cappuccino. (n.d.). freepik. Retrieved from https://www.freepik.com/photos/cappuccino , Indiamart. (n.d.). Usha Table Fan. Indiamart. Retrieved from https://www.indiamart.com/proddetail/usha-table-fan- 19384320588.html

Heat Transfer in Buildings – Convection Principles



Convective heat transfer is a function of angle (θ)



- Surface film resistance or conductance considers both radiative and convective heat transfer

- Varies with
  - Orientation of the surface
  - Surface emittance
  - Direction of heat flow
  - Air velocity
  - Surface and air temperature, and the temperature difference

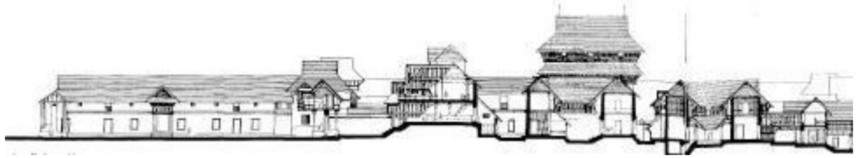
Heat Transfer in Buildings – Convection Principles

Airflow through a room
Wall temperatures of the room at 30 °C
Heat transfer coefficient on inside =10 W/m2K

Wind-induced airflow

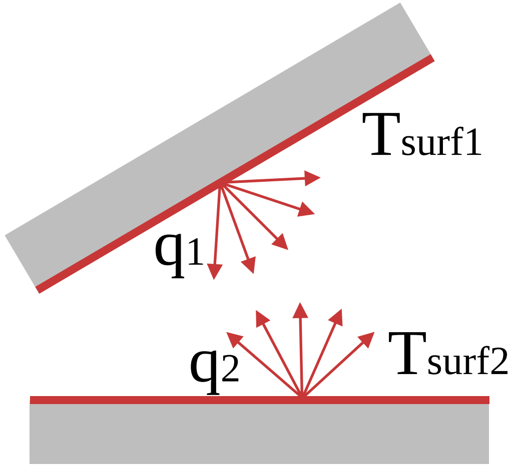
Stack effect

Buoyancy driven wind flow



Source:Tripadvisor. (n.d.). Padmanabhapuram Palace. Tripadvisor. Retrieved from https://www.tripadvisor.in/Attraction_Review-g608476-d3705659-Reviews-Padmanabhapuram_Palace_Kanyakumari_Kanyakumari_District_Tamil_Nadu.html

Heat Transfer in Buildings – Radiation Principles



Radiation

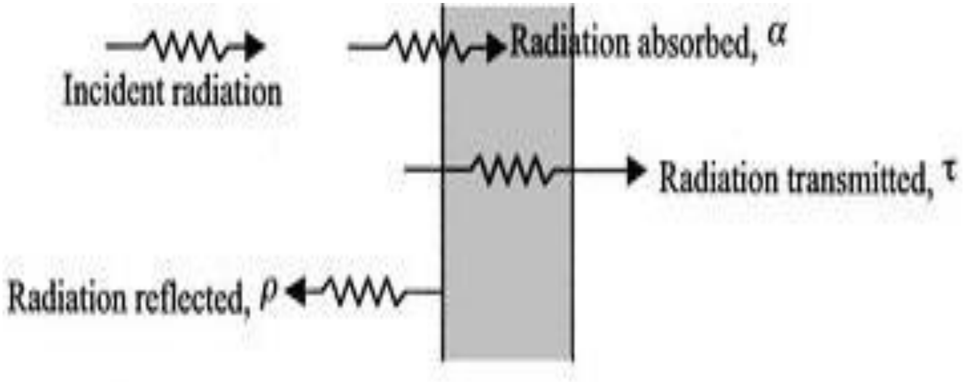
- Radiation heat transfer is a process where heatwaves are emitted that may be absorbed, reflected, or transmitted through a colder body.
- Energy has an electric field and a magnetic field associated with it,
- Wave-like properties. "electromagnetic waves"
- Wide range of electromagnetic radiation in nature. Visible light is one example.
- Others include forms like ultraviolet radiation, x-rays, and gamma rays.

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

Heat Transfer in Buildings – Radiation Principles

The behaviour of a surface with radiation incident upon it can be described by the following quantities:

= absorptance – a fraction of incident radiation absorbed
= reflectance - fraction of incident radiation reflected
= transmittance – a fraction of incident radiation transmitted.



$$\alpha + \rho + \tau = 1$$

Outdoor Climate & Heat Transfers - Climate Zones of India

	Conduction		Convection		Radiation	
	Spatial	Material & Methods	Spatial	Material & Methods	Spatial	Material & Methods
Walls						
Fenestrations (Windows)						
Roofs						

- V. Low
- Low
- Neutral
- High
- V. High

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

Heat Transfer in Buildings – Design Strategy

	Conduction	Convection	Radiation
Geometry - Massing	HD	WH	All Climates
Orientation		WH	All Climates
External Surface to Building Volume Ratio	HD	WH	HD
Extent of Fenestration and Thermal Characteristics	HD	WH	All Climates
Internal Volume – Stack Ventilation	X	HD	X
Location of Fenestration – Pressure Driven Ventilation	X	WH	X

WH: Warm Humid
HD: Hot-Dry
TE: Temperate CM: Composite CO: Cold

V. Low
Low
Neutral
High
V. High

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Heat Transfer in Buildings – Design Strategy

Thermal Conductivity
R Value – U Value
Thermal Mass
Specific Heat
Thermal Diffusivity

- **Walls**
  - Internal
  - External

Thermal Conductivity – Frames and Glass
R Value – U Value
Solar Gains
Solar Heat Gain Coefficient
Visual Light Transmittance
VLT

- **Fenestrations**
  - Windows
  - Skylights
  - Doors

Thermal Conductivity
R Value – U Value
Thermal Emissivity
Solar Reflectance

- **Roofs**
  - Floors
  - Foundations

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from https://solardecathlonindia.in/events/

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

10

Heat Balance & Adaptive Thermal Comfort Method

Comfort Theoory - Heat Balance Method

The heat balance method presents a physics based mathematical model that establishes thermal comfort when heat loss from the body is exactly equal to heat produced within the body. The heat balance method gives following equation:

M-W= qsk+qres+S=(C+R+ Esk)+(Cres+ Eres)+(Ssk+ Scr)

Where,

M = Rate of metabolic heat production, W/m 2

W = Rate of mechanical work accomplished, W/m 2

q_{sk} = Total rate of heat loss from skin, W/m 2

q_{res} = Total rate of heat loss through respiration, W/m 2

C+ R = Sensible heat loss from skin, W/m 2

E_{sk} = Total rate of evaporative heat loss from skin, W/m 2

C_{res} = Rate of convective heat loss from respiration, W/m 2

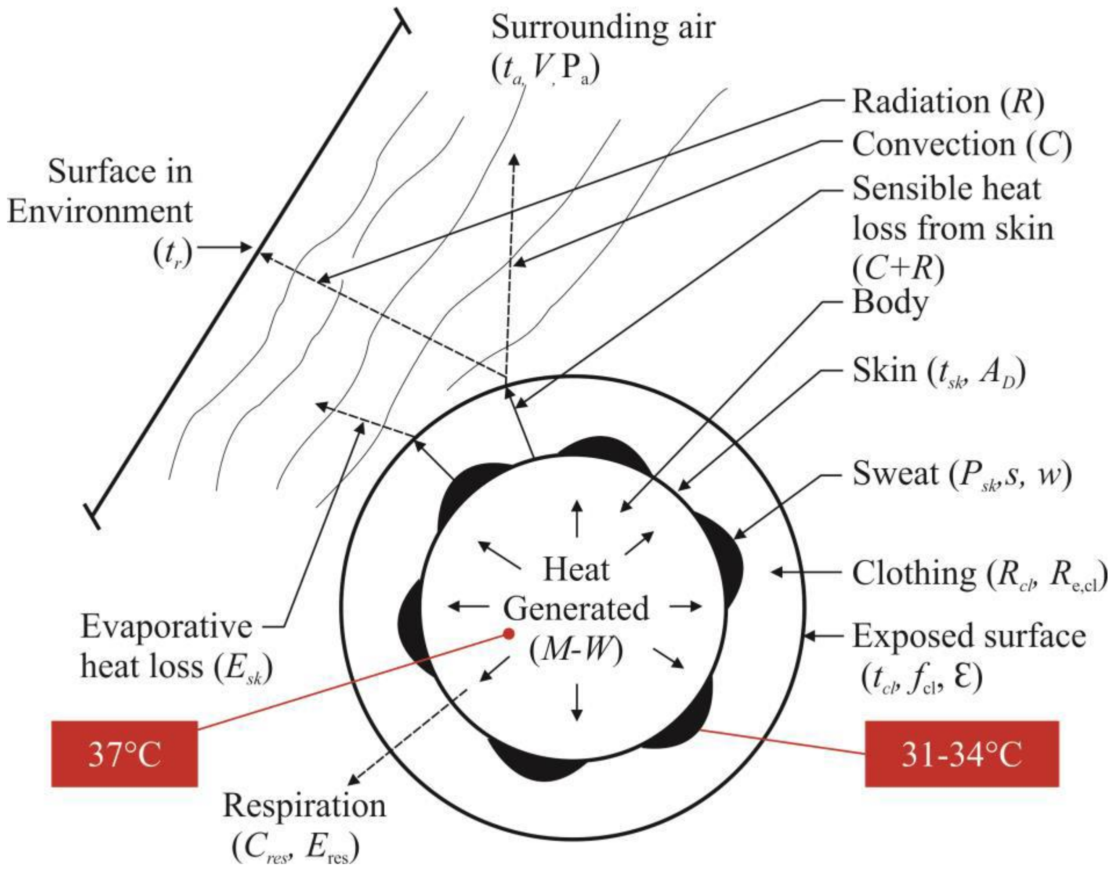
E_{res} = Rate of evaporative heat loss from respiration, W/m 2

S_{sk} = Rate of heat storage in skin compartment, W/m 2

S_{cr} = Rate of heat storage in core compartment, W/m 2

Source: Fantozzi, F., & Lamberti, G. (2019). Determination of thermal comfort in indoor sport facilities located in Moderate Environments: An overview. Atmosphere, 10(12), 769. https://doi.org/10.3390/atmos10120769

Comfort Theoory - Heat Balance Method



In order to be comfortable: -

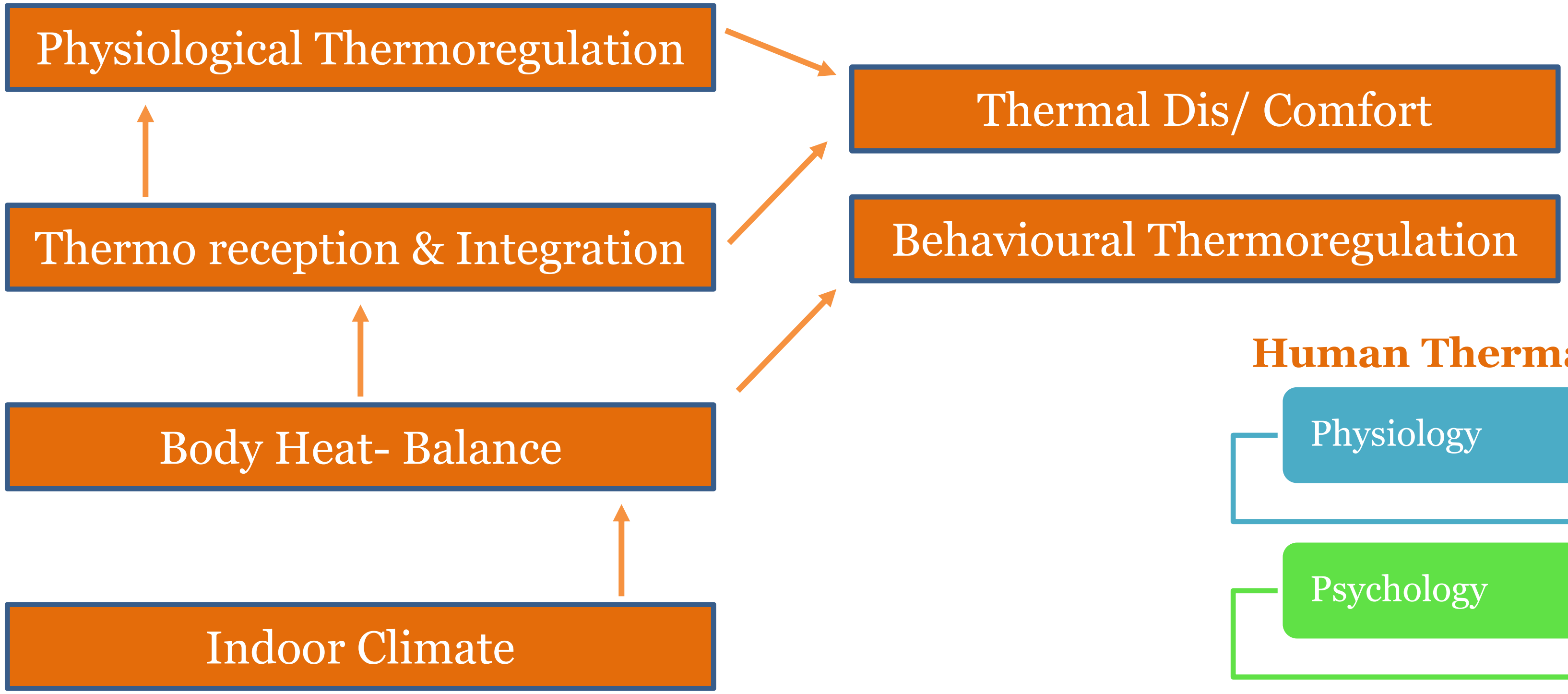
Heat production = Heat loss from the body

Heat loss > Production, then you feel Cold

Heat loss < Production, then you feel Hot

Source: Fantozzi, F., & Lamberti, G. (2019). Determination of thermal comfort in indoor sport facilities located in Moderate Environments: An overview. Atmosphere, 10(12), 769. https://doi.org/10.3390/atmos10120769

Comfort Theoory – Adaptive Thermal Comfort Mehod



Human Thermal Comfort Depends upon

Source: Fantozzi, F., & Lamberti, G. (2019). Determination of thermal comfort in indoor sport facilities located in Moderate Environments: An overview. Atmosphere, 10(12), 769. https://doi.org/10.3390/atmos10120769

11

Local Thermal Discomfort

Human Comfort Range as per ASHRAE 55 Standard

To accommodate Local thermal Discomfort, most standards like ASHRAE specify conditions to ensure 80% acceptability of the thermal environment amongst occupants.

Most Humans are comfortable under this conditions

- Winters
  - 68°F to 76°F
    60% to 30% RH
- Summer
  - 74°F to 80°F
    60% to 30% RH

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 COMFORT

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

THERMAL COMFORT

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

Local 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.

To accommodate Local thermal Discomfort, most standards like ASHRAE specify conditions to ensure 80% acceptability of the thermal environment amongst occupants.

Local Thermal Discomfort - Causes

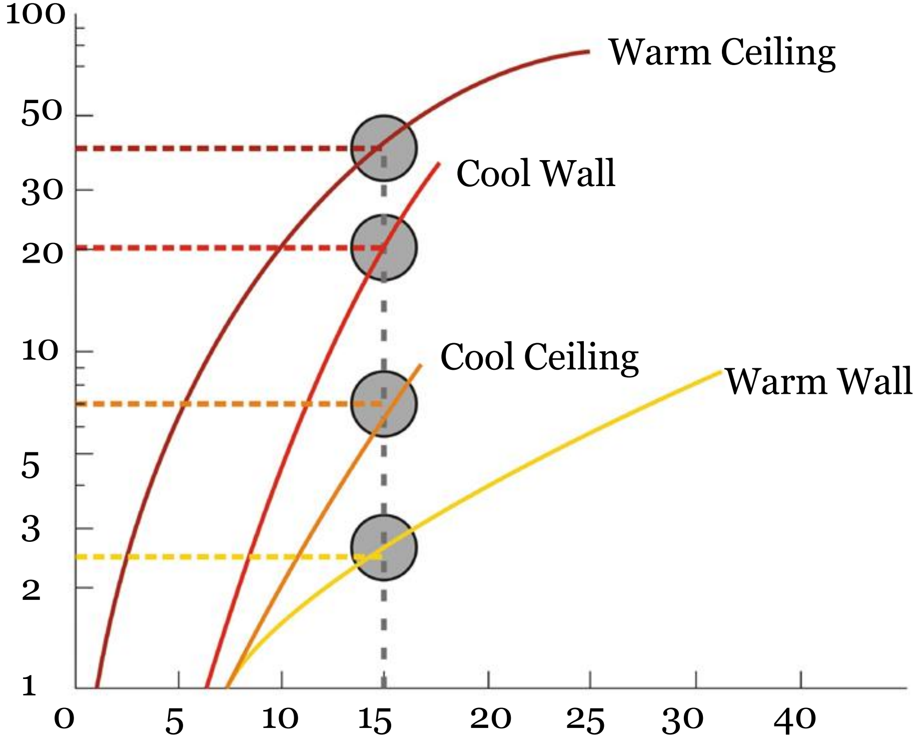
Local Thermal Discomfort is primarily caused by the Asymetric Thermal Radiation. Where :

Radiant asymmetry is defined as the difference in radiant temperature of the environment on opposite sides of the person/ Difference in radiant temperatures seen by a small flat element looking in opposite directions
(ASHRAE, 2021)

Radiant Asymmetry Types in Buildings

- Radiant Temperature Asymmetry – Walls and Roof
- Radiant Temperature Asymmetry – Floors
- Radiant Temperature Asymmetry Between head and ankles

Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



Occupant dissatisfaction levels due to radiant temperature asymmetry in walls and roof.
Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017). ASHRAE Fundamentals SI edition.

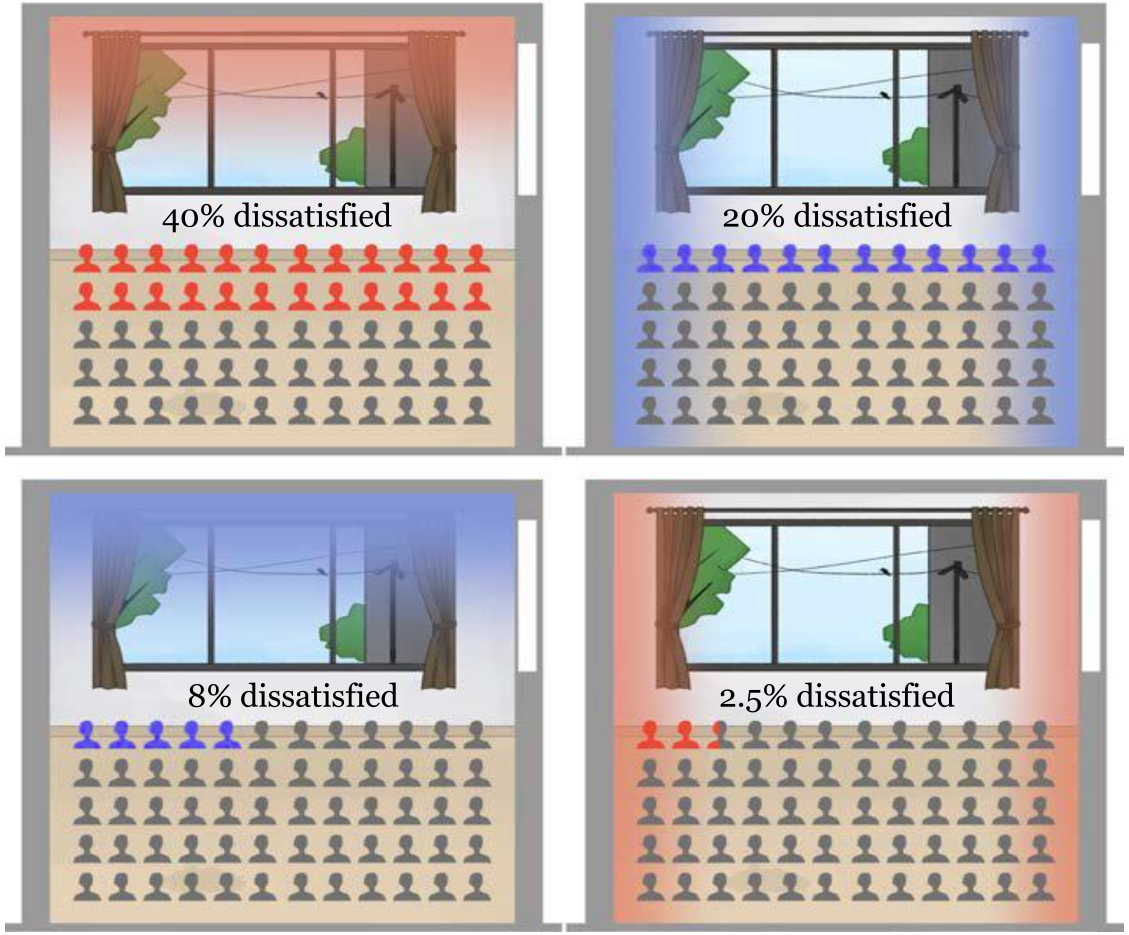
Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

Radiant Thermal Asymmetry (15 C) Cause	Warm Ceiling	Cool Walls	Cool Ceiling	Warm Walls
PPD	40%	20%	8%	2.5%

The descending order of PPD expressed in radiant thermal asymmetry for walls and ceilings can be given as

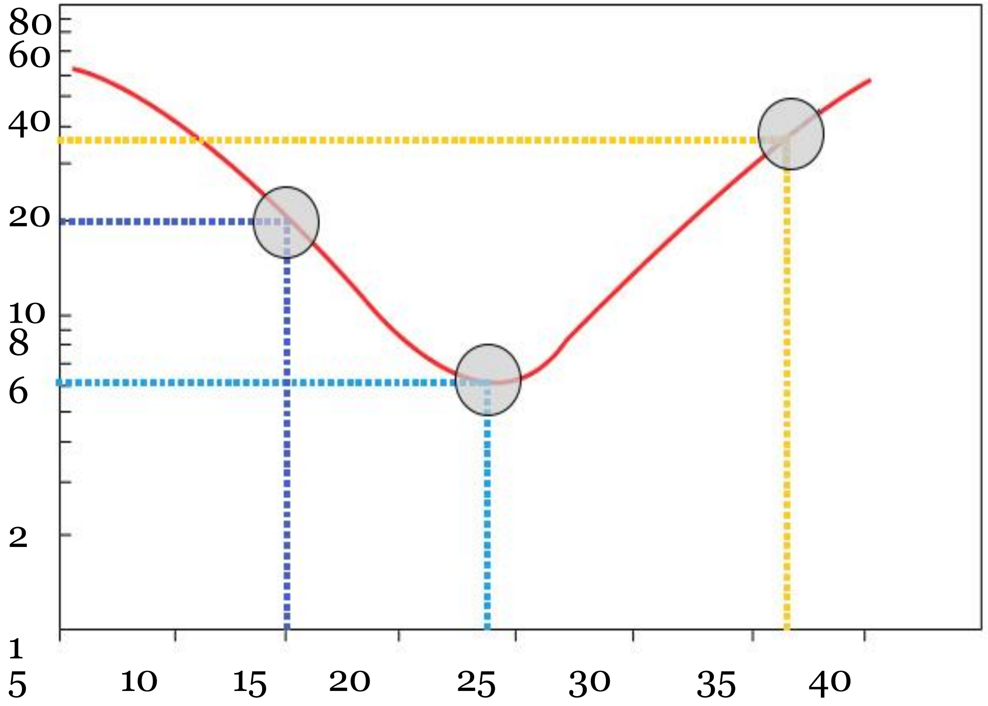
Warm Ceiling > Cool Wall > Cool Ceiling > Warm Wall.

Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



- Representation of radiant thermal asymmetry in walls and roof with resultant percentages of dissatisfied occupants.

Local Thermal Discomfort due to Radiant Temperature Asymmetry – Floors



Occupant dissatisfaction levels due to radiant temperature asymmetry in floor.
Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017).
ASHRAE Fundamentals SI edition..

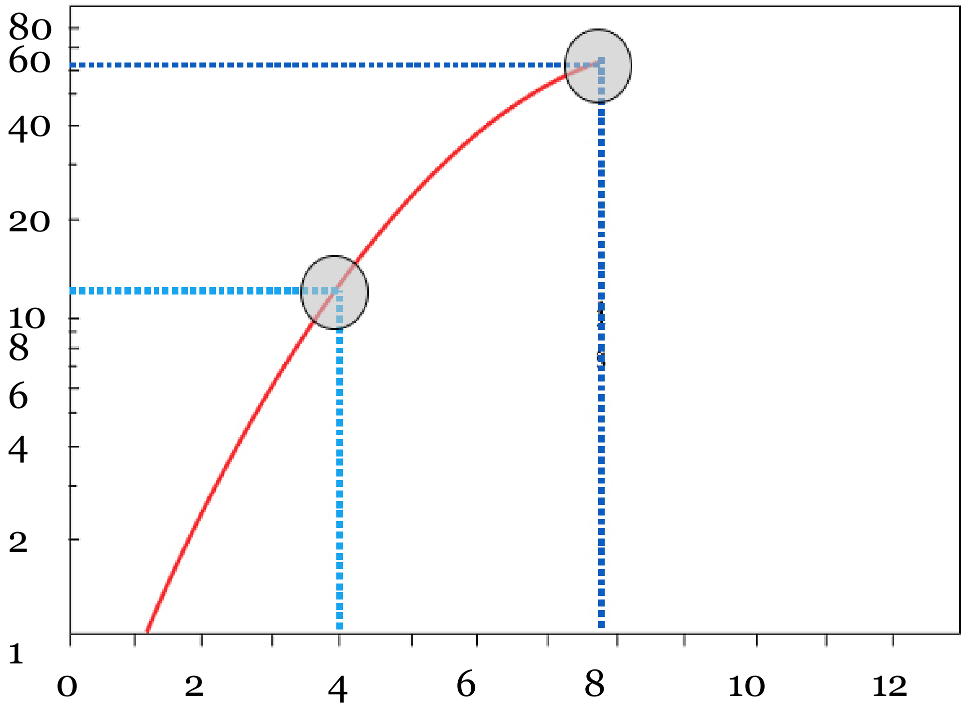
Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

Categorization of Floor Temp.	Cold	Cool/ Neutral	Warm
Floor Temperature	15 °C	24 °C	36 °C
PPD	20%	6%	35%

The descending order of PPD expressed due to floor temperature is Warm Floor > Cold Floor> Cool Floor. An explanation of why cooler or neutral floor temperatures are preferred over warm floors lies in the understanding of

- the amount of hot and cold receptors present at the base of our feet
- The sensitivity level of these receptors towards heat or coolth.

Local Thermal Discomfort due to Radiant Temperature Asymmetry – Head and Ankles



Air Temp Difference between head and Ankles °C

Percentage of Seated People Dissatisfied as Function of Air Temperature Difference Between Head and Ankles
Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017). ASHRAE Fundamentals SI edition.

Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

Categorization of Floor Temp.	Cold	Cool/ Neutral	Warm
Floor Temperature	15 °C	24 °C	36 °C
PPD	20%	6%	35%

The descending order of PPD expressed due to floor temperature is Warm Floor > Cold Floor> Cool Floor. An explanation of why cooler or neutral floor temperatures are preferred over warm floors lies in the understanding of

- the amount of hot and cold receptors present at the base of our feet
- The sensitivity level of these receptors towards heat or coolth.

DAY 1

Session 4: Passive Strategies & Building Materials

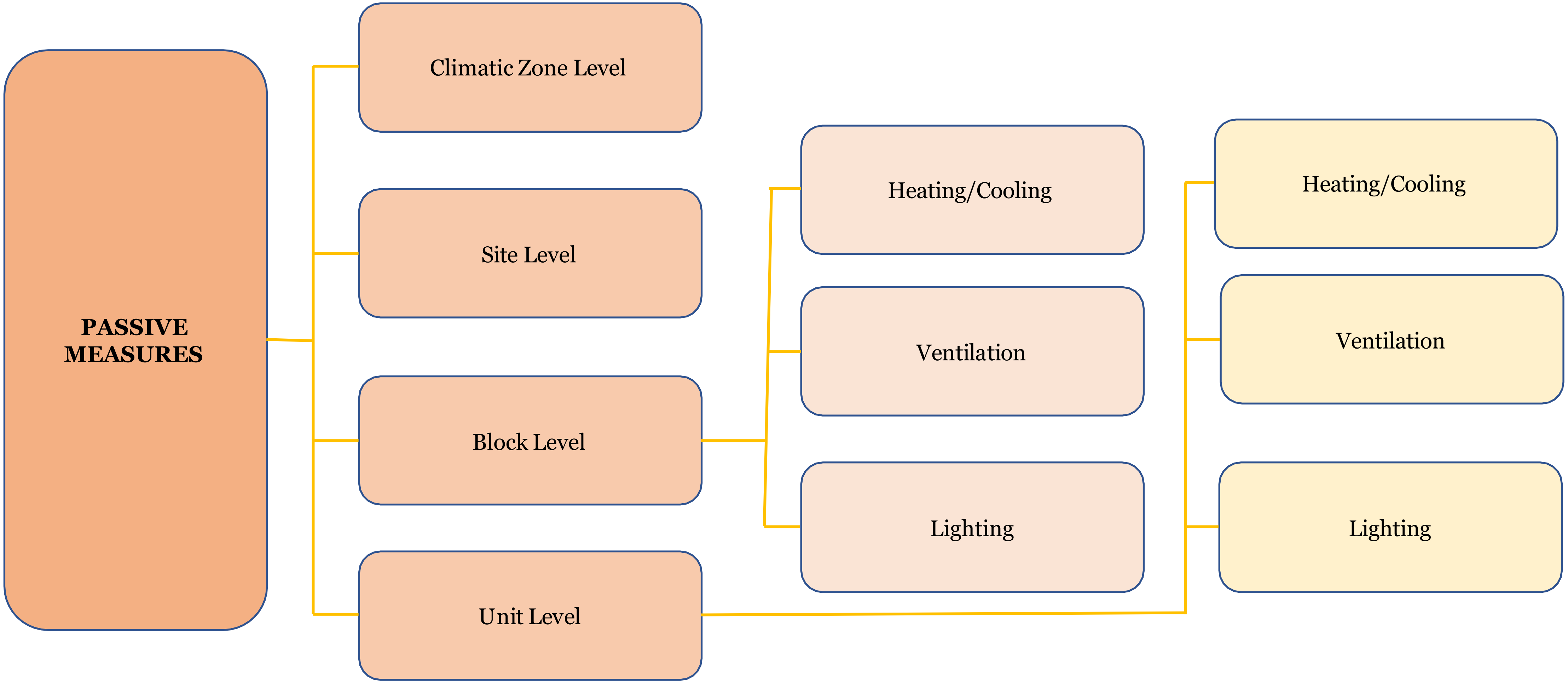
12

Affordable Housing & Passive Design Strategies

Passive Strategies & Building Physics

Passive Measures		Level of Response	
Climatic Zone Level	Temperature, rainfall, wind direction, sun radiation, humidity, and other environmental factors are taken into consideration when designing.	Block Level	Interaction of the block with its surroundings and plants to ensure that it has adequate heating, ventilation, and lighting.
Site Level	To take advantage of the positive aspects of the site and its microclimatic features while minimising the negative aspects.	Unit Level	Design solutions that influence heat, light, and ventilation based on climatic variables at the unit level.

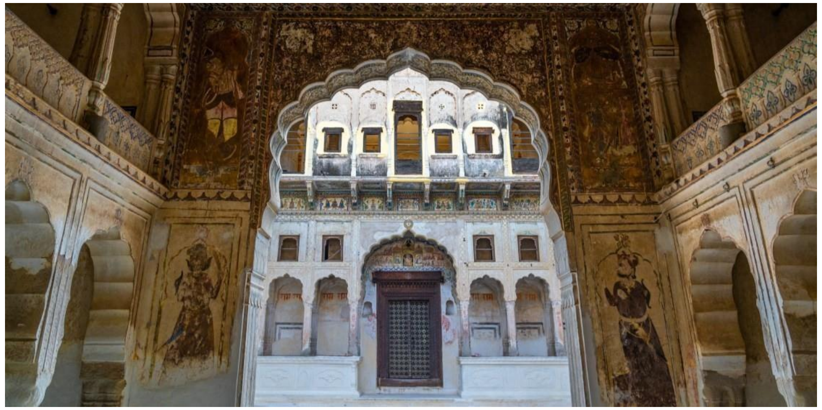
Passive Strategies & Building Physics



Passive Strategies & Building Physics

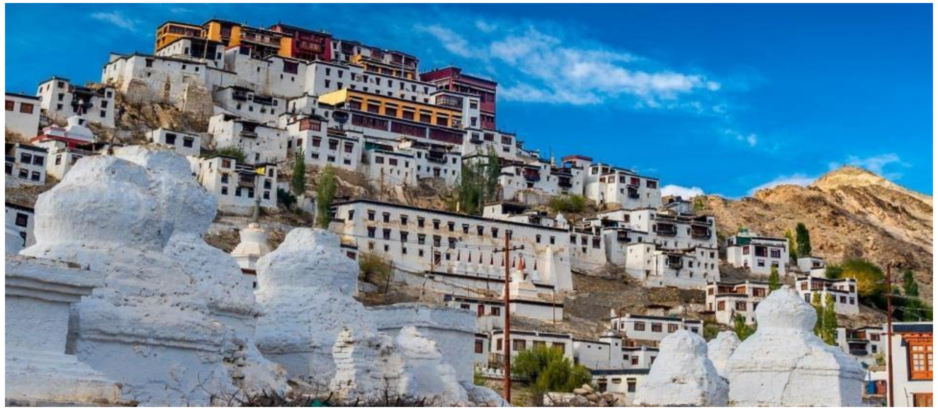
Passive Measures – Climatic Zone Level

Vernacular / traditional architectural typologies that respond to the region's distinct environment are best exemplified.



Example

- In Ladakh, earth architecture with thick walls and limited windows provides optimal insulation.
- In Rajasthan, courtyard havelis take advantage of pressure differences and reciprocal shading to provide natural cooling and ventilation.
- In Kerala, sloping roofs are used to guard against severe rains.



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

Passive Strategies & Building Physics

Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

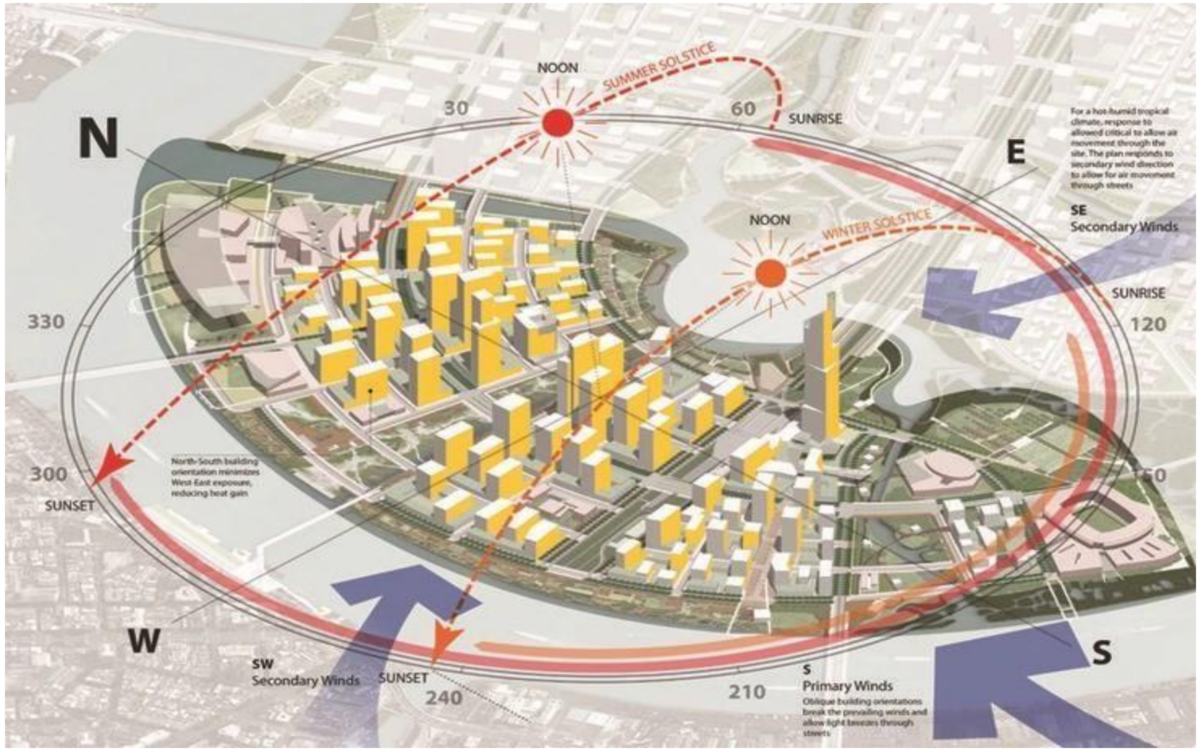
Courtyards / open courts are often surrounded by construction.

Taking advantage of block mutual shading

Using site massing to create wind passageways

lowering the amount of hard paving to allow for water absorption

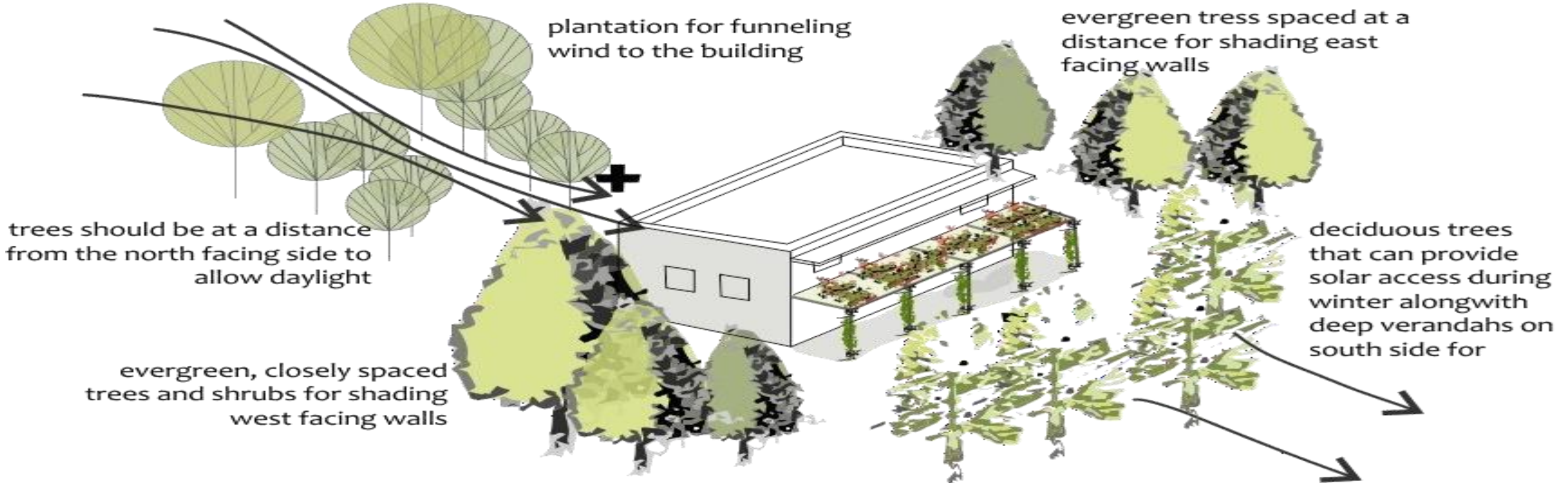
Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change

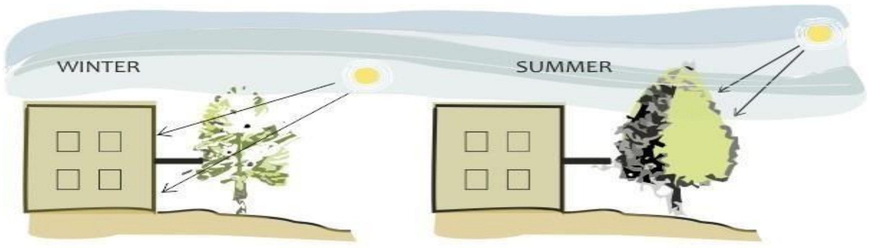


Passive Strategies & Building Physics

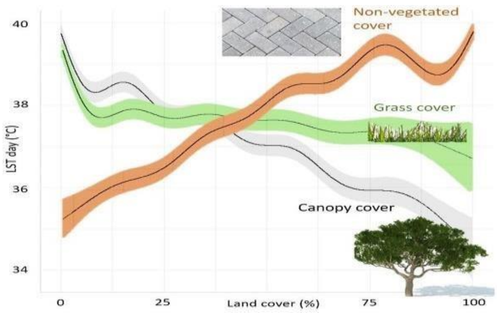
Passive Measures – Leveraging Plantation

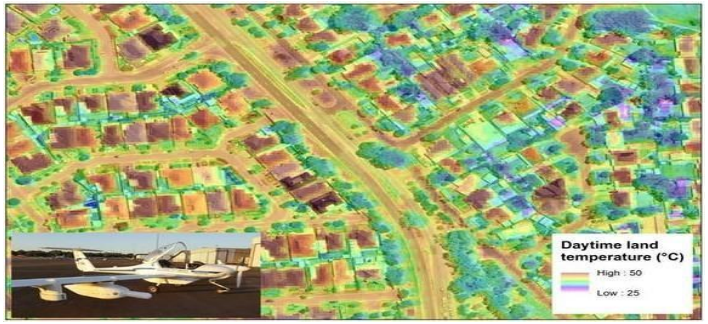
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained cooler by up to 6°C.





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

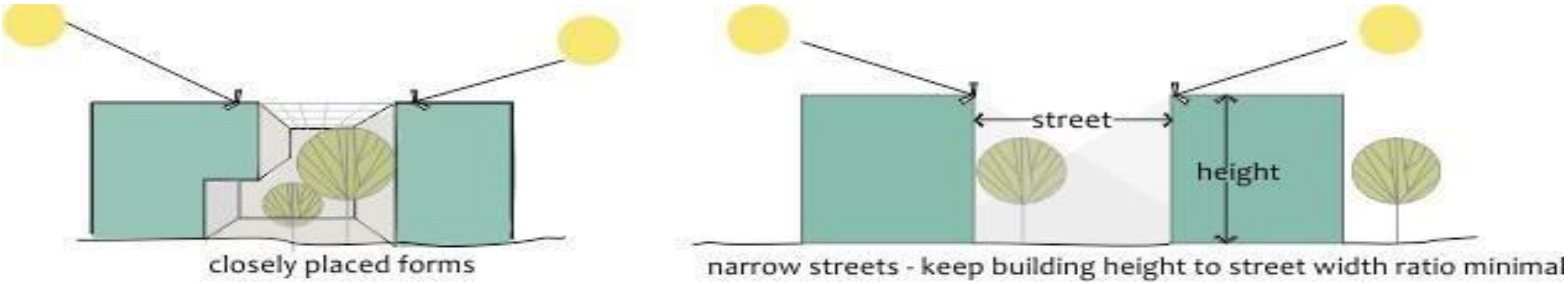




Passive Strategies & Building Physics

Block Level

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



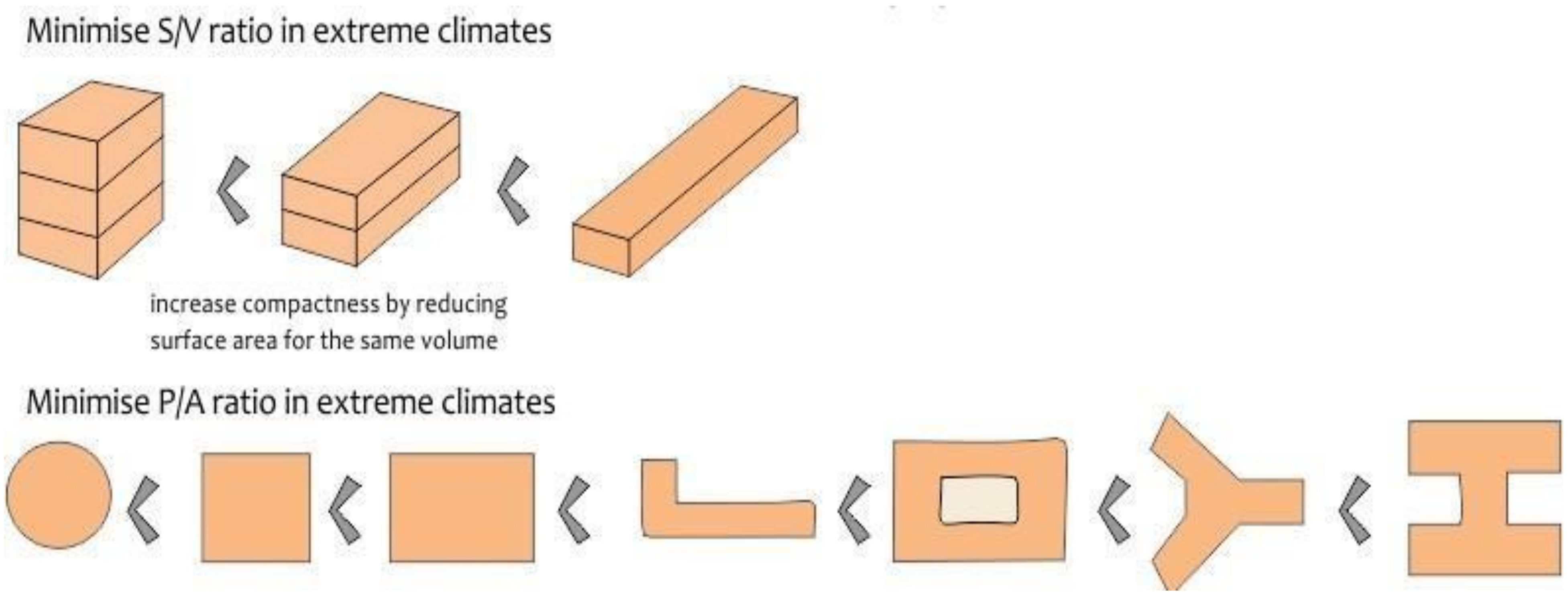
-

HEATING/ COOLING

Passive Strategies & Building Physics

Block Level

In harsh climate zones, reduce the surface area to building volume and perimeter to area ratios to reduce solar radiation exposure.

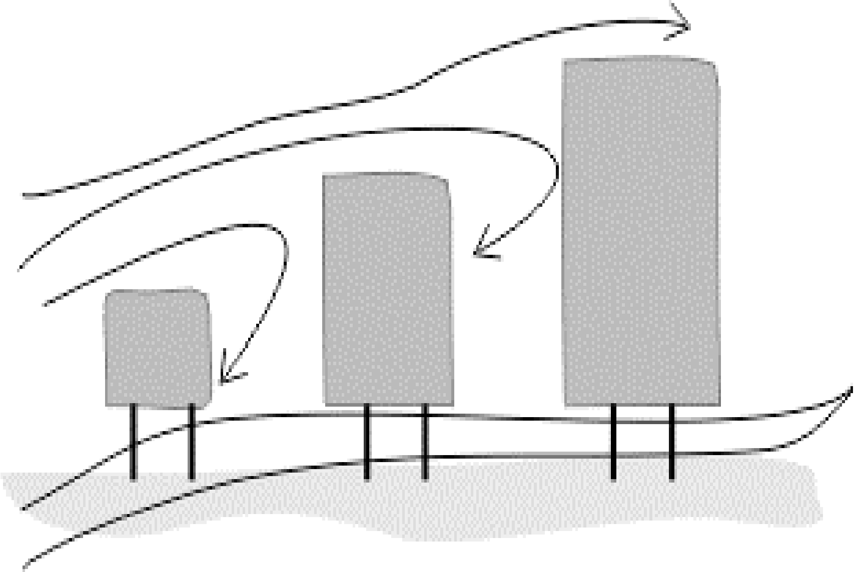


HEATING/ COOLING

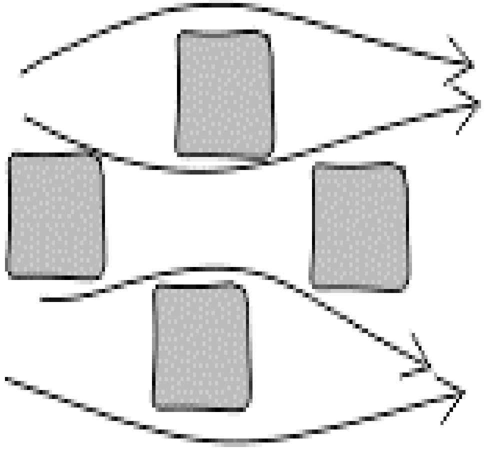
Passive Strategies & Building Physics

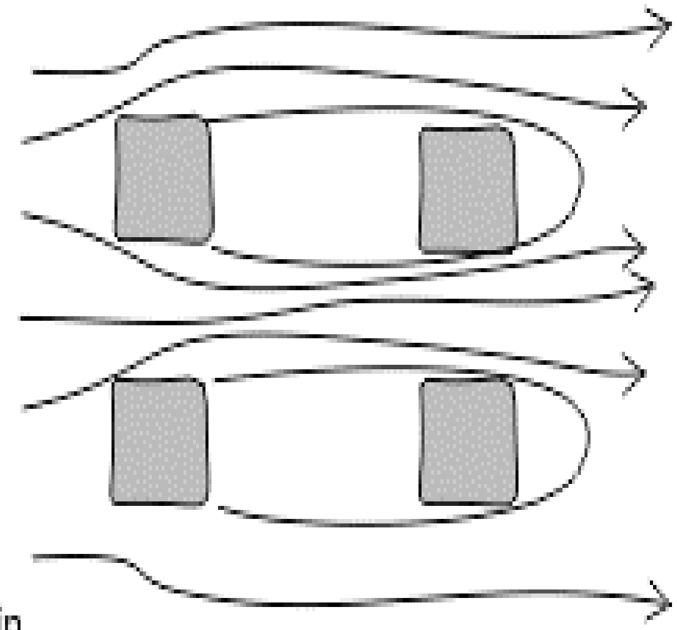
Block Level

Wind shadows should be avoided by building orientation.



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





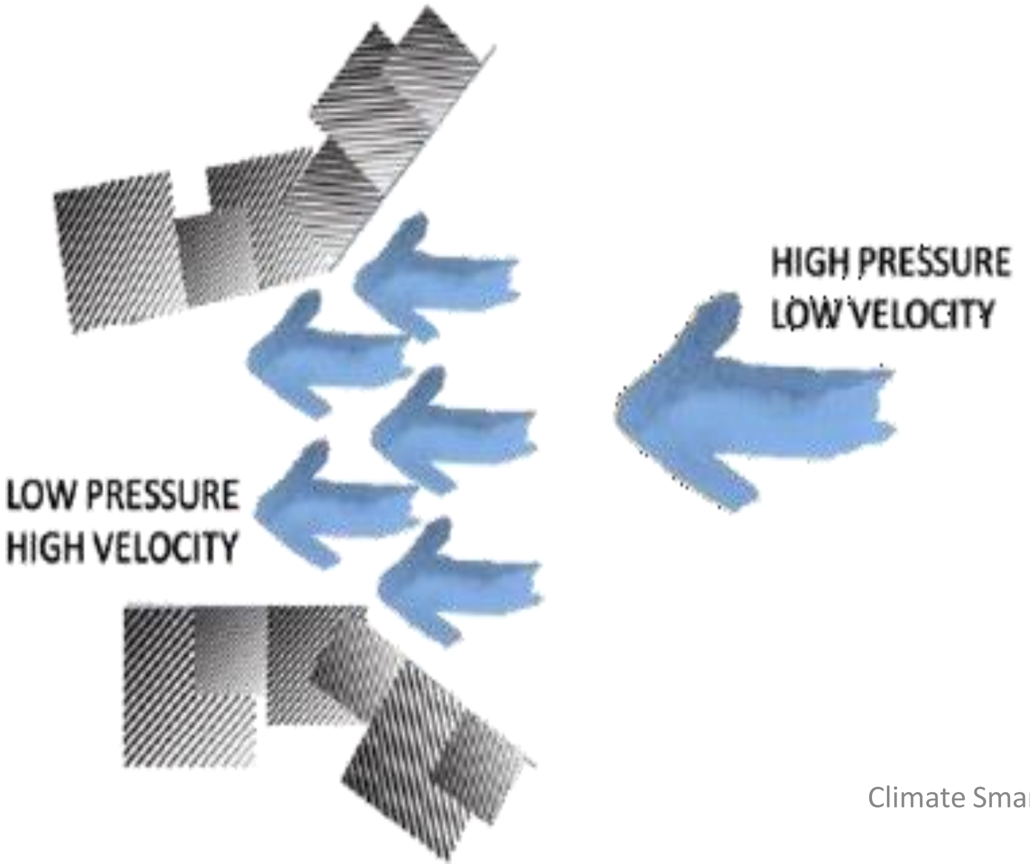
staggered layout helps in accentuating wind movement

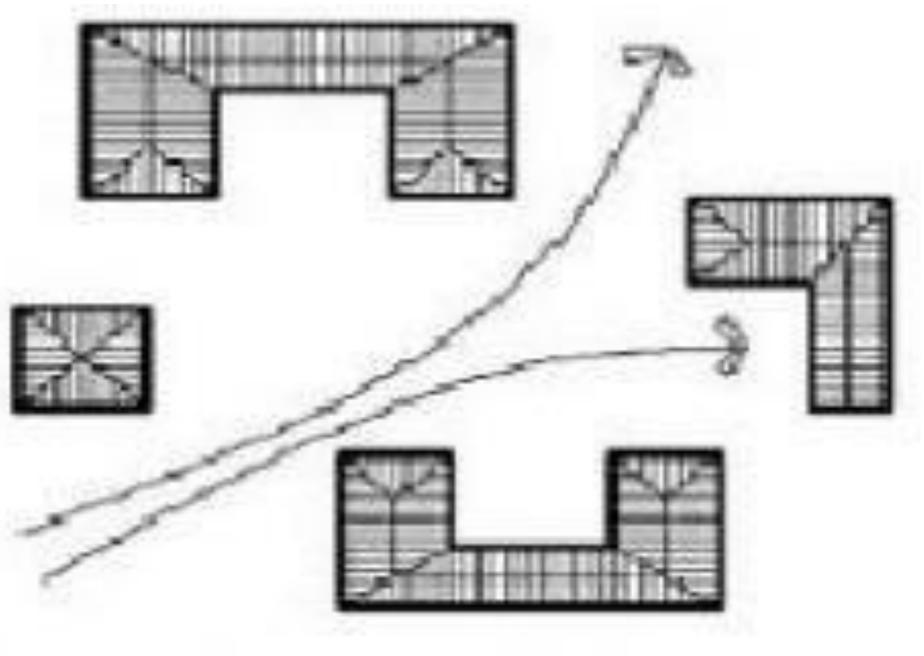
VENTILAT ION

Passive Strategies & Building Physics

Block Level

Wind flows can be harnessed by constructing courts and catchment zones of various sizes. This can help to improve airflow and provide a cooling effect for the blocks.





BUILDING SPACING SUCH THAT AIR FLOW IS PROMOTED

VENTILATION

Passive Strategies & Building Physics

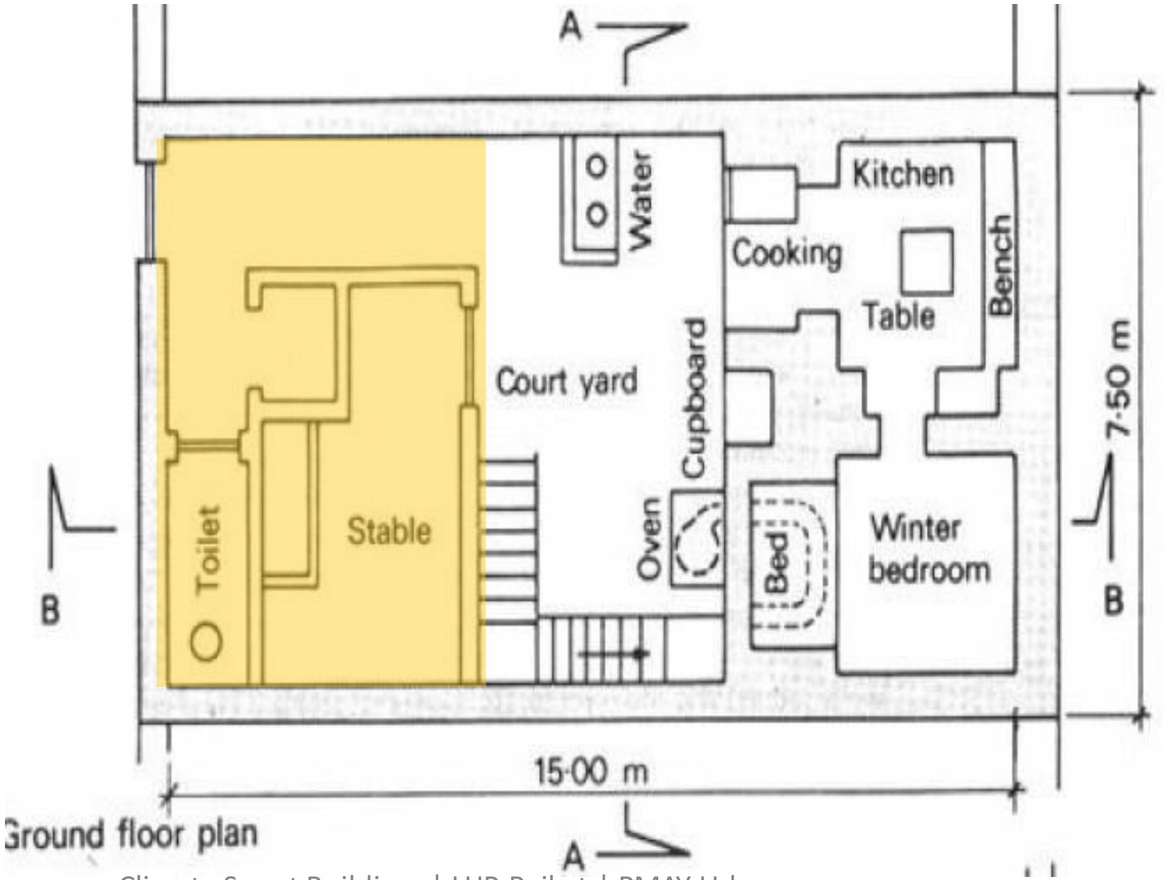
Unit Level

FORMS AND ORIENTATION:

Sun radiation penetration patterns and, as a result, heat uptake and loss in a building are affected by changes in solar route during different seasons.

Internal layout is of the courtyard type, which is rather compact. Reduced sun exposure on East-West external walls to reduce heat gain.

If planned and situated on the east and, especially, the west end of the structure, non-habitable rooms (stores, bathrooms, etc.) can be efficient thermal barriers.



HEATING/ COOLING

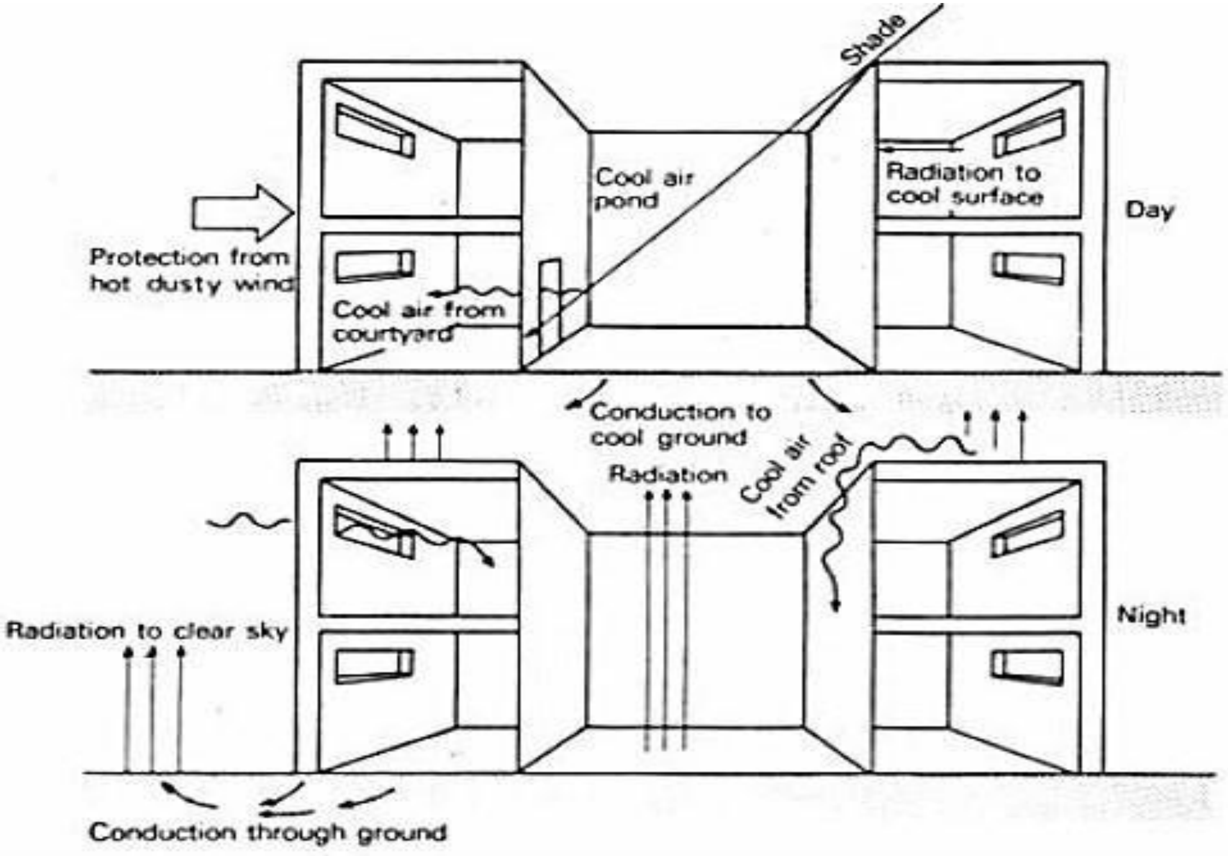
Passive Strategies & Building Physics

Unit Level

FORMS AND ORIENTATION:

High walls block the sun, resulting in significant portions of the inner surfaces and courtyard floor being shaded during the day.

The dirt beneath the courtyard will extract heat from the surrounding places and remit it to the open sky during the night, resulting in cooler air and surfaces.



HEATING/ COOLING

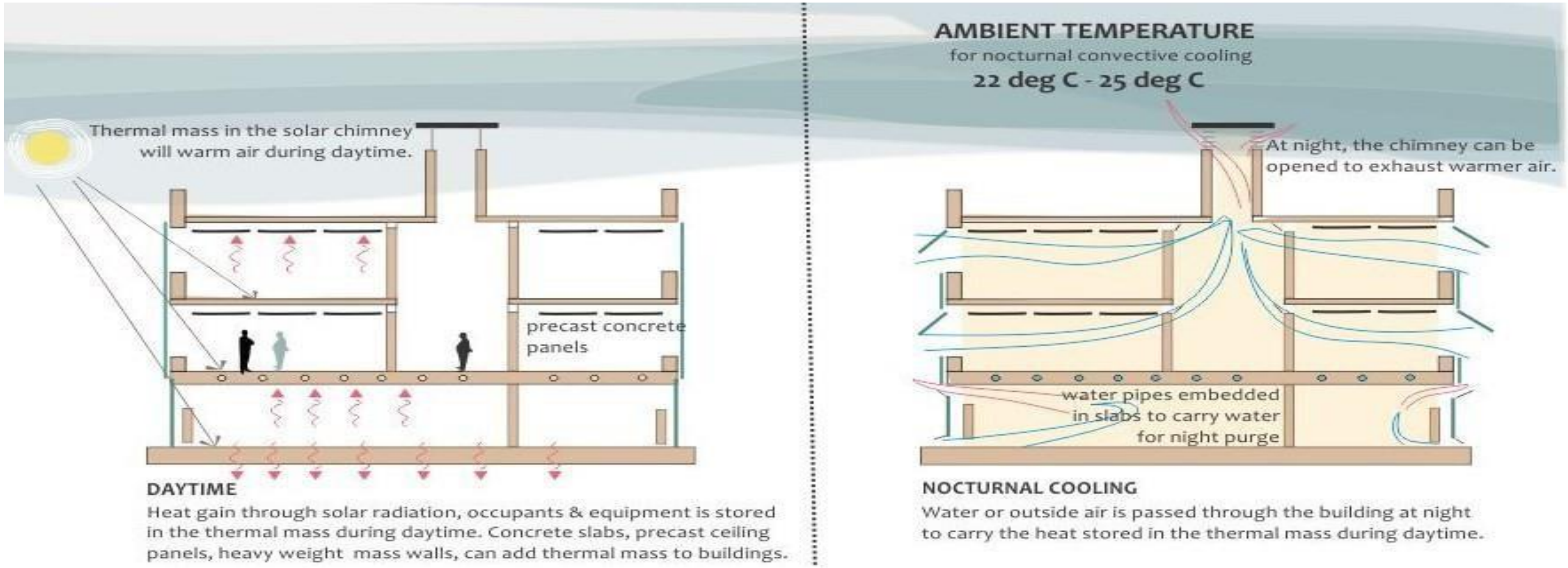
Passive Strategies & Building Physics

Unit Level

THERMAL MASS:

Thermal mass can be combined with night-time convective cooling, sometimes known as "night cooling," to passively cool buildings.

Thermal mass as a passive cooling and heating approach requires a large diurnal swing.



HEATING/ COOLING

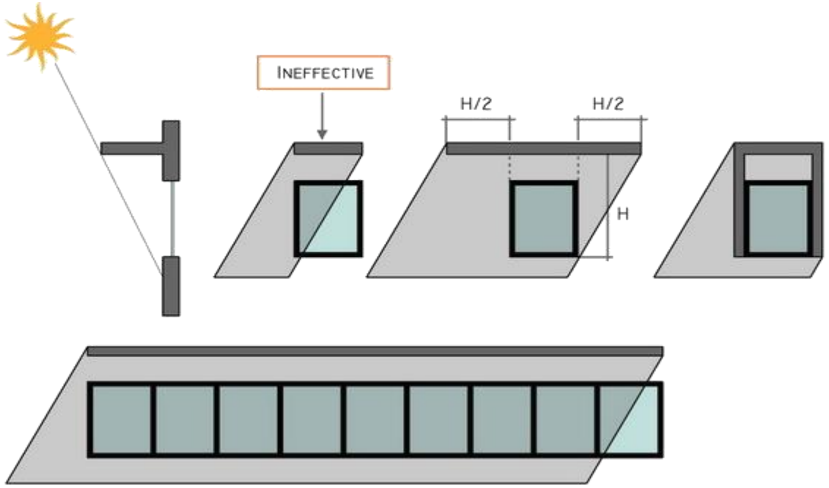
Passive Strategies & Building Physics

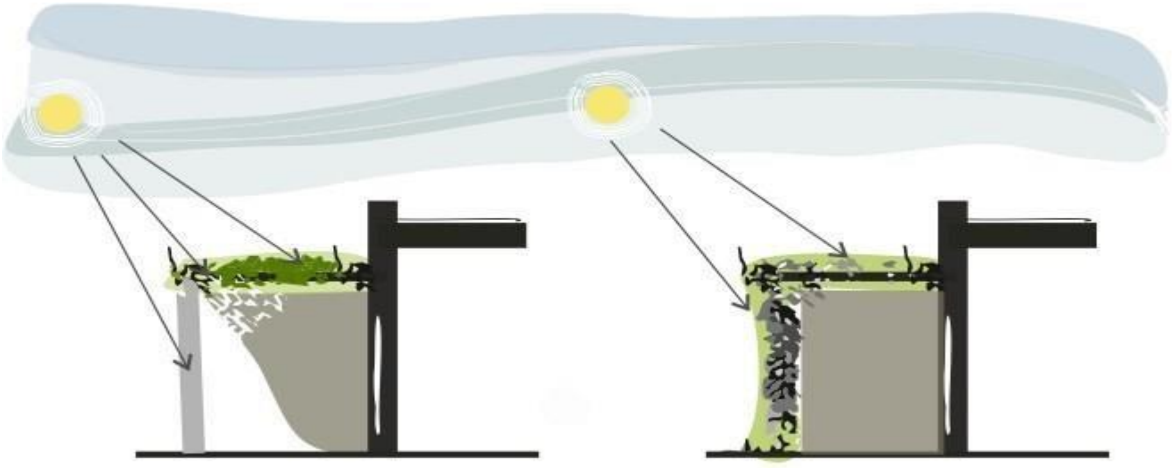
Unit Level

SHADING:

Shade-producing plants, such as creepers, can be used.

Fenestrations and shades/chajjas can be built to maximise solar radiation depending on the environment.





HEATING/ COOLING

Passive Strategies & Building Physics

Unit Level

ORIENTATION:

Buildings can be orientated in relation to the prevailing wind direction at angles ranging from 0° to 30°.

In buildings with a courtyard, positioning the courtyard 45 degrees from the prevailing wind maximises wind flow into the courtyard and improves cross ventilation in the building (in climates where cooling is required).

CREATING PRESSURE DIFFERENCES:

A 'squeeze point' occurs when wind enters through a smaller opening and escapes through a larger opening. This generates a natural vacuum, which speeds up the wind.

The total area of apertures should be at least 30% of the total floor space.

The window-to-wall-ratio (WWR) should not exceed 60%.

VENTILATION

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

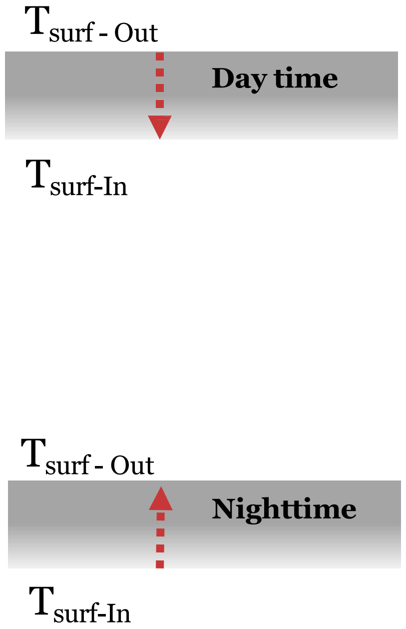
13

Innovative Building Materials

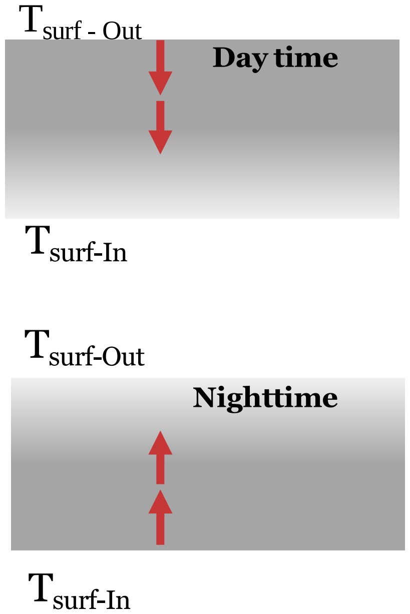
Walling Material and Walling Assemblies

Heat Transfer in Buildings: Insulation and Thermal Mass

Thermal Insulation, Thermal Conductivity



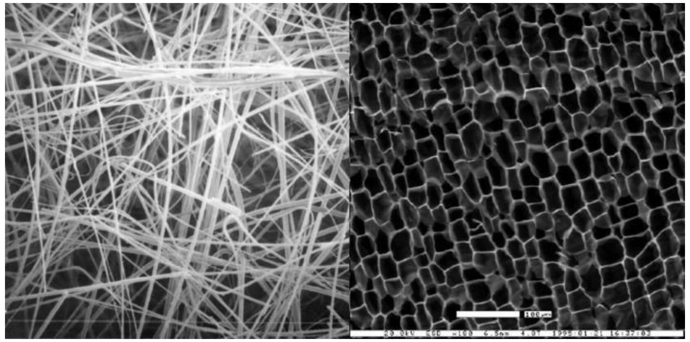
Thermal Insulation, Specific Heat Capacity



Source: unsplash. (n.d.). Cloth. unsplash. Retrieved from https://images.unsplash.com/photo-1564814183940-fb79790e1e45?ixlib=rb-1.2.1&q=80&fm=jpg&crop=entropy&cs=tinysrgb&dl=mhrezaa-O5R-dr8E2qk-unsplash.jpg

Walling Material and Walling Assemblies

Walling Materials and Methods: Insulation and Thermal Mass



The main thermal insulating material in buildings is locked air

Air is a poor thermal conductor

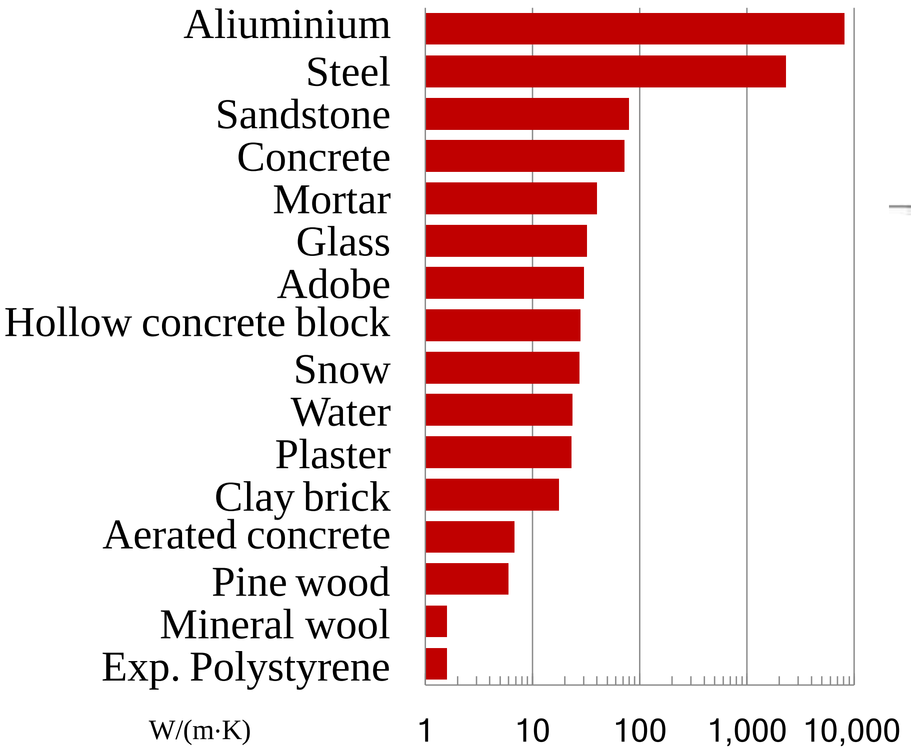
Air is locked in foam bubbles or between fibers

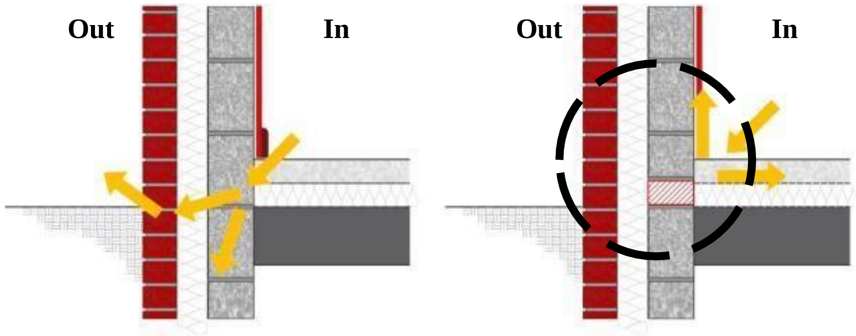
Bubble walls and fibers are themselves opaque to thermal radiation.

Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

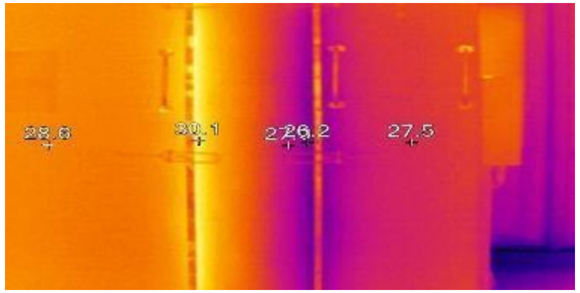
Walling Material and Walling Assemblies

Walling Materials and Methods : Conductivity & Thermal Bridge





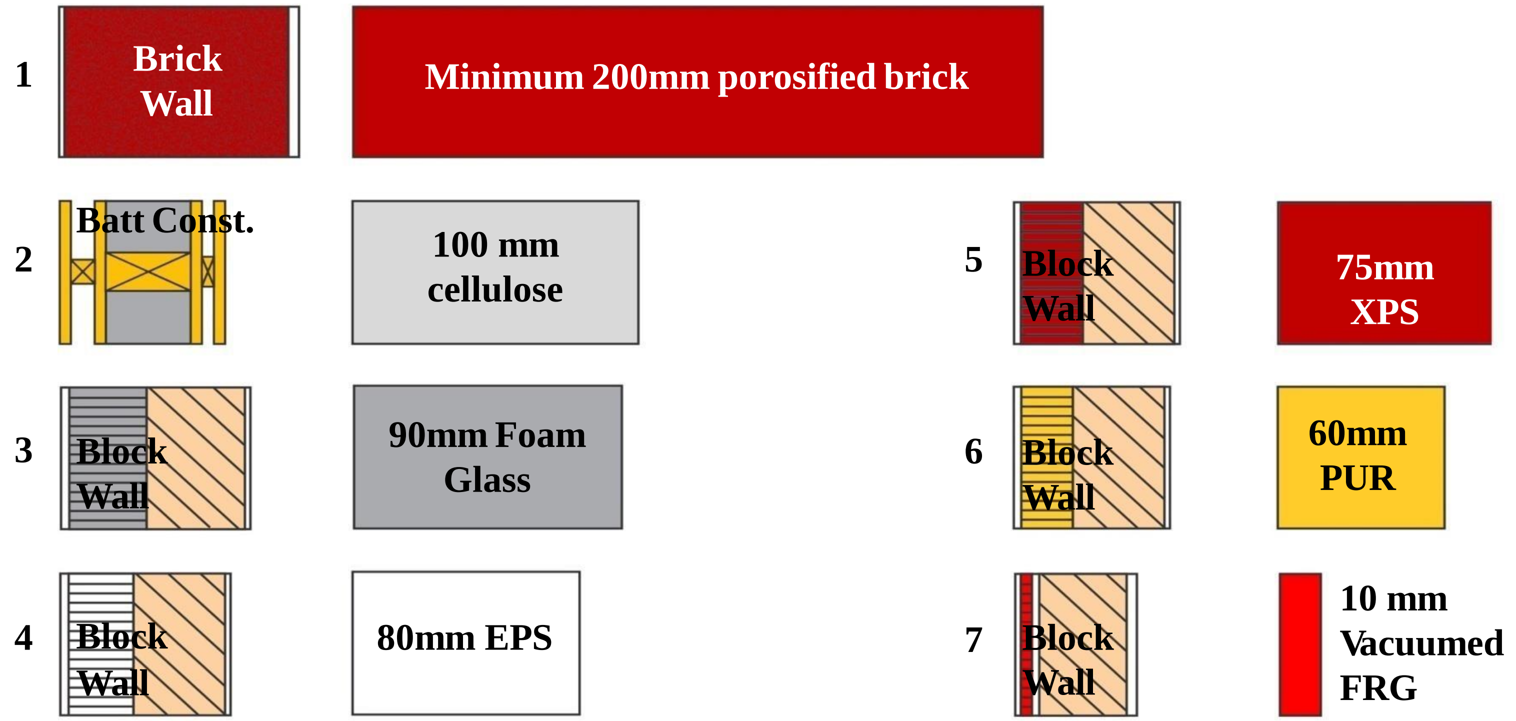
Air = 1
0.0002 Sq mts of aluminium (2 Sq Cms) = 1 Sq mts of insulation



Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

Walling Materials and Methods : Construction



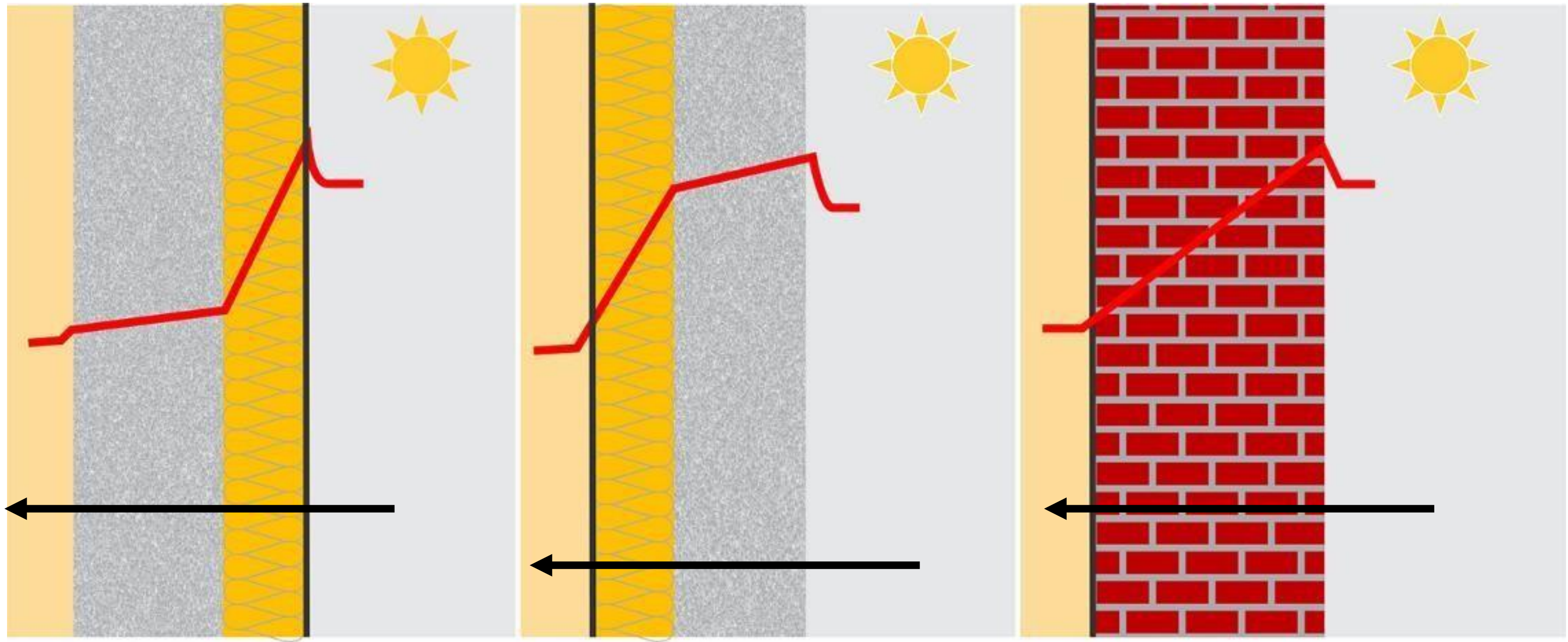
Minimum Thickness Needed to Achieve U value of < 0.40W/m²K

Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

Walling Materials and Methods : Construction

Steady State Indoors and Variable Outdoors – Hot and Sunny Outdoors



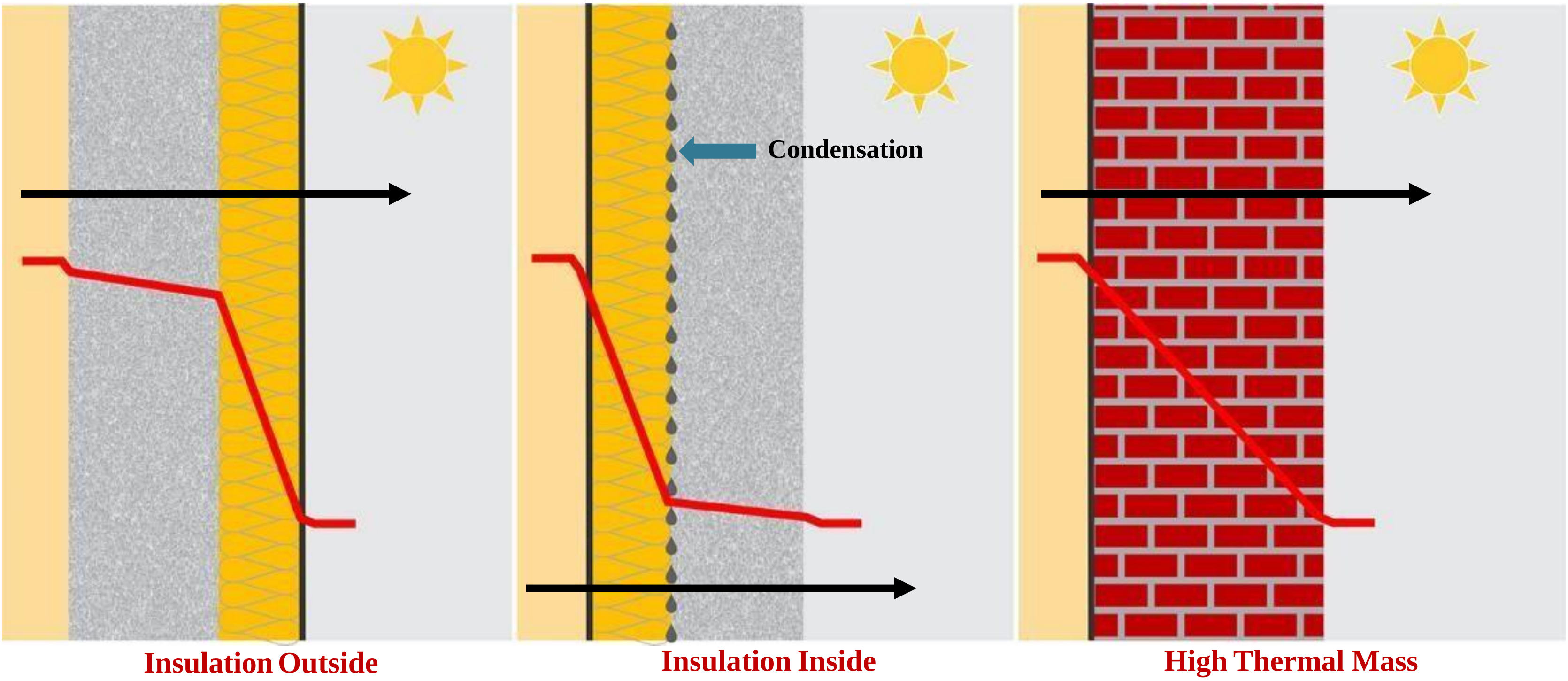
Insulation Outside | **Insulation Inside** | **High Thermal Mass**

Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

Walling Materials and Methods : Construction

Steady State Indoors and Variable Outdoors – Cold and Sunny Outdoors

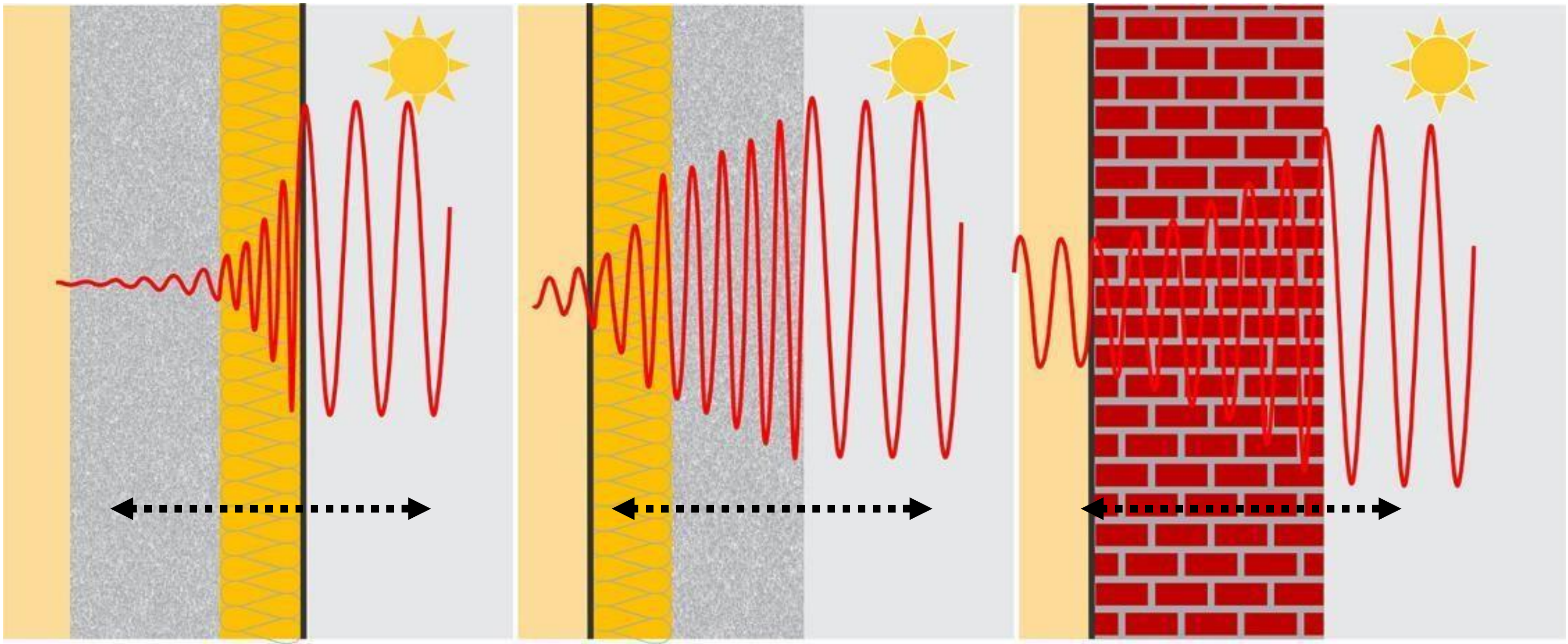


Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

Walling Materials and Methods : Construction

Variable Indoors and Variable Outdoors

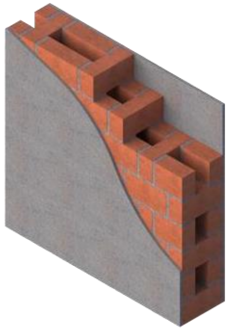


Insulation Outside | **Insulation Inside** | **High Thermal Mass**

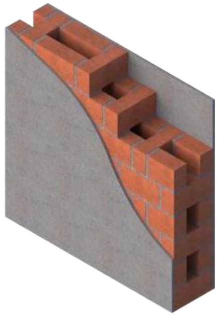
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

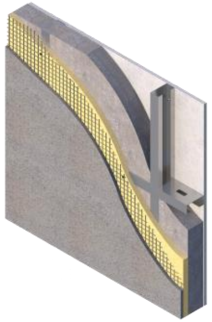
Nonhomogeneous Walling Technologies, Industrial



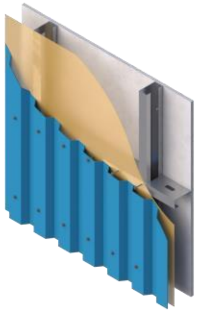
230 MM Clay Brick Wall Base Line



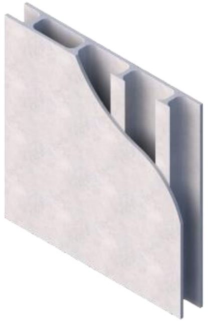
Rat Trap Bond



LGFSS- EPS



PPGL

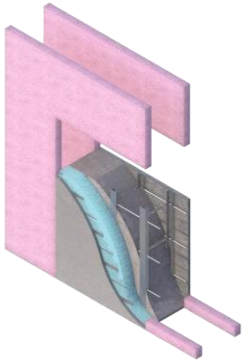


GFRG Unfilled

GFRG Partially Filled

GFRG Fully Filled

Reinforced EPS Core



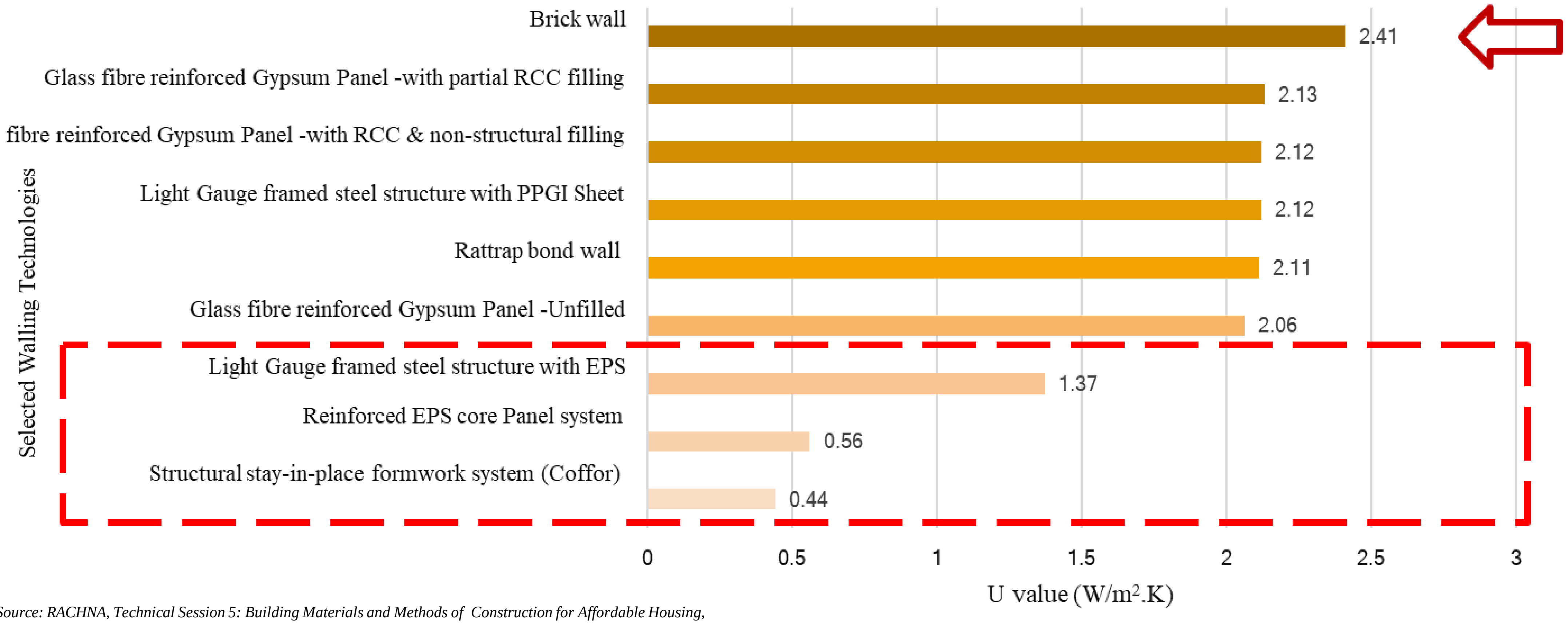
Stay-in-Place Coffer

Source: RACHNA, Technical Session 5: Building Materials and Methods of Construction for Affordable Housing, CEPT

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Walling Material and Walling Assemblies

Walling Technologies: U Values, Industrial



Source: RACHNA, Technical Session 5: Building Materials and Methods of Construction for Affordable Housing, CEPT

Walling Material and Walling Assemblies

Nonhomogeneous Walling Technologies, Traditional

Bamboo-Crete
U - VALUE (W/m²K)= 1.82

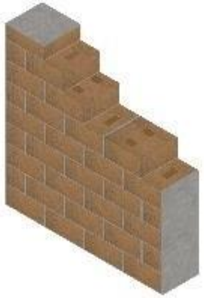
Wattle and Daub
U - VALUE (W/m²K)= 2.09

Stabilized Adobe
U - VALUE (W/m²K)= 1.50

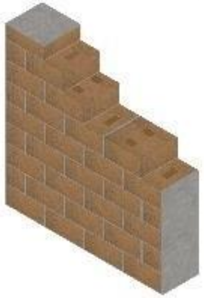
Laterite block wall
U - VALUE (W/m²K)= 1.61

Unstabilized Adobe
U - VALUE (W/m²K)= 1.57

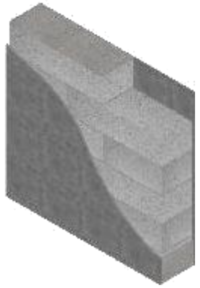
Compressed Stabilized Earth block wall
U - VALUE (W/m²K)= 1.59



Unstabilized Compressed Earth block wall
U - VALUE (W/m²K)= 1.42



AAC block wall
U - VALUE (W/m²K)= 0.45



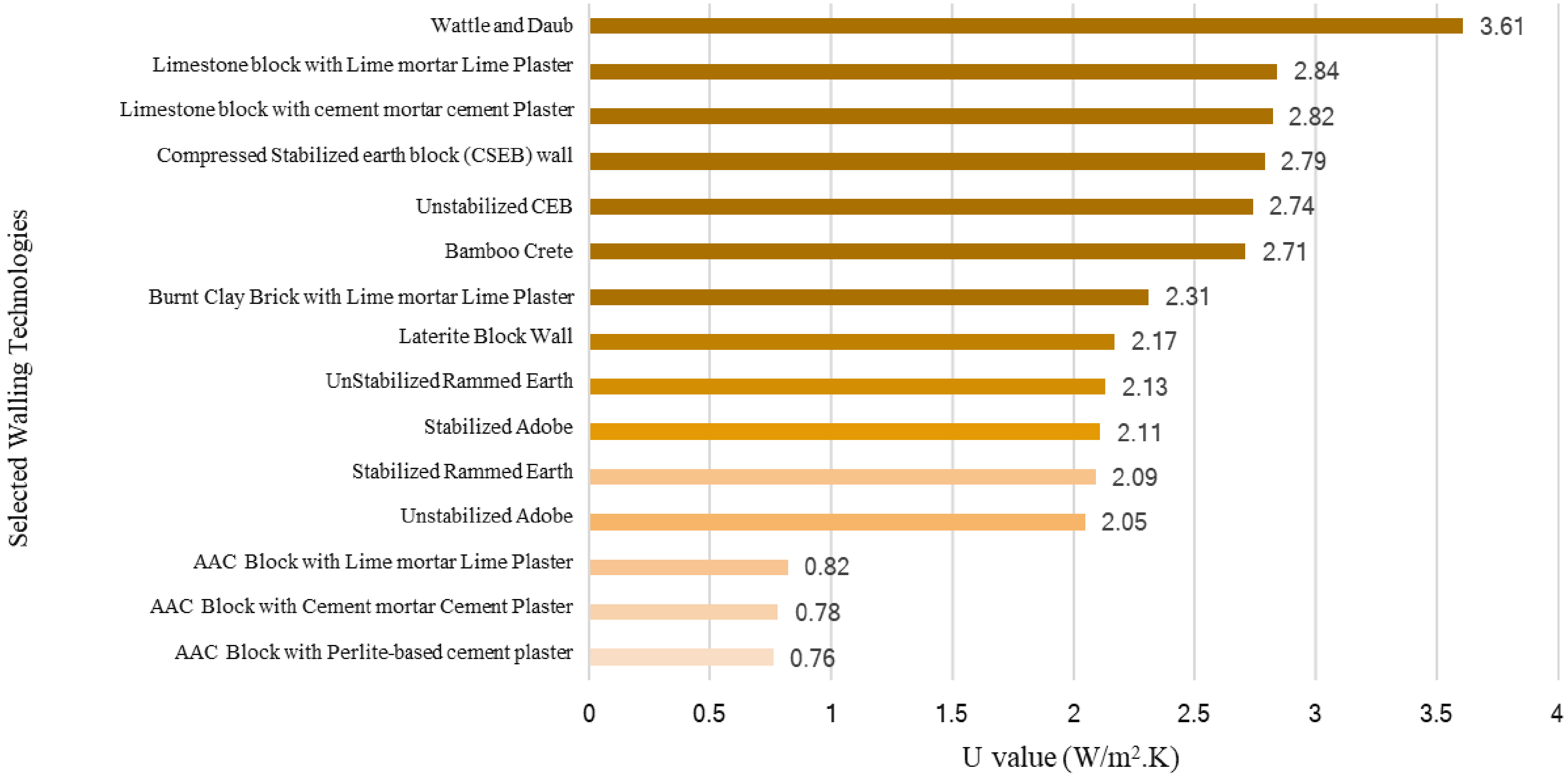
Unstabilized Rammed Earth Wall assembly
U - VALUE (W/m²K)= 1.68

Stabilized Rammed Earth Wall assembly
U - VALUE (W/m²K) = 1.495

Source: RACHNA, Technical Session 5: Building Materials and Methods of Construction for Affordable Housing, CEPT

Walling Material and Walling Assemblies

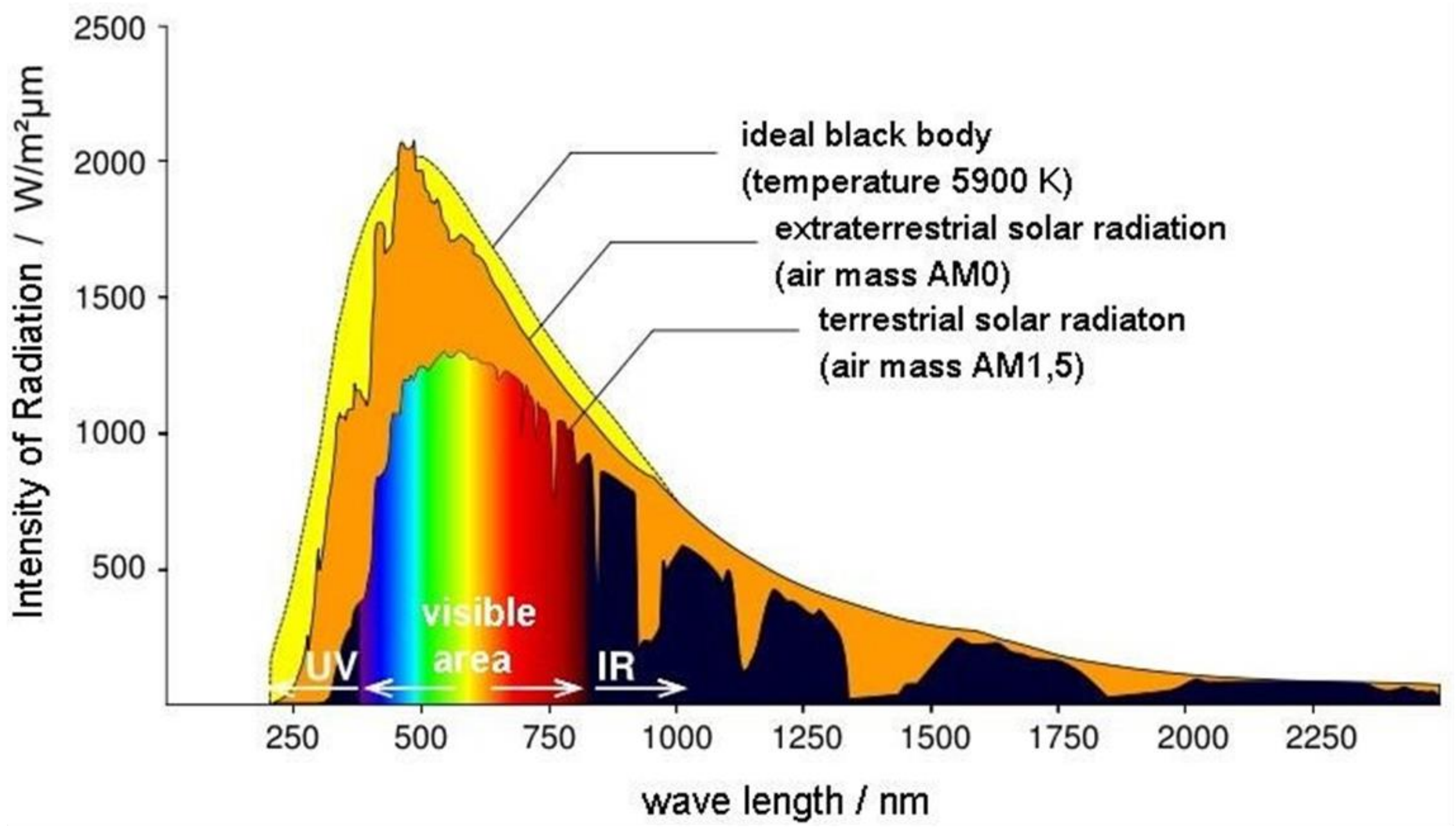
Walling Technologies: U Values, Traditional



GLAZING MATERIAL and GLAZING ASSEMBLIES

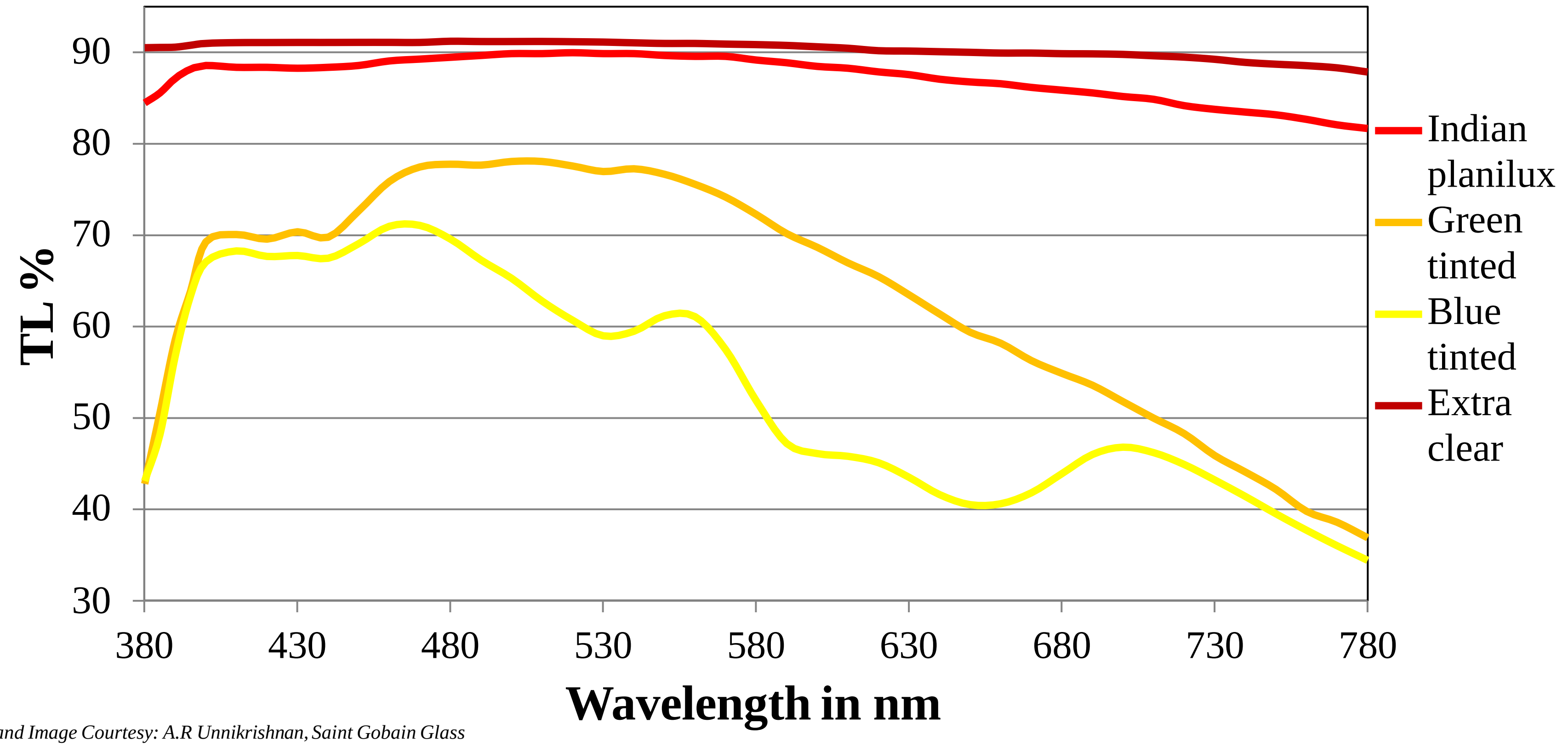
Glazing Material and Glazing Assemblies

Glazing Material and Methods: Solar Spectrum



Glazing Material and Glazing Assemblies

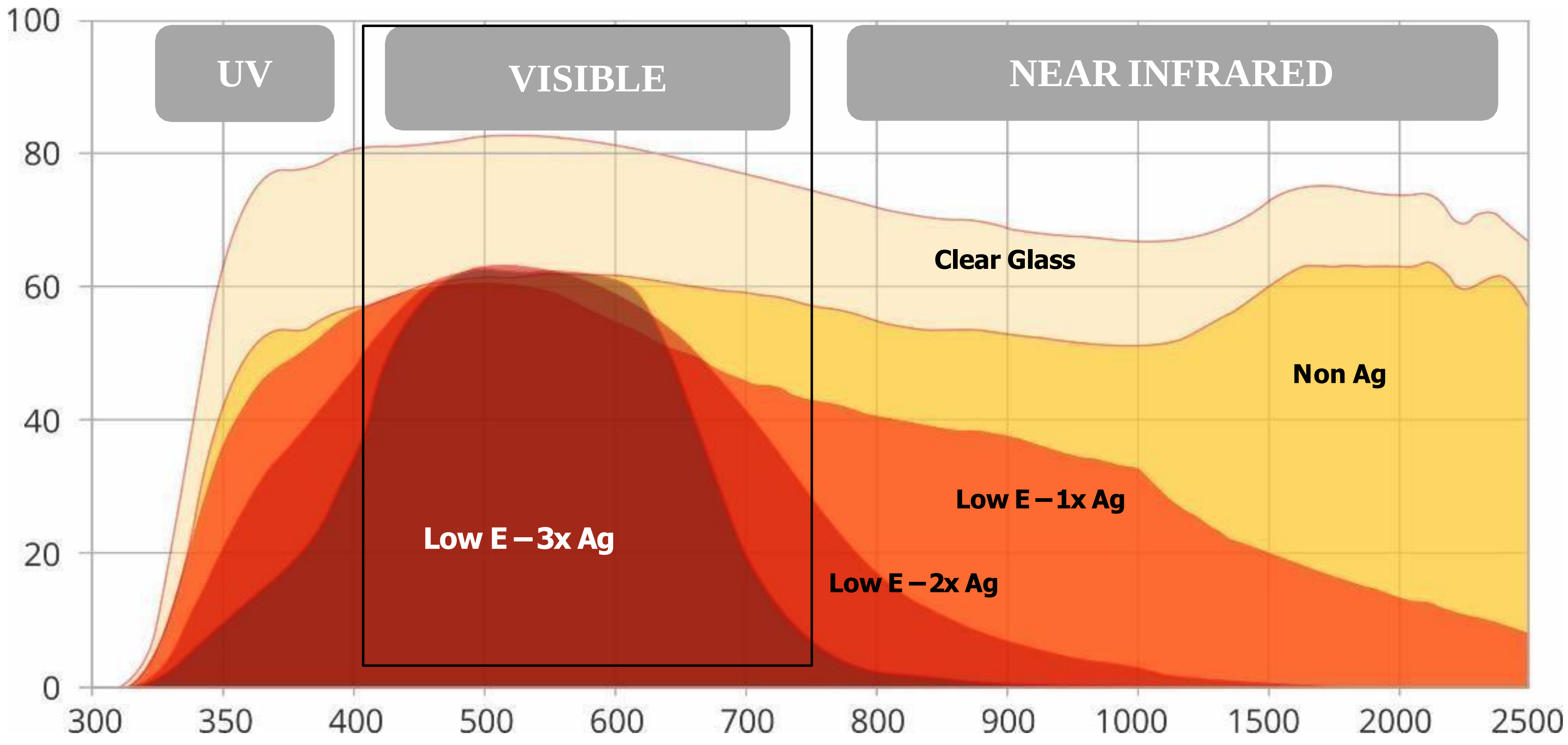
Glazing Material and Methods : Solar Radiation through Glass



Information and Image Courtesy: A.R Unnikrishnan, Saint Gobain Glass

Glazing Material and Glazing Assemblies

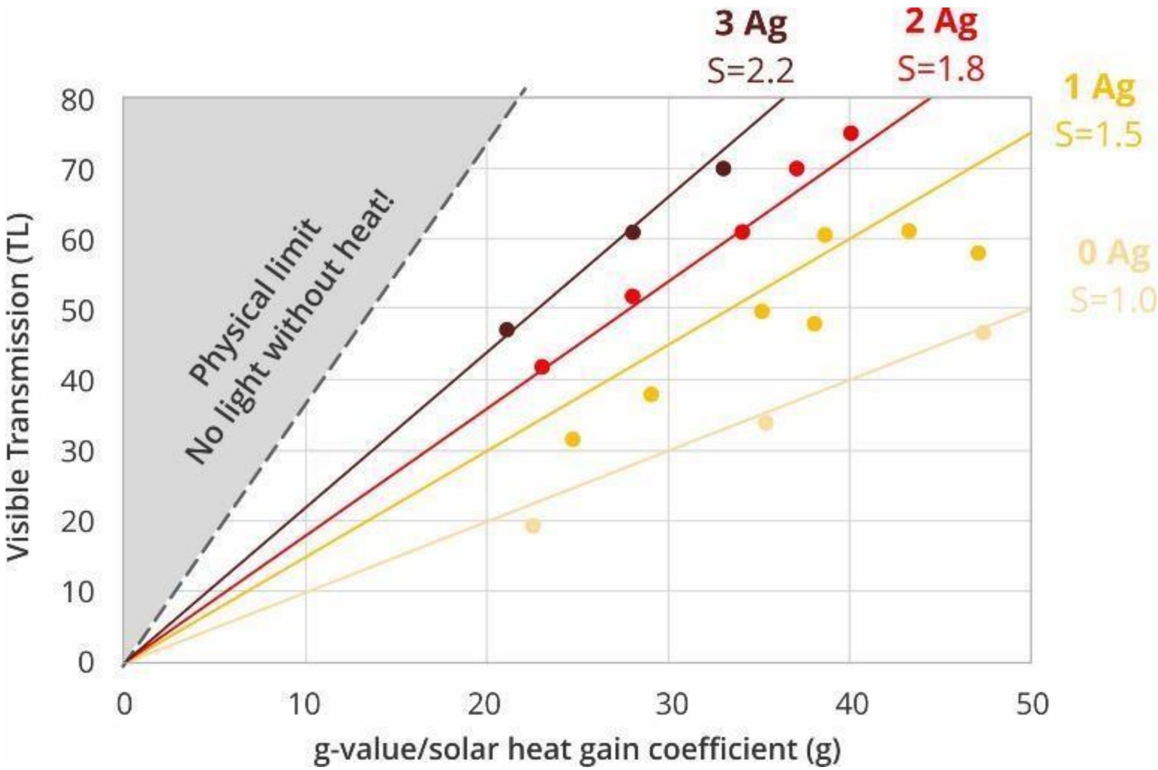
Glazing Material and Methods : Solar Control



Information and Image Courtesy: A.R Unnikrishnan, Saint Gobain Glass

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Solar Control



Selectivity = $\frac{TL}{g}$ = $\frac{Light}{Heat}$

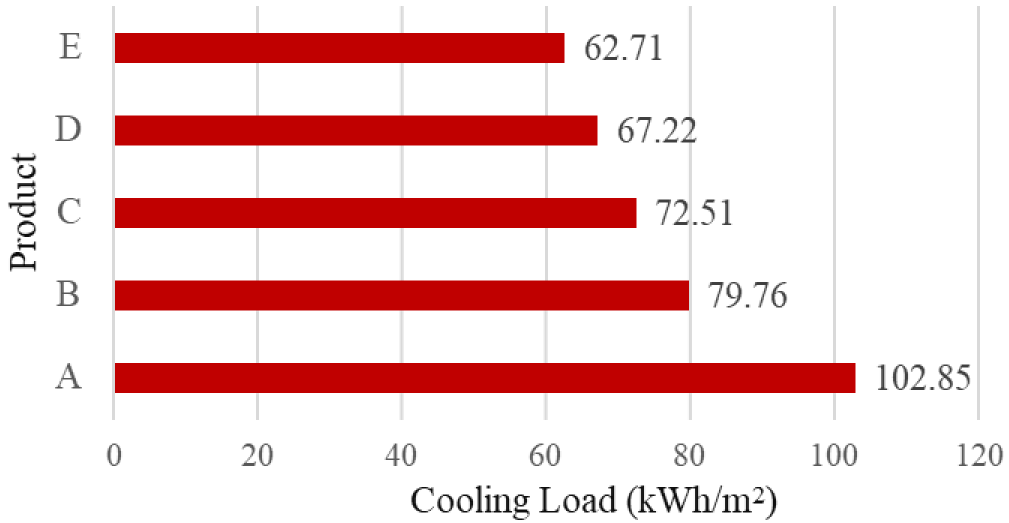
Silver (Ag) based coater products have the maximum selectivity

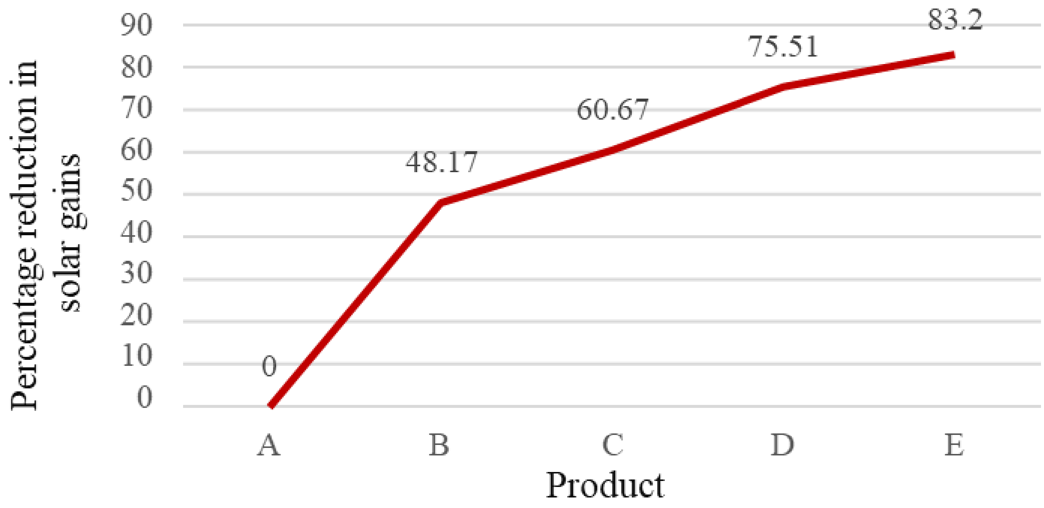
The higher the selectivity the better the performance of glass, it enables optimum light to enter our living spaces while blocking excess heat

Information and Image Courtesy: A.R Unnikrishnan, Saint Gobain Glass

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Cooling Load Reduction



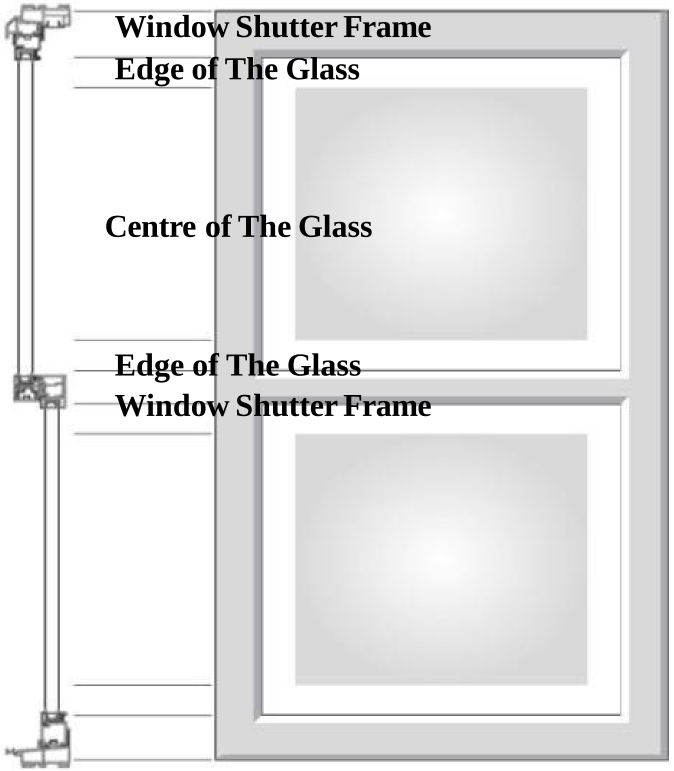


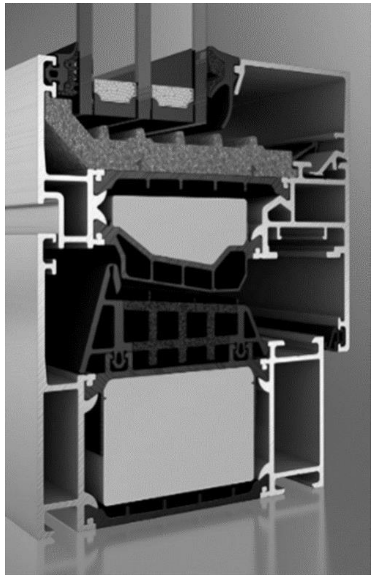
Product	VLT (%)	External Reflection (%)	Internal Reflection (%)	Solar Factor	Shading coefficient	U-value
A	80	15	15	0.76	0.87	2.6
B	46	16	18	0.22	0.25	1.5
C	46	20	22	0.47	0.54	2.8
D	51	18	22	0.28	0.33	1.5
E	47	17	11	0.38	0.43	1.9

Information and Image Courtesy: A.R Unnikrishnan, Saint Gobain Glass

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Window Frame



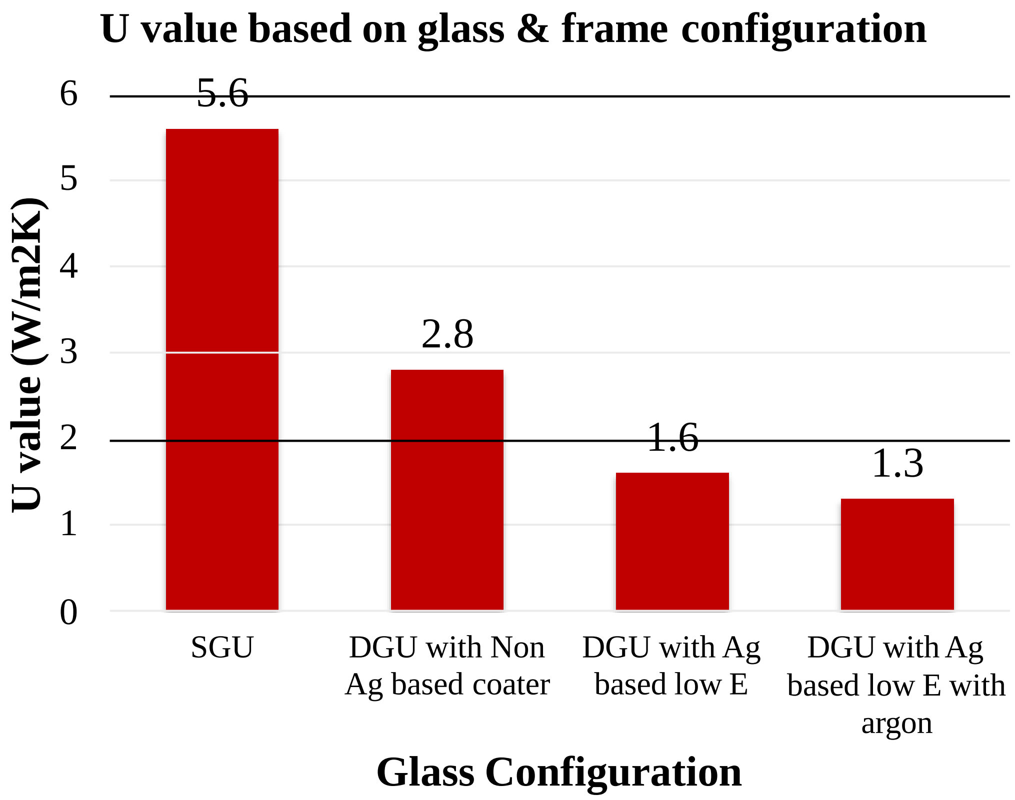


Source: Neuffer. (n.d.). Schüco Aws 90. Neuffer. Retrieved from http://192.169.1.1:8090/httpclient.html Grabex. (n.d.). Sliding-Folding Doors For Your Space. Grabex. Retrieved from https://grabex.co.uk/doors/bi-fold-

Information and Image Courtesy: A.R Unnikrishnan, Saint Gobain Glass

Glazing Material and Glazing Assemblies

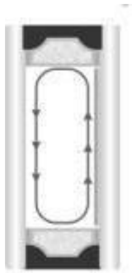
Glazing Material and Methods : Window Frame



SGU

DGU with air

DGU with Argon gas



1.1 W/m².K

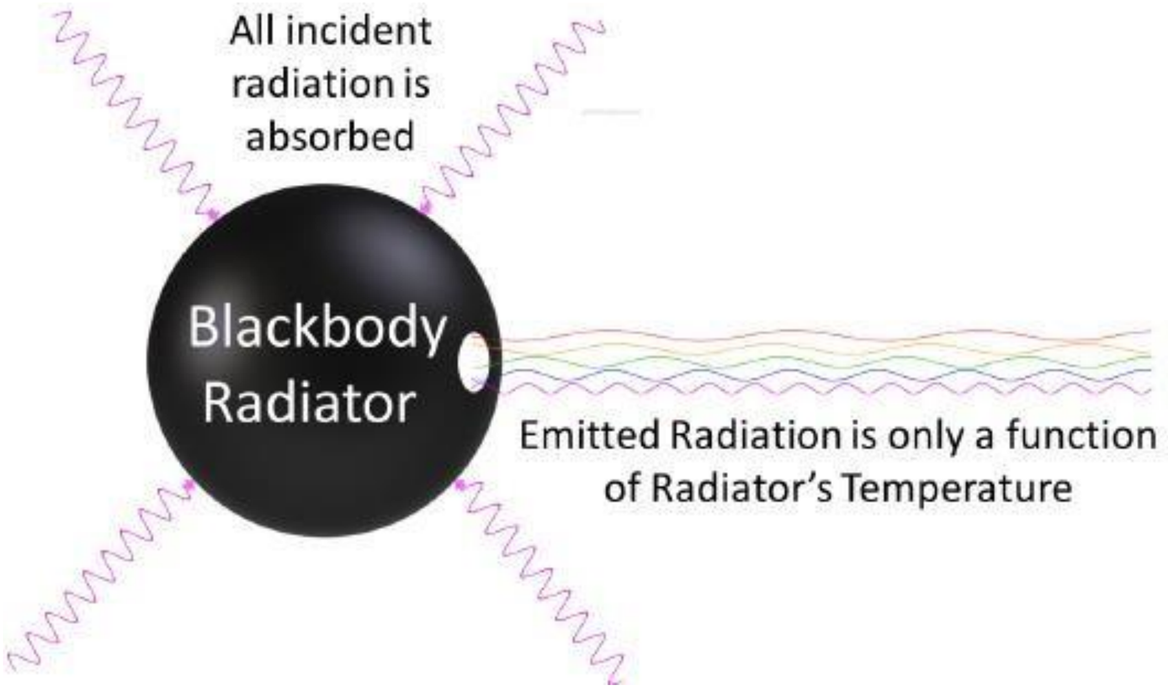
1.5 W/m².K

1.7 W/m².K

ROOFING COATING MATERIAL

Glazing Material and Glazing Assemblies

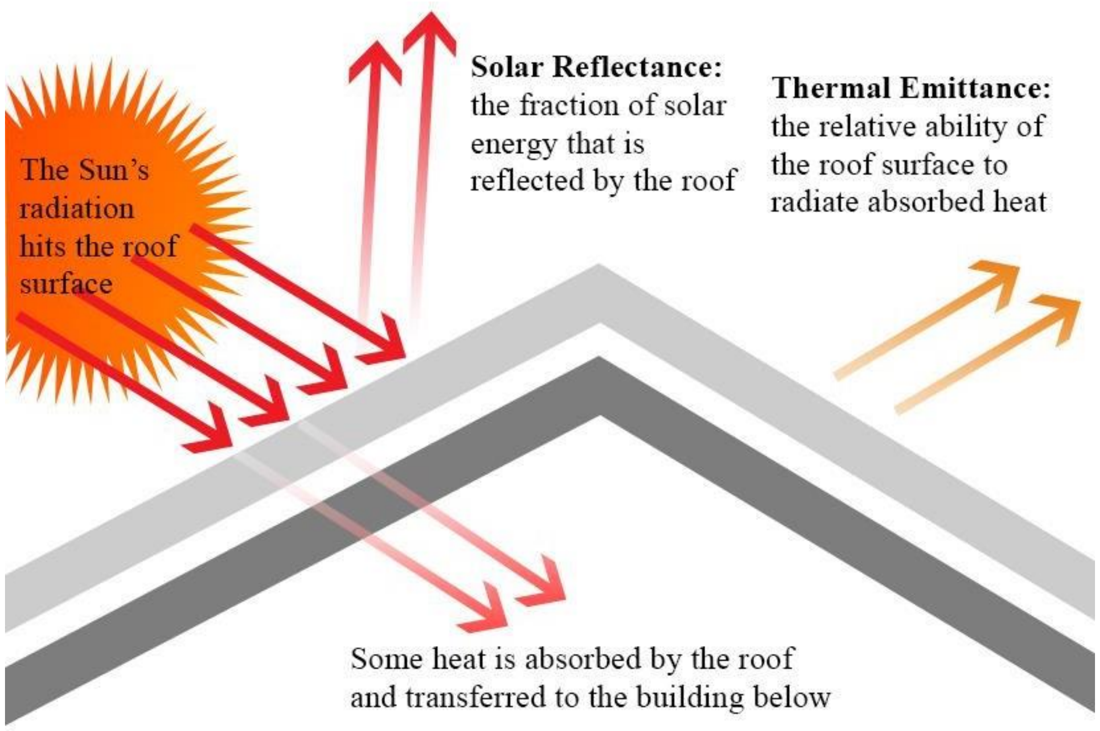
Roofing Coating Material : Black Body



Source: freepik. (n.d.). Food Wood . freepik. Retrieved from https://www.freepik.com/photos/food-wood , freepik. (n.d.). Saucepan. freepik. Retrieved from https://www.freepik.com/vectors/saucepan

Glazing Material and Glazing Assemblies

Roof Coating Material and Solar Reflectance Index

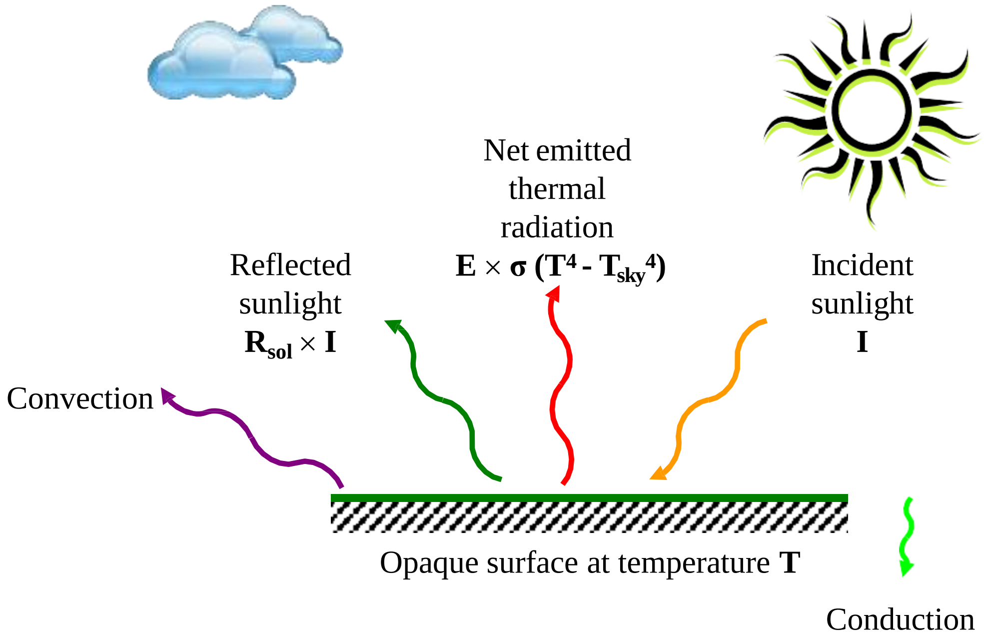


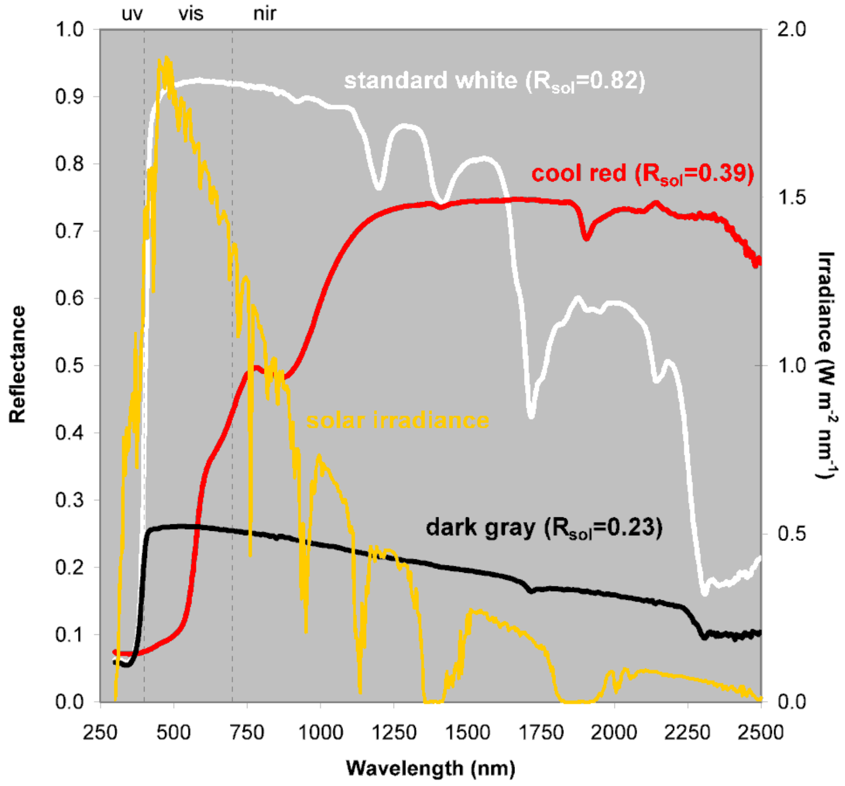
- Reflectance
- Thermal Emittance.
- Emissivity
- Solar Reflectance Index (SRI)

Source: ASC Building Products. (2020). Energy-Efficient Cool Colors in Today's Metal Roofing. ASC Building Products. Retrieved from https://www.ascbp.com/cool-colors-and-energy-savings/.

Glazing Material and Glazing Assemblies

Roof Coating Material and Solar Reflectance Index





- High solar reflectance (R_{sol}) lowers solar heat gain (0.3 - 2.5 μm)
- High thermal emittance (E) enhances thermal radiative cooling (4 - 80 μm)

Glazing Material and Glazing Assemblies

Roof Coating Materials

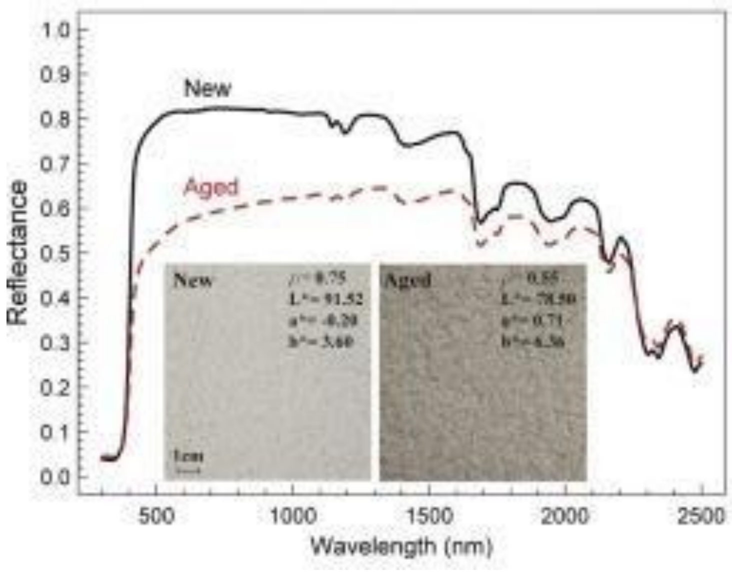
Paints

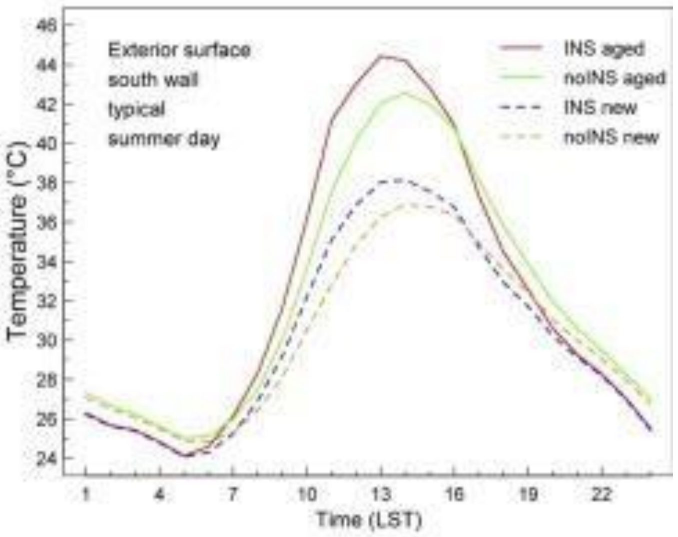
Coated Sheets

Tiles

Glazing Material and Glazing Assemblies

Roof Coating Materials





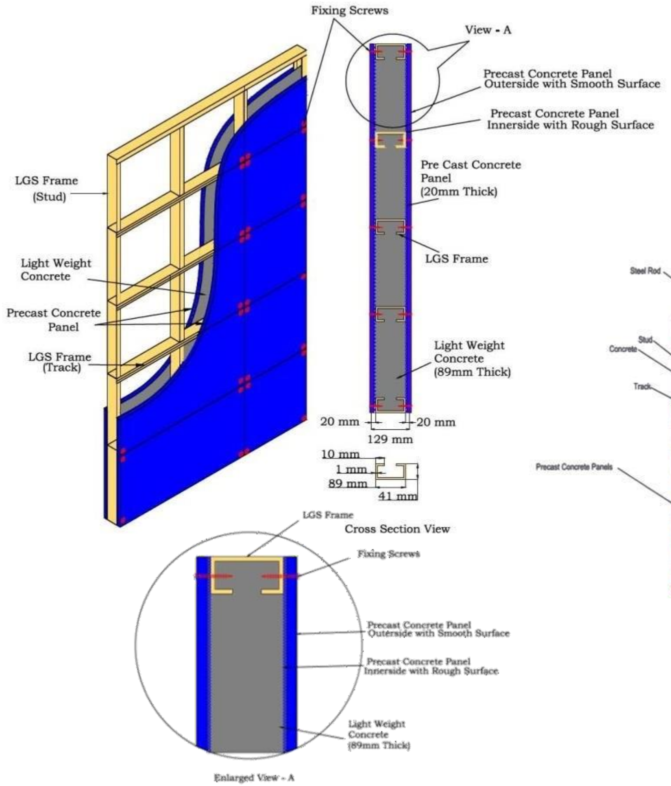
- PM 10, PM 2.5
- Dust, Sooth
- Vegetation

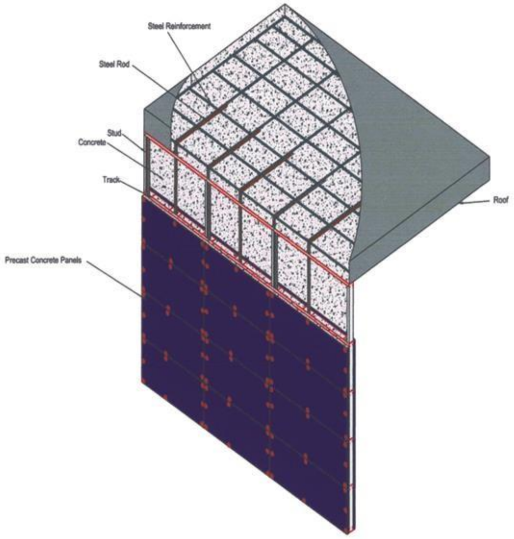
Source: Paolini, R., Zani, A., Poli, T., Antretter, F., & Zinzi, M. (2017). Natural aging of cool walls: Impact on solar reflectance, sensitivity to thermal shocks and building energy needs. Energy and Buildings, 153, 287–296. https://doi.org/10.1016/j.enbuild.2017.08.017

WALLING MATERIAL CASE STUDIES, Light House Projects

Walling Material Case Studies, Light House Projects

Light House Project: Agartala

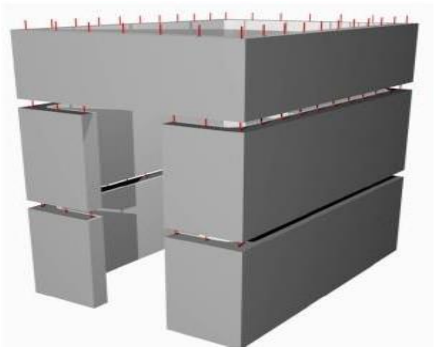


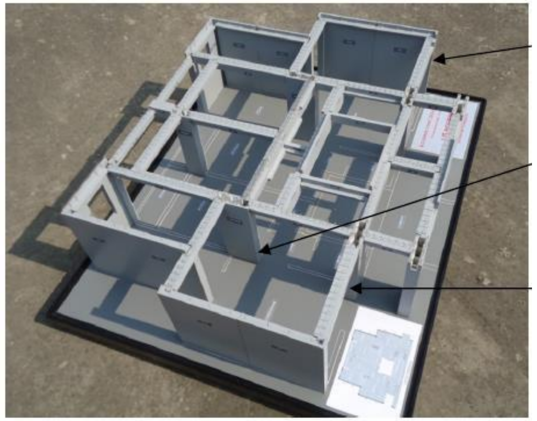


- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)
- Ground and 06 Floors
- Weight of the LGSFS-ICP building is about 20-30% lighter
- The LSG frames are manufactured using numerically controlled roll
- forming machine using CAD design

Walling Material Case Studies, Light House Projects

Light House Project: Chennai

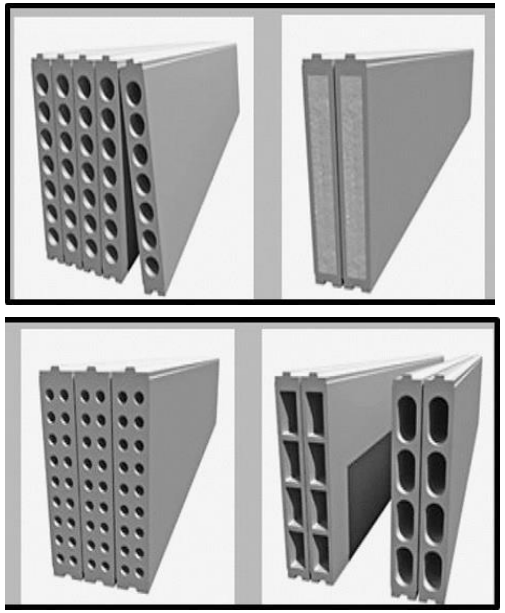




- Precast Concrete Construction System and Precast component Assembly at the site
- G and 05 Floors
- Precast dense reinforced cement concrete hollow core columns, structural RCC shear walls, T/L/Rectangular shaped beams, stairs, floor/roof solid….
- AAC blocks are used for partition walls

Walling Material Case Studies, Light House Projects

Light House Project: Indore



- Prefabricated Sandwich Panel System
- S and 08 Floors
- Lightweight composite wall, floor, and roof sandwich panels made of thin fiber cement/calcium silicate board
- Face covered boards and the core material is EPS granule balls

Walling Material Case Studies, Light House Projects

Light House Project: Lucknow

- PVC Stay in Place Formwork System
- S and 13 Floors
- Rigid polyvinyl chloride (PVC) based formwork system serves as a permanent stay-in-place durable finished form-work for concrete walls
- The PVC extrusions consist of the substrate (inner) and Modifier (outer). The two layers are co-extruded during the manufacturing process to create a solid profile.

Walling Material Case Studies, Light House Projects

Light House Project: Rajkot

- Monolithic Concrete Construction using tunnel formwork
- S and 8 Floors
- Tunnel forms are room size formworks that allow walls and floors to be caste in a single pour

Walling Material Case Studies, Light House Projects

Light House Project: Ranchi

- Pre-Cast Concrete Construction System – 3D volumetric
- Ground and 8 Floors
- 90% pre-casted at the casting yard
- Use of Fly Ash Ground granulated blast furnace slag (GGBS), micro silica.
- Minimal shutter and scaffolding

14

Case Studies

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 m²

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.

- 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.

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

EPI – 75kWh/m²/yr

GODREJ PLANT 13 ANNEXE

LOCATION	**MUMBAI, MAHARASHTRA**
COORDINATES	19° N, 73° E
OCCUPANCY TYPE	OFFICE – PRIVATE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	WARM AND HUMID
PROJECT AREA	24,443 m^2

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. The structure is a 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.

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."

EPI – 75kWh/m²/yr

INDIRA PARYAVARAN BHAWAN, MoEF

LOCATION	NEW DELHI
COORDINATES	29° N, 77° E
OCCUPANCY TYPE	OFFICE & EDUCATIONAL
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	9565 m^2

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.

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

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.

EPI – 44kWh/m²/yr

Renewable Energy Integration 930 kW PV panels with a total area of 4650m² for on- site generation, tilted at 23º facing south to generate equivalent to 70kWh/m²/yr

JAQUAR HEADQUARTERS

LOCATION	**MANESAR HARYANA**
COORDINATES	28° N, 77° E
OCCUPANCY TYPE	CORPORATE AND MANUFACTURING
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	48000 m^2

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
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	5574 m^2

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
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	2322 m^2

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
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	5100 m^2

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
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	9888 ft^2

GRIDCO BHUBANESWAR

LOCATION	BHUBANESWAR.
COORDINATES	20° N, 85° E
OCCUPANCY TYPE	OFFICE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	WARM AND HUMID
PROJECT AREA	15,793.5 m^2

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.

DAY 1

Tea Break

DAY 1

Q & A Session

DAY 1

Vote of Thanks

DAY 2

DAY 2

Session 5: Thermal Comfort Study Methods

15

Thermal Comfort Study Methods - Study Environments

Thermal Comfort Study Methods

Indoor Environment (Physical)

Air Temp.
Relative Humidity Air Velocity
Mean Radiant Temperature (Globe Temp)

Human Body (Physical)

Metabolic Rate
Clothing Value *Skin Temp*
Core Body Temp
Skin Temp/Heat Flux of Body Parts

Human Body (Psychological)

Votes on Comfort

Air Quality
Overall acceptance

Source: freepik. (n.d.). Tape Measure. freepik. Retrieved from https://www.freepik.com/free-photos-vectors/tape-measure , freepik. (n.d.). Stethoscope. freepik. Retrieved from https://www.freepik.com/search?format=search&query=stethoscope , freepik. (n.d.). Vote. freepik. Retrieved from https://www.freepik.com/search?format=search&query=vote

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Thermal Comfort Study Methods

Field Studies

Occupant Comfort
User Behaviour
Productivity

Laboratory Studies

Thermal Comfort
Body Parts Cooling
Systems Control
Systems Productivity

Digital Simulations

Thermal Comfort Body
Parts Cooling Systems
Control Systems

Source: freepik. (n.d.). Field studies. freepik. Retrieved from https://www.freepik.com/search?format=search&query=field%20studies , freepik. (n.d.). Laboratory Studies. freepik. Retrieved from https://www.freepik.com/search?format=search&query=Laboratory%20Studies , freepik. (n.d.). Desert. freepik. Retrieved from https://www.freepik.com/photos/desert

Field Studies – Initial Planning

Climate Zones
Selection of cities

Selection of building based on typology, and income

Determination of Environmental parameters, personal parameters and occupant behaviour related questionnaire

Detailed Methodology Protocol
Detailed Instrumentation Plan

Determination of timeline for each cities, identification of on-site researchers and deployment of equipment

Sensitization of occupants , Training workshop for Surveyors

Field Studies – Execution

Building Selection
Typologies

Climate Zones	Cities
Hot & Dry (HD)	Ahmedabad
Warm & Humid (WH)	Chennai, Mumbai, Kolkata
Composite (CT)	Delhi, Hyderabad
Moderate (MD)	Bangalore
Cold (CD)	Simla

Instantaneous, Right Now Right Here Survey - Environmental Parameters

- Indoor Air Temperature
- Indoor Relative Humidity
- Air Velocity
- Globe Temperature (Mean Radiant Temperature to be derived)

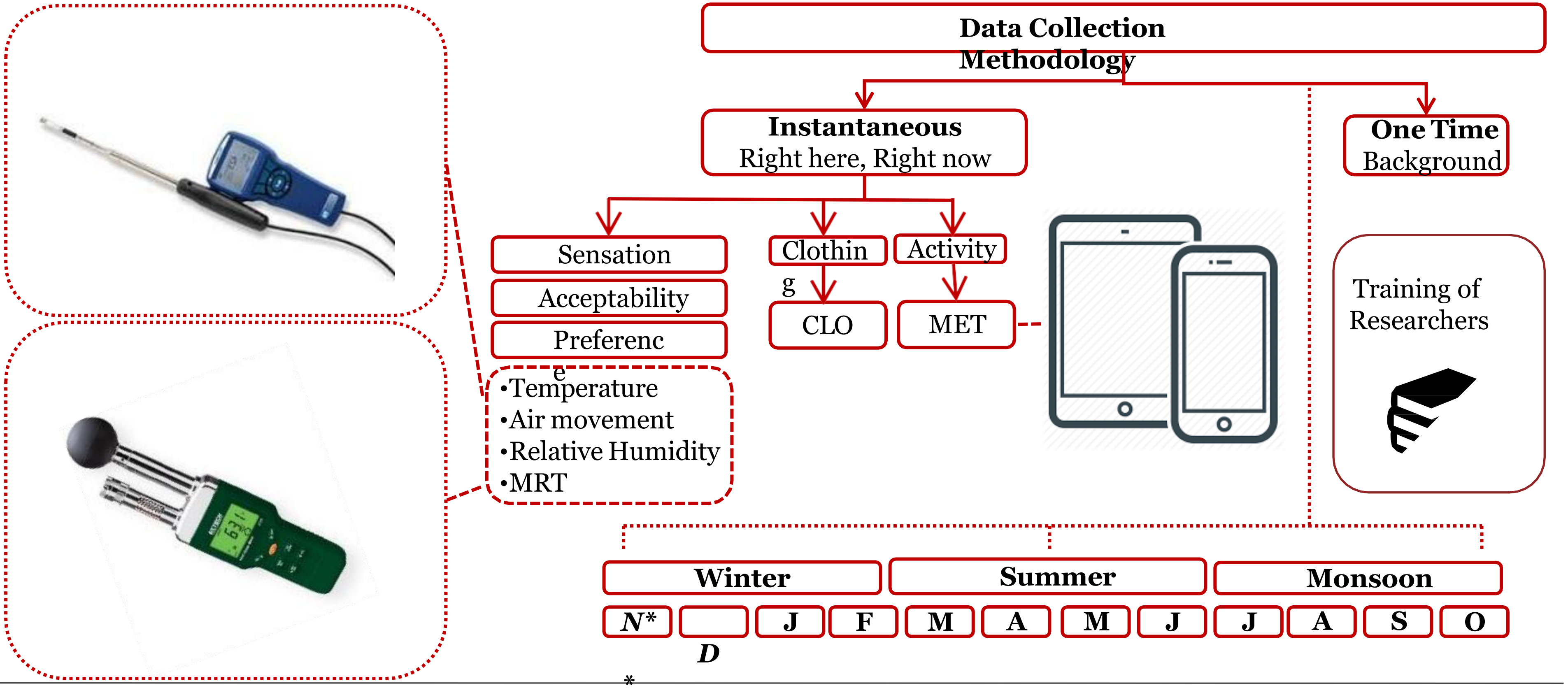
Right Now Right Here Survey – Personal Parameters

- Metabolic Rate
- Clothing - Seat
- Thermal Sensation
- Thermal Acceptance
- Thermal Preference

One time – Background Survey

- Building Information
- Workspace – Occupation Information
- Appliances and Electricity Use Information
- Transport options Information

Field Studies – Execution



Field Studies – Execution

Vote scale	Thermal Sensation	Thermal Acceptability	Thermal Preference	Humidity Sensation	Air movement preference
-3	Very cold			Very humid	
-2	Cold	Completely unacceptable		Humid	
-1	Slightly cold	Just unacceptable	Cooler	Slightly humid	Want less
0	Neutral	Acceptable	No change	Neutral	No change
1	Slightly warm	Just acceptable	Warmer	Slightly dry	Want more
2	Warm	Completely acceptable		Dry	
3	Hot			Very dry	

Field Studies – Post Processing – QA/QC

Right Now Right Here Survey of Occupants

Mapping of Environmental Parameters

Building Characteristics and Occupant Behaviour Pattern

Quality Assurance and Quality Check at location

Continuous check on functioning of instruments

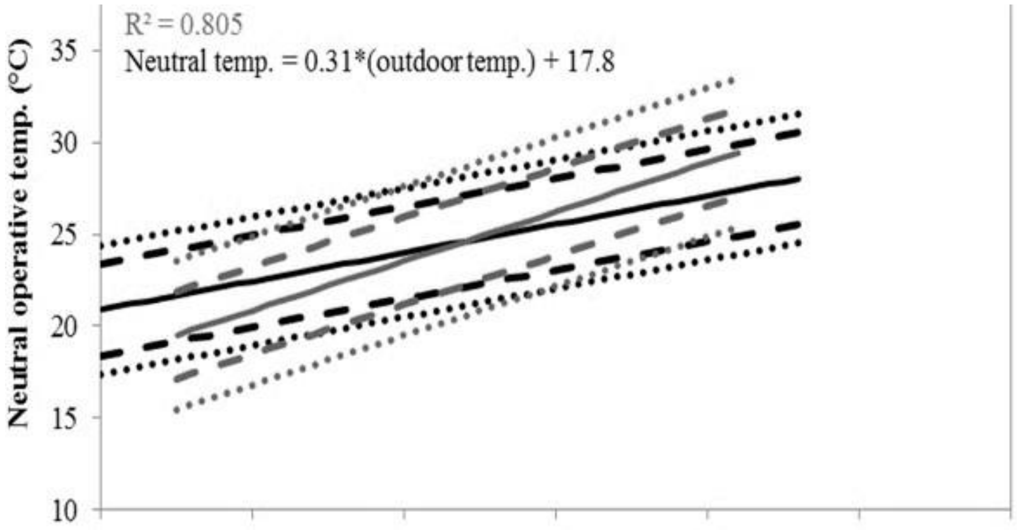
Collection of data on weekly bases, and QA/QC at central location

Deliverable: A Dataset having sampling with 95% confidence level and 5% margin of error

Field Studies: Measurements: ASHRAE Class 1 and ASHRAE Class 2

Instrument	Parameter	Range	Resolution	Accuracy
Instrument A	Indoor air temperature	-10 to 60°C	0.1°C	±0.3°C
	Indoor air velocity	0 to 30 m/s	0.01 m/s	±3% of reading or (±0.015 m/s), whichever is greater
	RH	5 to 95% RH	0.1% RH	±3% RH
Instrument B	Wet Bulb Globe Temperature (WBGT) – (without sunlight)	0 to 59°C	0.1°C	WBGT = (0.7×WET)+(0.3×TG)
	Wet Bulb Globe Temperature (WBGT) – (with sunlight)	0 to 56°C	0.1°C	WBGT=(0.7×WET)+(0.2×TG)+(0.1×TA)

Field Studies – Post Processing – QA/QC



Indoor Operative Temperature = (*0.00* x outdoor temperature) + *00.00*

90% acceptability ± *0.00* °C

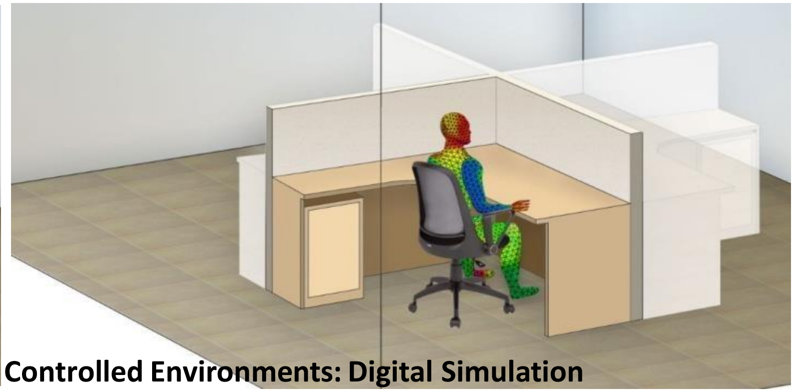
80% acceptability ± *0.00* °C

Laboratory Studies : Controlled Environment - Thermal Comfort Chambers

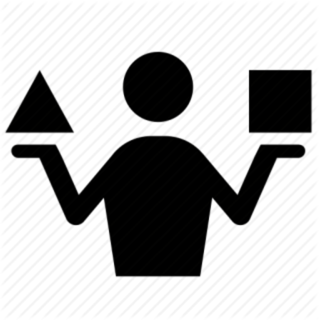

Controlled Environments: Measurements

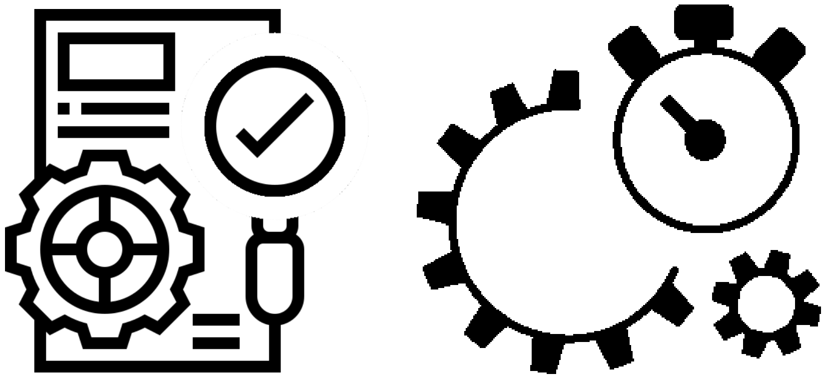

Controlled Environments: Occupants


Controlled Environments: Mannequins


Controlled Environments: Digital Simulation

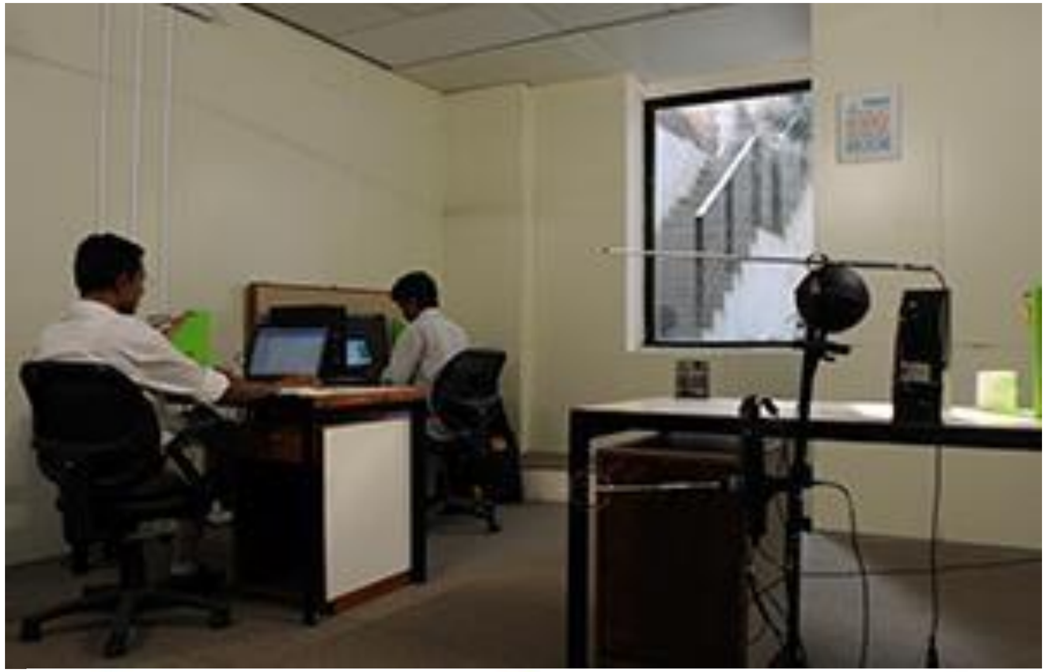
Laboratory Studies : Controlled Environment -o Thermal Comfort Chambers

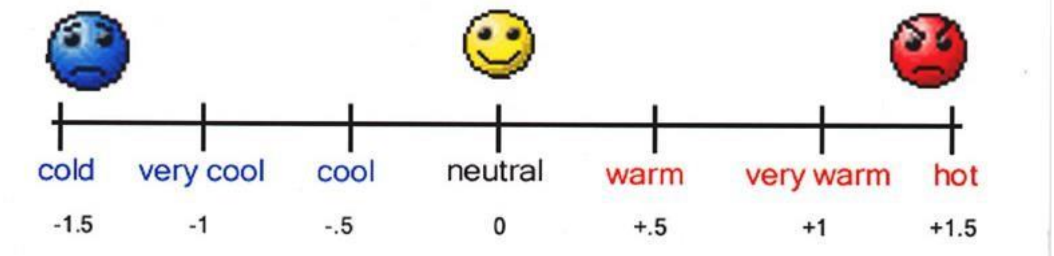




- **Comparable cases**
  - Body Mass Index
  - Clothing Insulation
  - Age
  - Acclimatization of local weather conditions
- **Important to achieve and maintain desired indoor Environmental Conditions**
  - Stabilization time
  - Experiment time
  - Cooldown time
- **System responses are critical when conducting behaviour studies**
- **Ethical clearances and research protocols**

Laboratory Studies : Controlled Environment -o Thermal Comfort Chambers





Work with Human Subjects

Under various environmental conditions

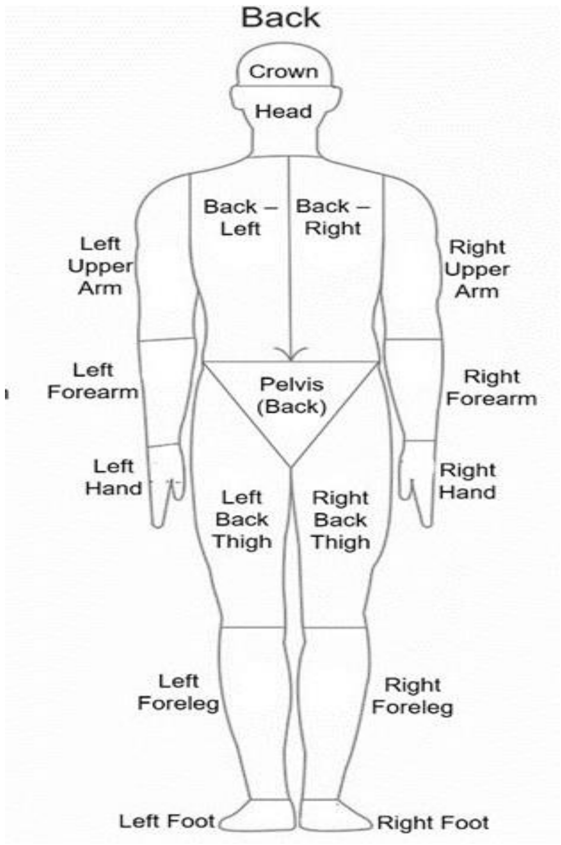
- Preference Vote
- Sensation Vote
- Comfort Vote

- HVAC (lighting Acoustic) System Interaction

- Behaviour Responses

- Met Value derivation

Laboratory Studies : Controlled Environment -0 Thermal Comfort Chambers

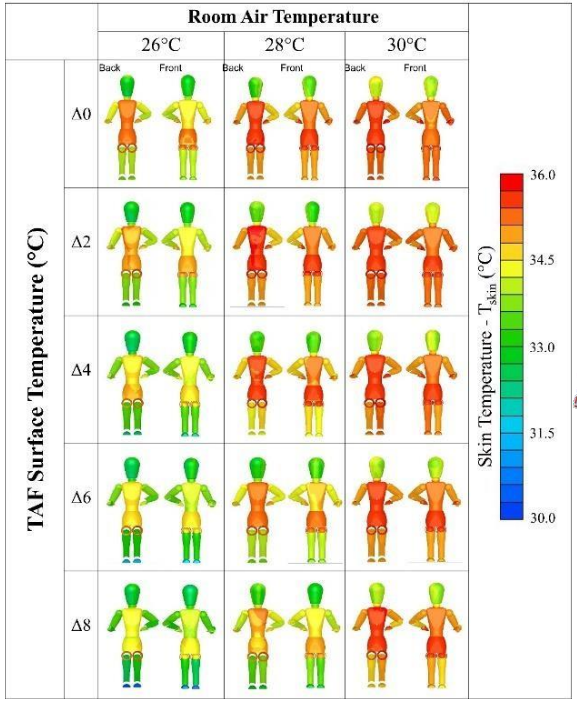


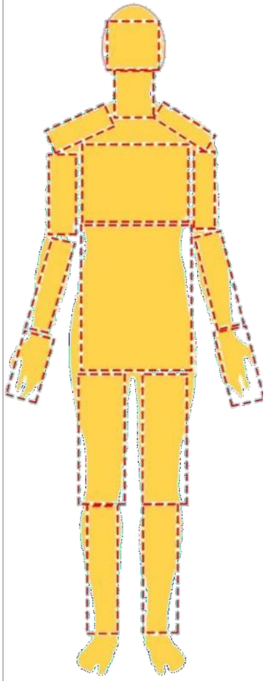
Work with Thermal Mannequin

- Body Parts
- Clo Value Derivation
- Simulation Model Development

- *Airflow, – Breathing Studies*
- *Sweat – Physiological Studies*
- *Indoor Air Quality Studies*

Laboratory Studies : Controlled Environment -o Thermal Comfort Chambers





Work with Digital Simulations

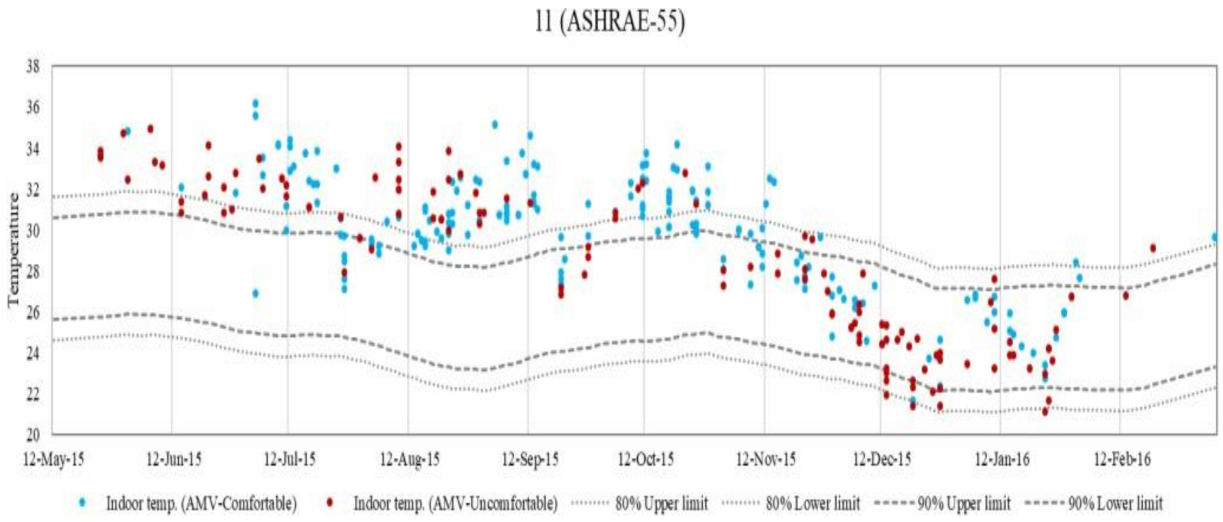
- Scalable – Cost-effective
- Calibration is a must
- Combination with Physiology and Indoor Environment
- Co- Simulation with HVAC, CFD, and Thermal Modelling of Buildings

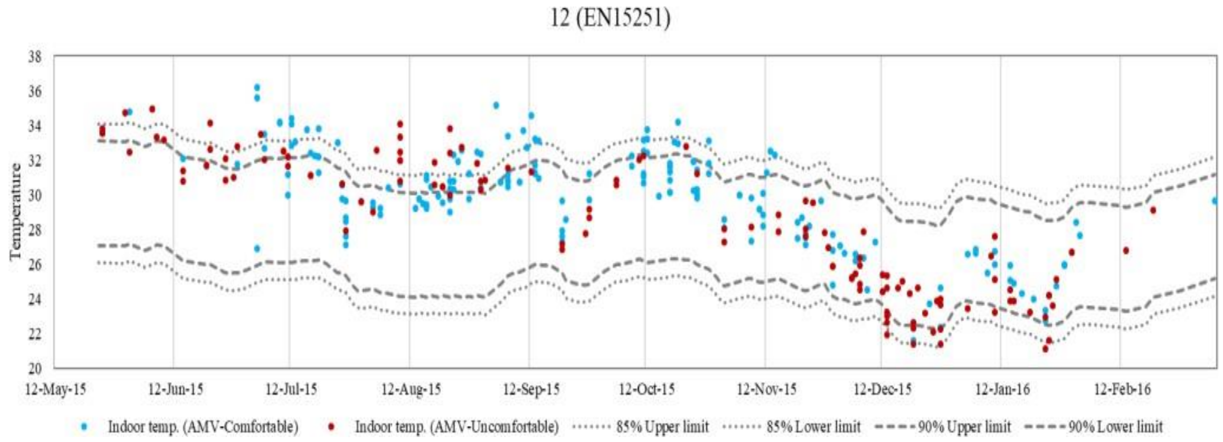
Source: Yoshito Takahashi, Akihisa Nomoto, Shu Yoda, Ryo Hisayama, Masayuki Ogata, Yoshiichi Ozeki, Shin-ichi Tanabe, Thermoregulation model JOS-3 with new open source code,, Energy and Buildings, Volume 231, 2021, 110575, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2020.110575

16

Thermal Comfort Study Methods – Statistical Analysis

Statistics for Thermal Comfort Studies





- Null hypothesis (H0) - a statement of the status quo
- Alternate hypothesis (H1) - a contrary to the status quo

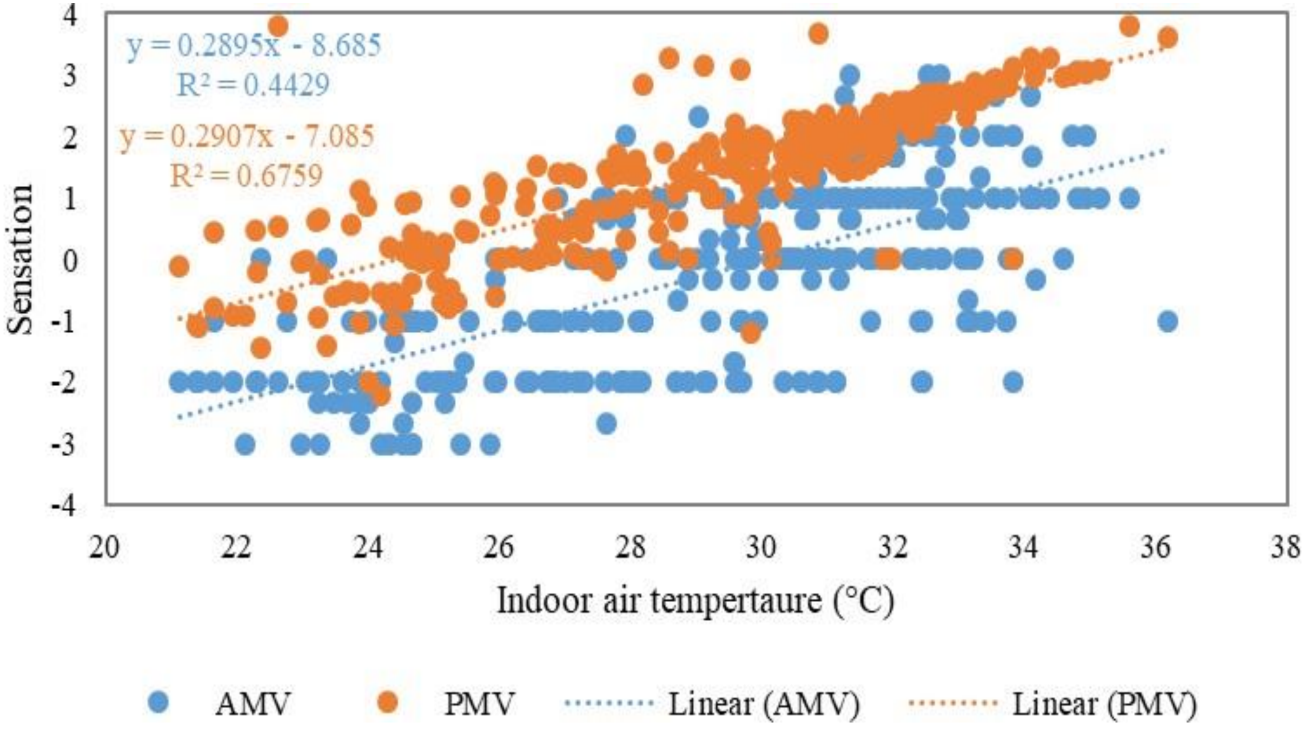
Filtering the data

- Bogus
- Contradictory
- Mistakes

Building correlation

- Between Objective and Subjective data
- Physical reason of causing the other
- Linear Regression
- Kendall Correlation
- Spearman Correlation

Statistics for Thermal Comfort Studies



- **Nature of Data Distribution**
  - Shapiro – Wilk test to examine the specific distribution
  - ANOVA, Analysis of Variance
  - Kruskal-Wallist Test
  - T test
  - Wilcoxon Rank test
    - Deal with ranks of data
- **Significant difference between two sets**
  - i.e., huge difference in MRT and Air Temp.

CASE STUDIES

Case Studies

- **Case studies: Vernacular Architecture**
  - Vernacular buildings of North-East India
  - Ahmedabad Pol Houses

- **Case studies : Eco Niwas Samhita**
  - Rajkot Smart Ghar 3
  - Revisiting, In-situ Slum up-gradation PMAY affordable housing in Ahmedabad to meet ENS

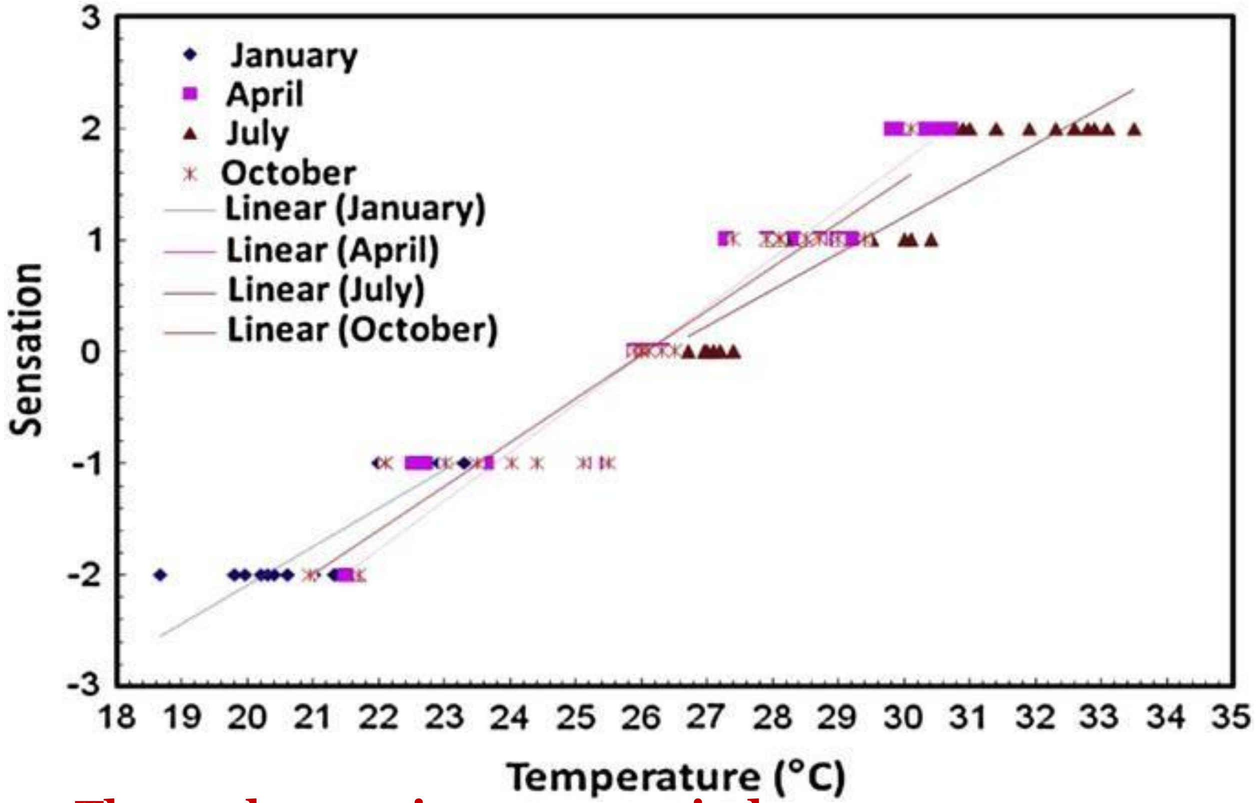
Thermal and Comfort Performance of NE India vernacular house

Case studies : Vernacular: Imphal

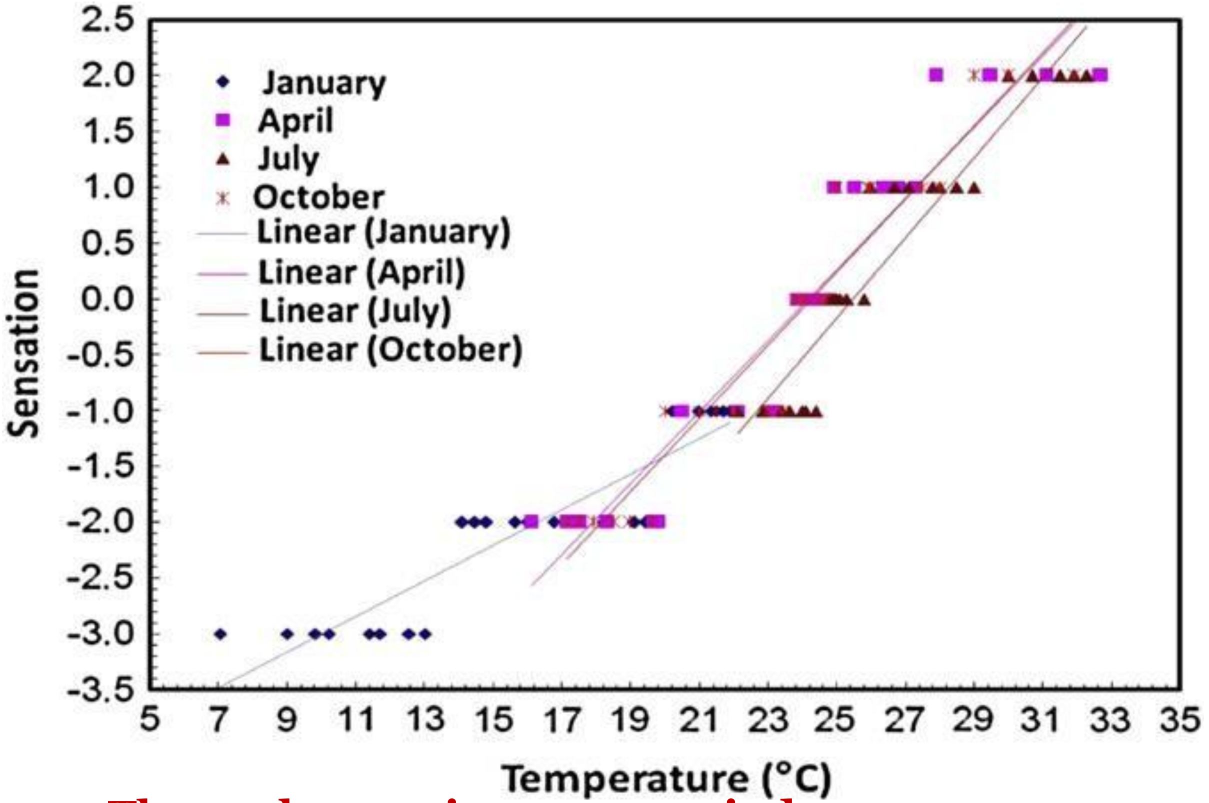
Case studies : Vernacular: Tejpur

Source: Singh, M. K., Mahapatra, S., & Atreya, S. K. (2010). Thermal performance study and evaluation of comfort temperatures in vernacular buildings of northeast India. Building and Environment, 45(2), 320– 329. https://doi.org/10.1016/j.buildenv.2009.06.009

Thermal and Comfort Performance of NE India vernacular house



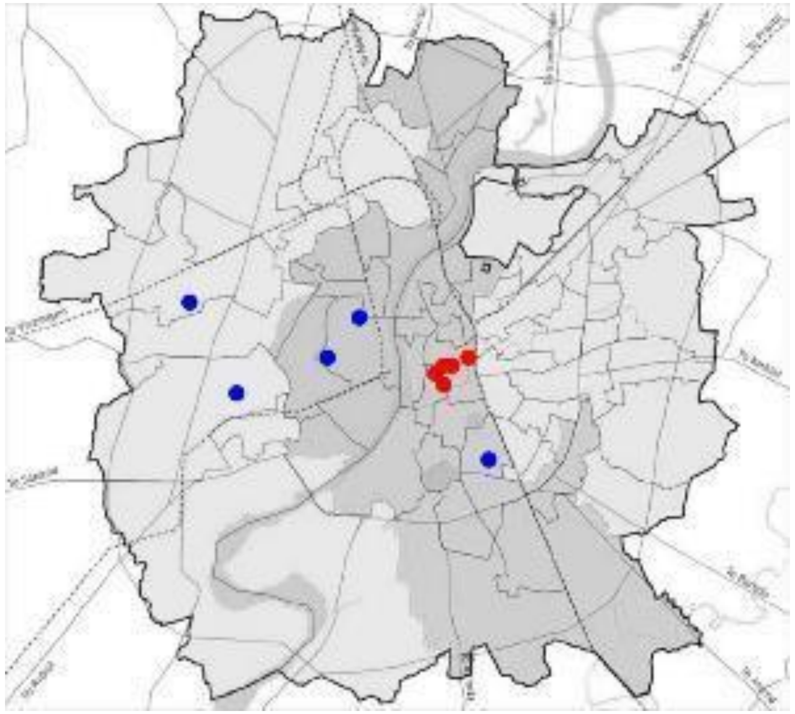
Thermal sensation votes vs. indoor temperature in Tezpur (warm and humid climate).

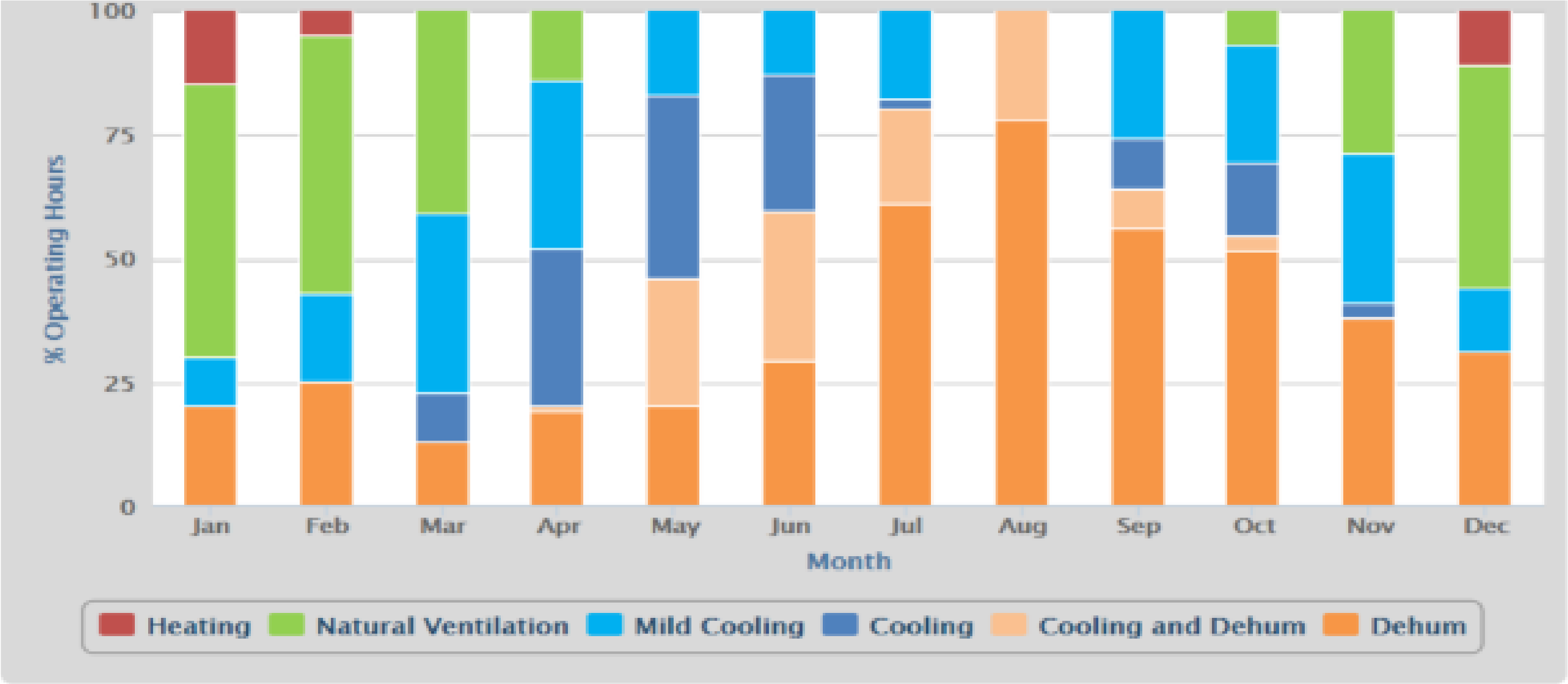


Thermal sensation votes vs. indoor temperature in Imphal (cool and humid climate).

Source: Singh, M. K., Mahapatra, S., & Atreya, S. K. (2010). Thermal performance study and evaluation of comfort temperatures in vernacular buildings of northeast India. Building and Environment, 45(2), 320– 329. https://doi.org/10.1016/j.buildenv.2009.06.009

Thermal and Comfort Performance of Pol vernacular house



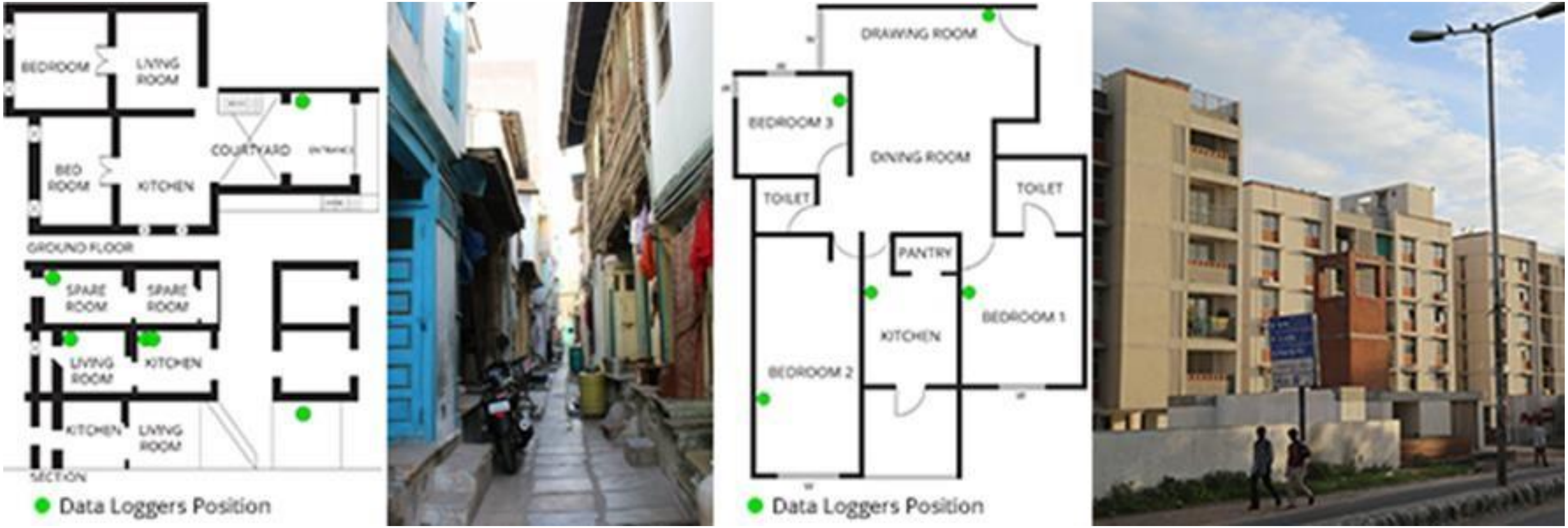


City map of Ahmedabad showing the location of PH (red) and CH (blue)

Estimated operation modes for a typical building in Ahmedabad

Source: Rawal, R., Kumar, D., & Manu, S. (2017). PLEA 2017. In What do the traditional pol houses teach us for contemporary dwellings in India? Edinburgh; PLEA 2017. Retrieved from https://www.researchgate.net/publication/321309565_What_do_the_traditional_pol_houses_teach_us_for_contemporary_dwellings_in_India

Thermal and Comfort Performance of Pol vernacular house



Plans of Pol House (PH) and Conventional House (CH) with data logger positions (green dots) and photographs

Source: Rawal, R., Kumar, D., & Manu, S. (2017). PLEA 2017. In What do the traditional pol houses teach us for contemporary dwellings in India? Edinburgh; PLEA 2017. Retrieved from https://www.researchgate.net/publication/321309565_What_do_the_traditional_pol_houses_teach_us_for_contemporary_dwellings_in_India

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

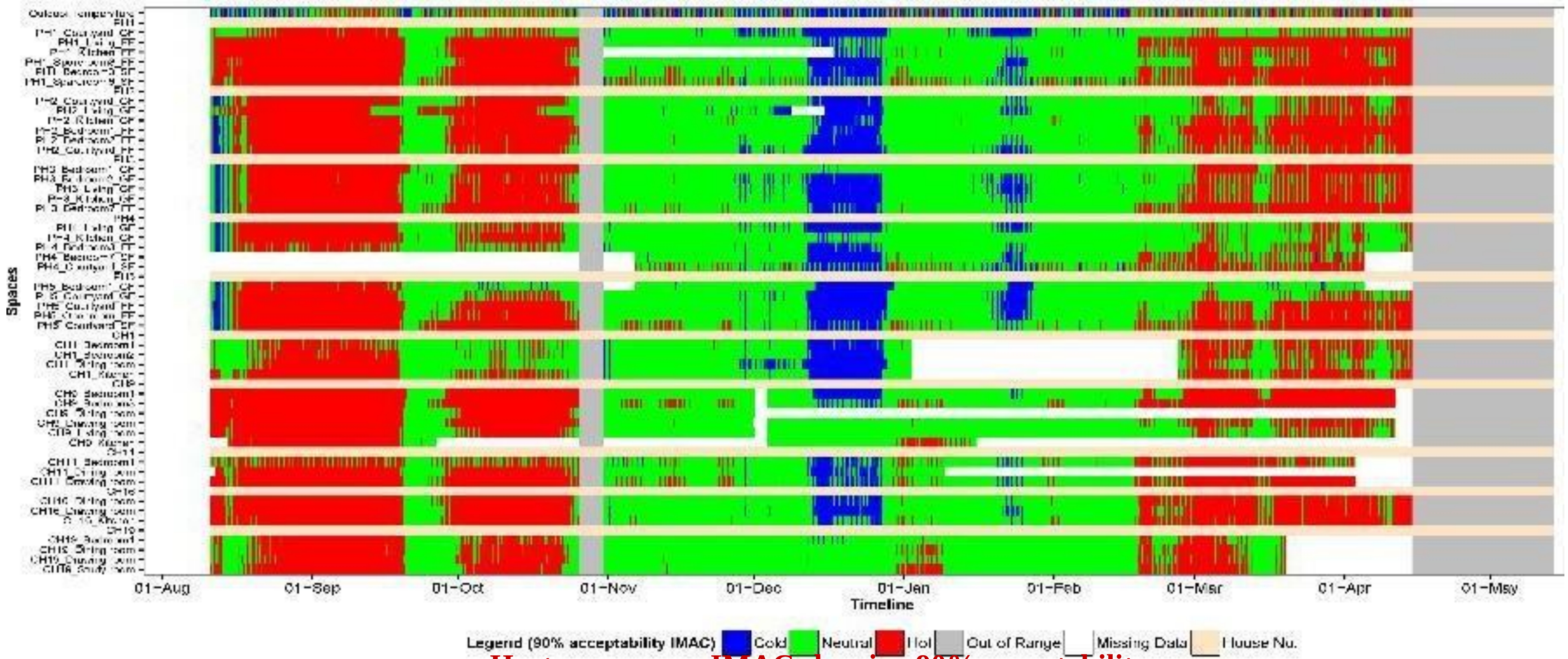
प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

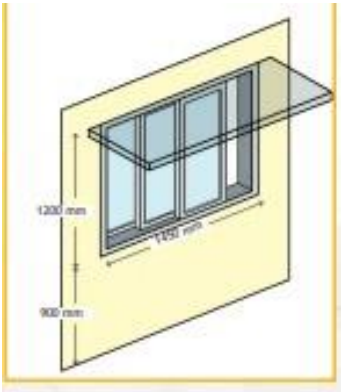
Thermal and Comfort Performance of Pol vernacular house

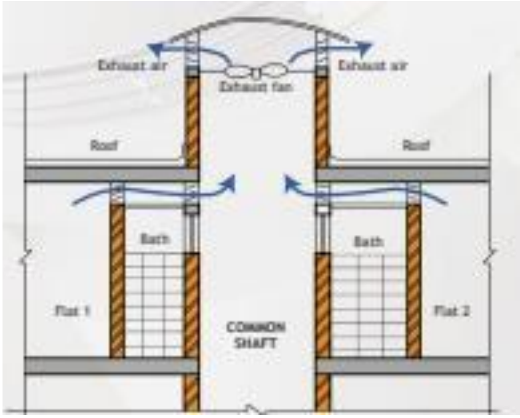


Heat map as per IMAC showing 90% acceptability range

Source: Rawal, R., Kumar, D., & Manu, S. (2017). PLEA 2017. In What do the traditional pol houses teach us for contemporary dwellings in India? Edinburgh; PLEA 2017. Retrieved from https://www.researchgate.net/publication/321309565_What_do_the_traditional_pol_houses_teach_us_for_contemporary_dwellings_in_India

Rajkot Smart Ghar





- Indo Swiss Building Energy Efficiency Project – Bureau of Energy Efficiency
- 1176 Units of 33.6 m^2/each
- U value of 0.8 W/m^2 achieved using AAC Blocks, South sidewall with 50mm air cavity leading to 0.3 W/ m^2
- Roof with PU foam 0.56 W/ m^2
- Window shutter glazing area reduced to 30%
- Improved ventilation through common service shaft

Source: Ministry of Power, & Bureau of Energy Efficiency. (n.d.). Indo-Swiss, Building Energy Efficiency Project, Case Study on "Green" Affordable Housing: Smart GHAR III, Rajkot. Retrieved from https://www.beepindia.org/wp-content/uploads/2013/12/Smart-GHAR_final_0_14.pdf

Code Compliance to Implementation : A case study

The aim of the study was To bridge the gap between implementation of Eco Niwas Samhita.

Design Intervention

- Building orientation
- Building material
- Addition of shading/overhang

Cost Strategy

- No additional cost – alternative
- With additional cost - alternative

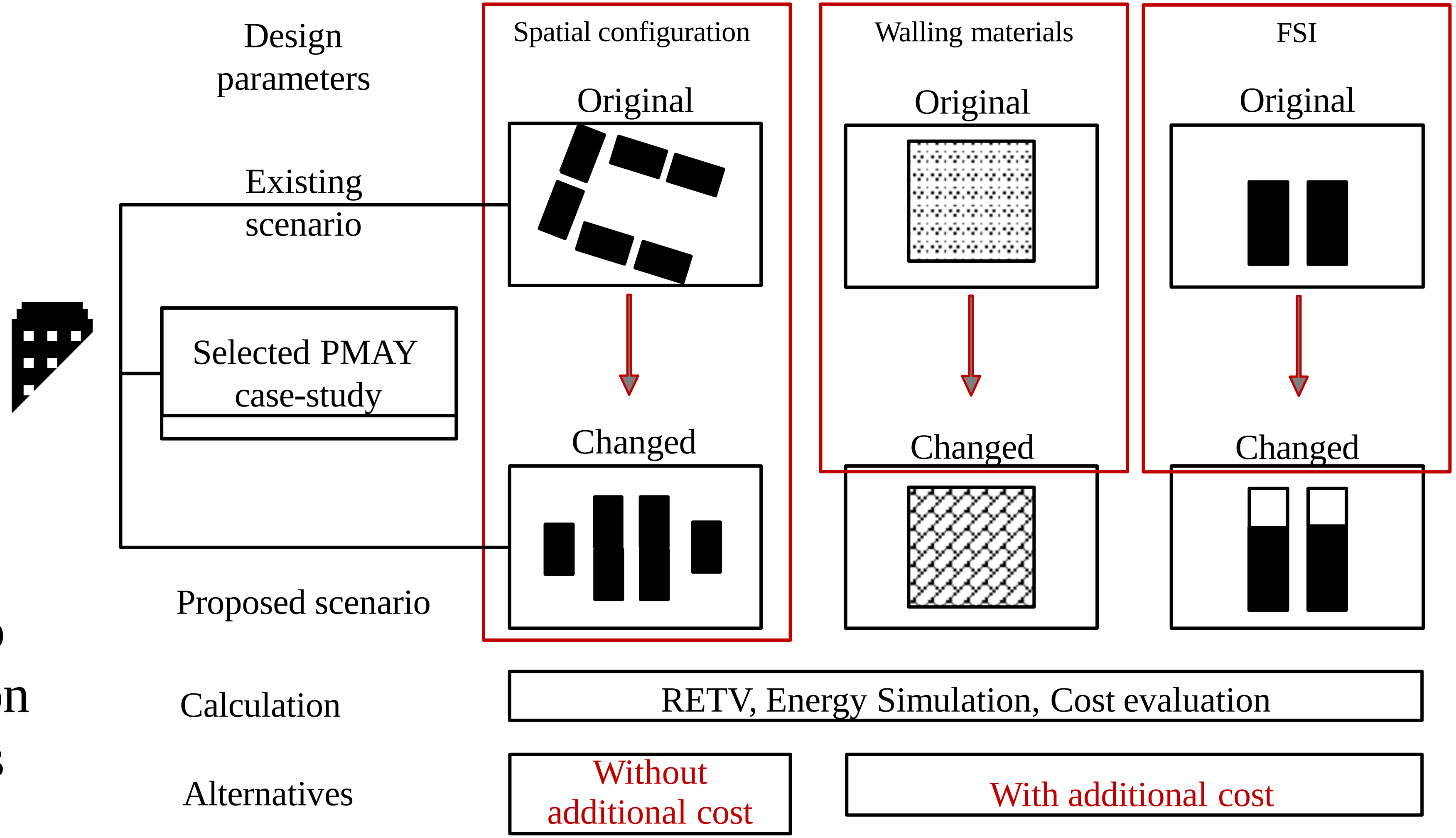
Source: Ministry of Power, & Bureau of Energy Efficiency. (n.d.). Indo-Swiss, Building Energy Efficiency Project, Case Study on "Green" Affordable Housing: Smart GHAR III, Rajkot. Retrieved from https://www.beepindia.org/wp-content/uploads/2013/12/Smart-GHAR_final_0_14.pdf

Code Compliance to Implementation

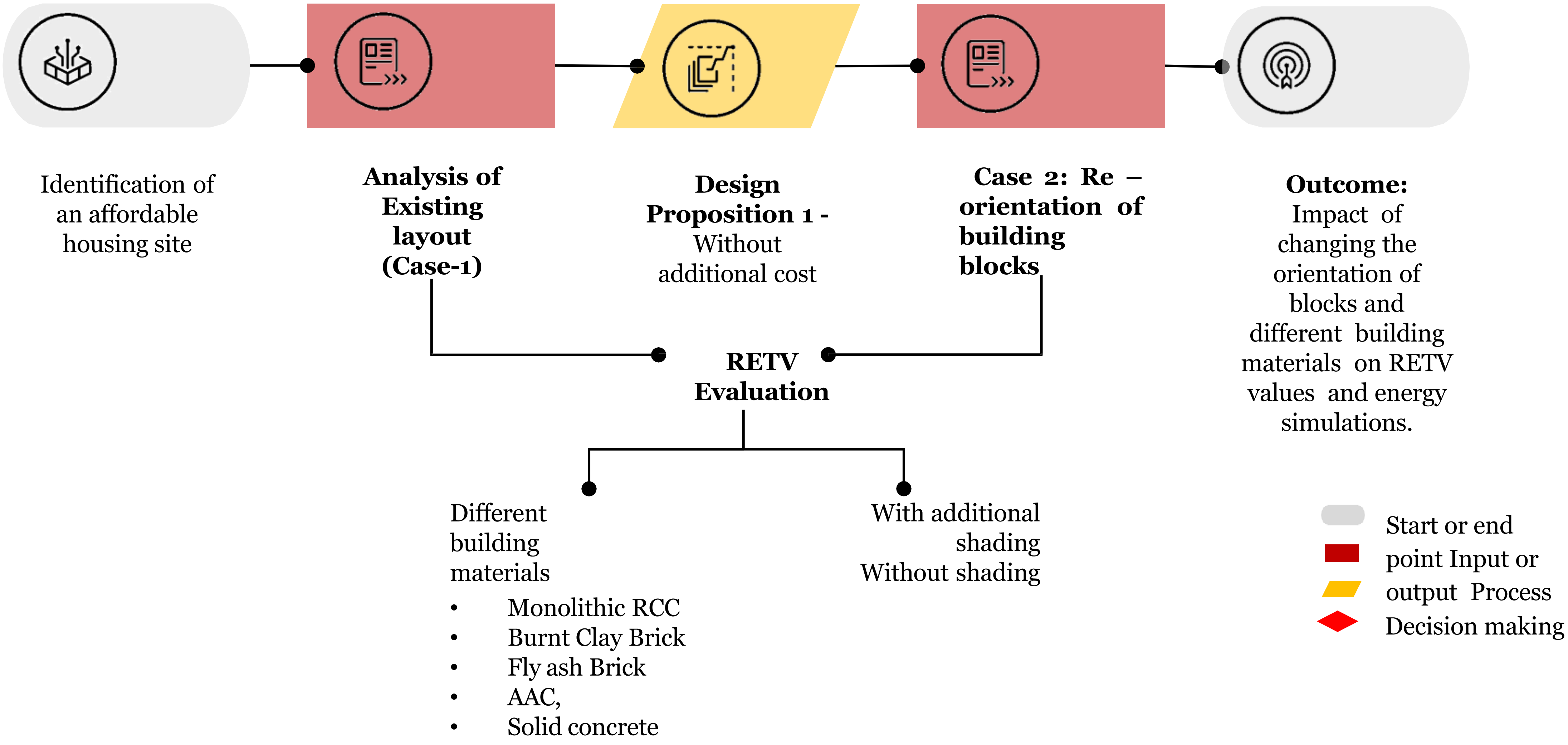
Identify the PMAY site	Proposition: 1	Proposition: 2	Outcome
Derive Building Characteristics Build an Energy Model	Derive '*without additional cost*' Strategy Operational energy consumption and thermal comfort	Identify '*with additional cost*' Operational energy consumption and thermal comfort.	Cost Analysis Challenges Local Bye Laws

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Code Compliance to Implementation : Interventions



Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.



Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Case study: Shree Ram Nagar Co-operative Housing society, Ahmedabad

Site plan

Building layout

No. of floors: 4

Carpet area: 26.76 m²

Building material: Monolithic RCC

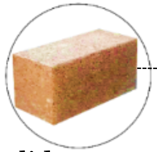
Walling material U- value: 4.15 W/m² K

RETV: 29.46 W/m²

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Total Cases: 30

Walling Materials

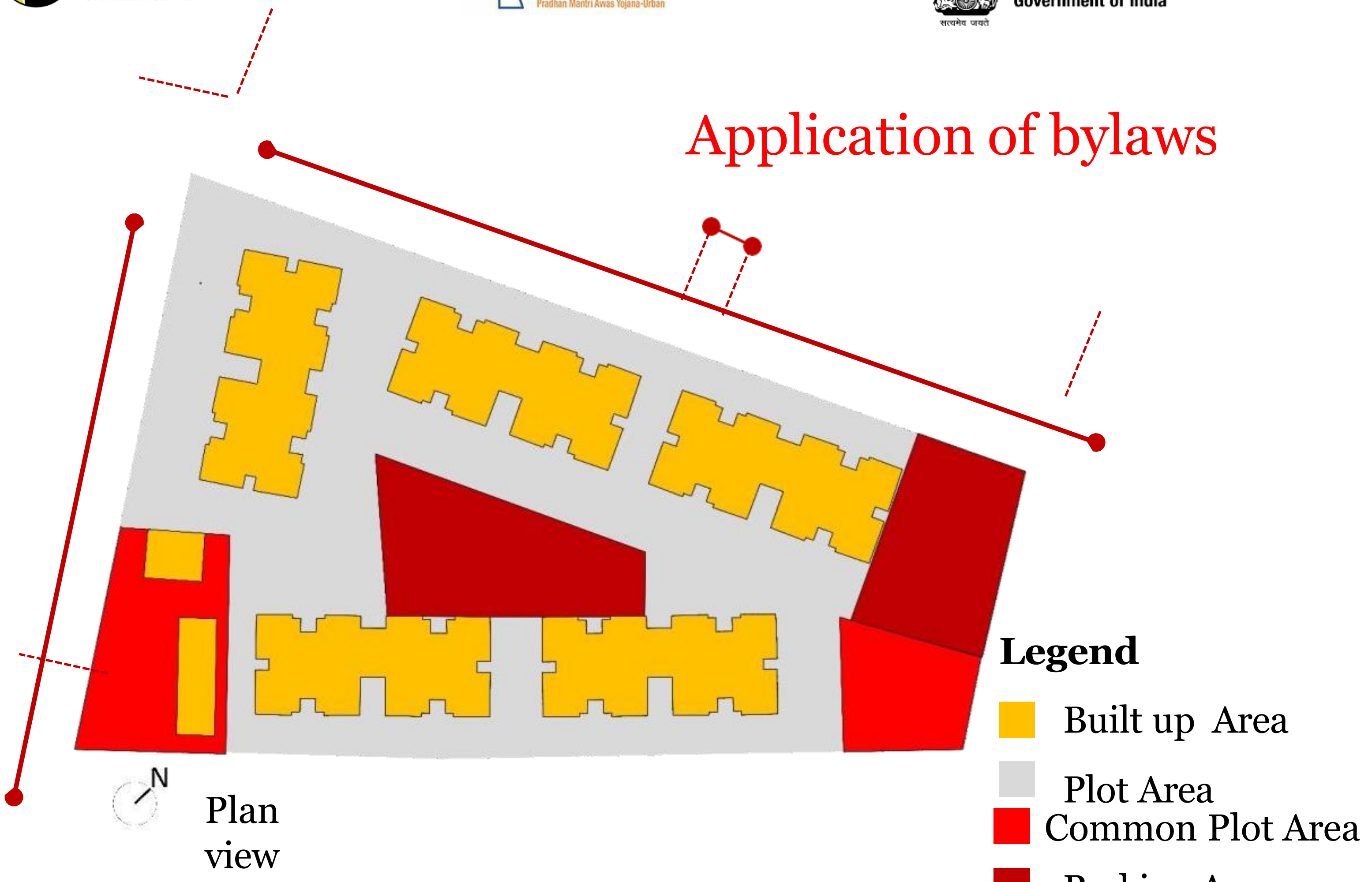
Walling material	Existing layout			
Monolithic RCC 	Case 1	Case 2	Case 3	Without Shading
	Case 1A 2	Case 2A 2	Case 3A 2	With Shading
Burnt Brick 	Case 1B 1	Case 2B 1	Case 3B 1	Without Shading
	Case 1B 2	Case 2B 2	Case 3B 2	With Shading
Fly Ash Brick 	Case 1C 1	Case 2C 1	Case 3C 1	Without Shading
	Case 1C 2	Case 2C 2	Case 3C 2	With Shading
AAC Block 	Case 1D 1	Case 2D 1	Case 3D 1	Without Shading
	Case 1D 2	Case 2D 2	Case 3D 2	With Shading
Solid concrete block 	Case 1E 1	Case 2E 1	Case 3E 1	Without Shading
	Case 1E 2	Case 2E 2	Case 3E 2	With Shading

Calculations

1. RETV
2. EPI
3. Comfort hours

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Application of bylaws



Case 1: Existing layout

No. of units – 160

Utilized FSI area – 64% of permissible

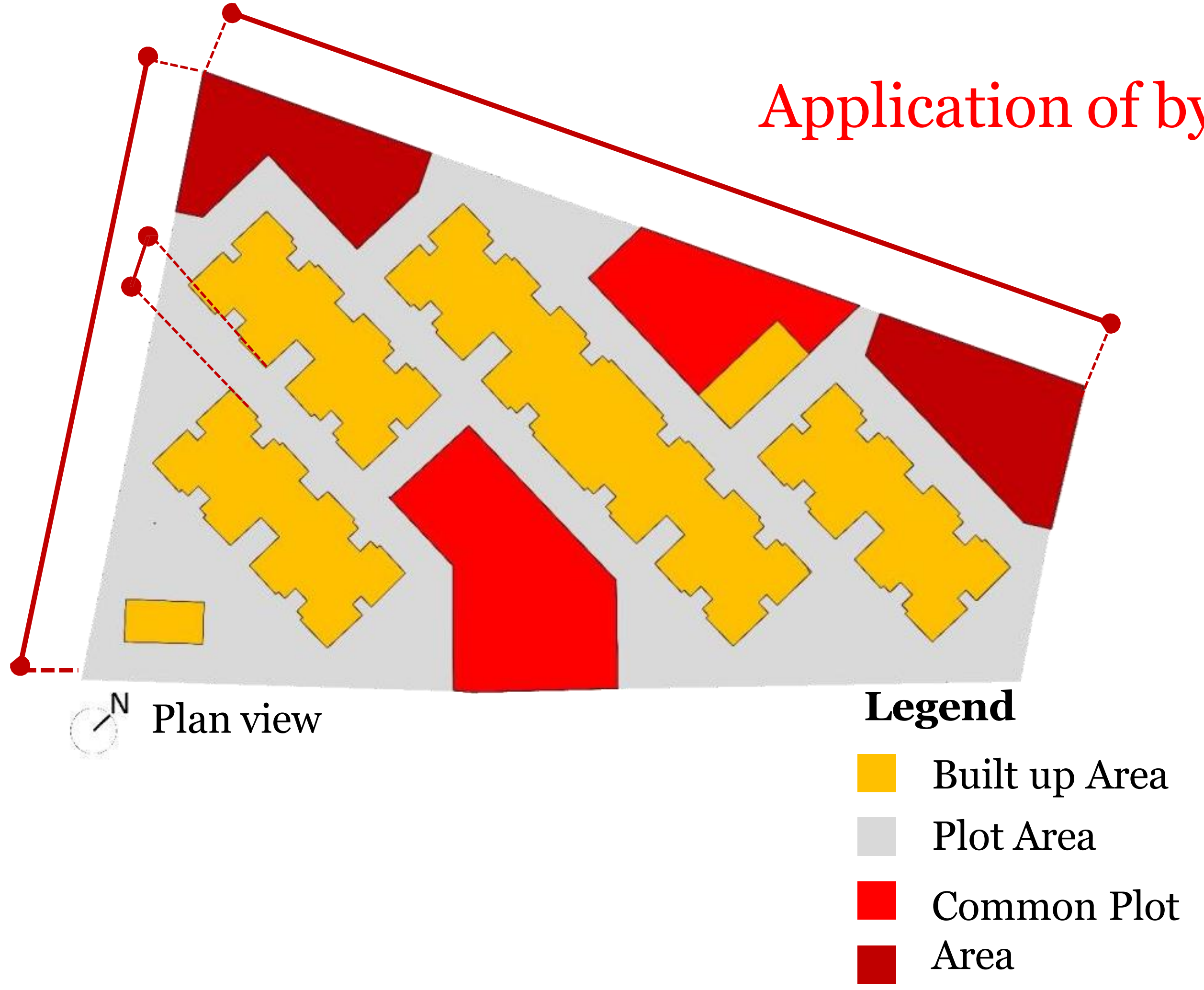
Common Plot Area – 10% of plot area

Parking Area - 21% of utilized FSI area

Distance between buildings – 4.5-5.0 m

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Application of bylaws



Case 2 (Proposed): Re – oriented site

No. of units – 160

Utilized FSI area – 47% of permissible

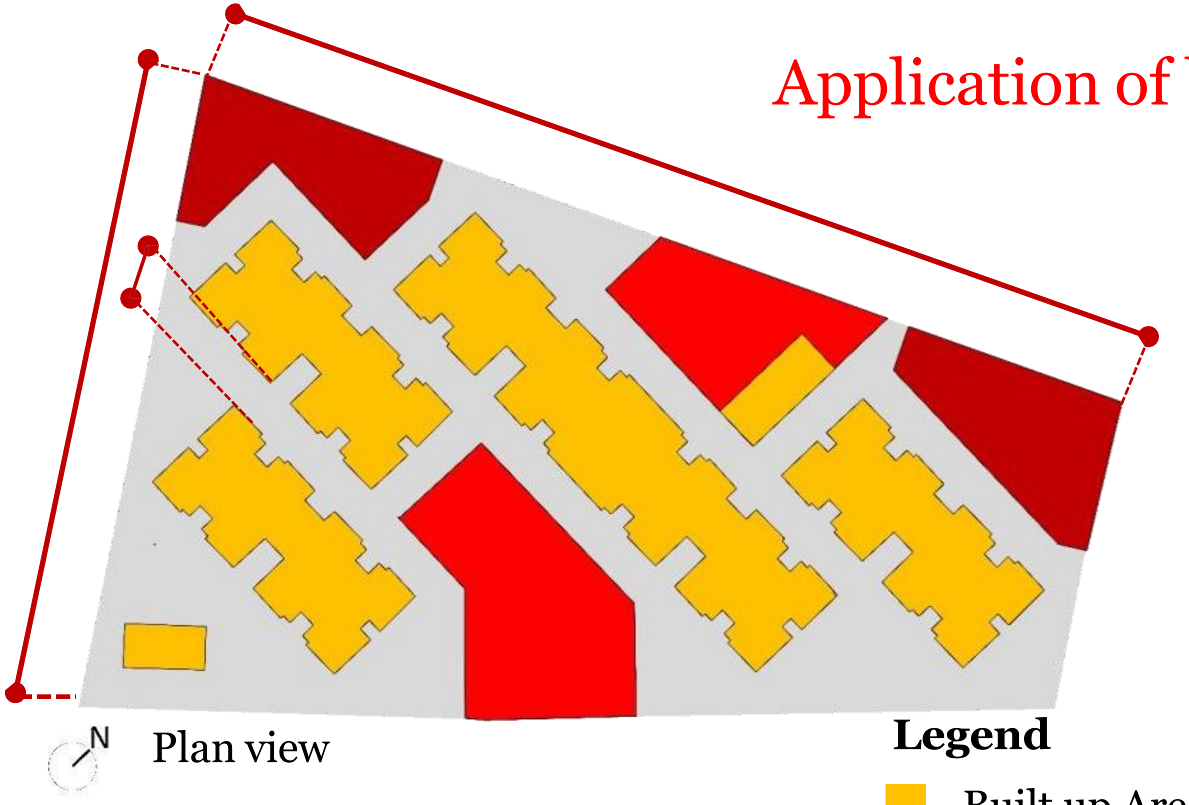
Common Plot Area – 13% of plot area

Parking Area - 11% of utilized FSI area

Distance between buildings – 4.5 M

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Application of bylaws



Plan view

Legend

- Built up Area Plot
- Area
- Common Plot Area
- Parking Area

Case 3 (Proposed): Re – oriented site
+
Increased FSI

No. of units – 200

Utilized FSI area – 58% of permissible

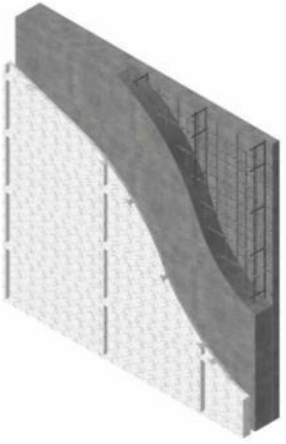
Common Plot Area – 13% of plot area
Parking Area - 12% of utilized FSI area

Distance between buildings – 4.5 M

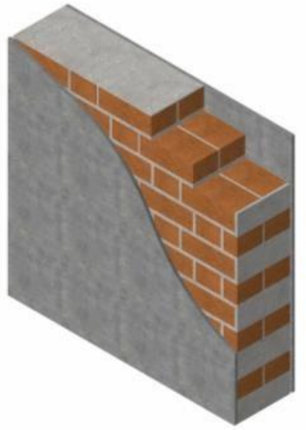
Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Existing Layout without Shading

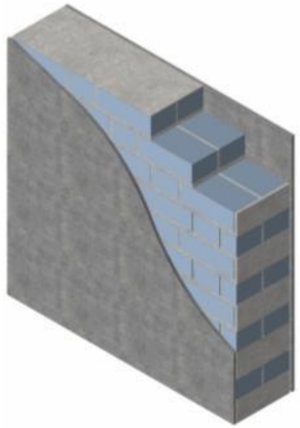
EXISTING RCC (MASCON)



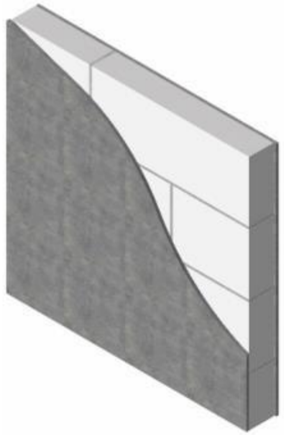
BURNT CLAY BRICK



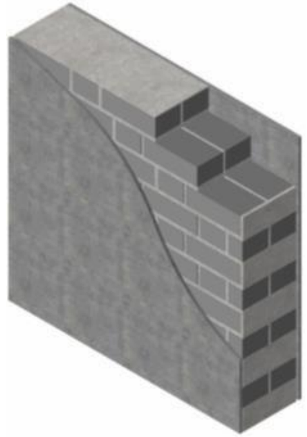
FLY ASH BRICK



AAC BLOCKS



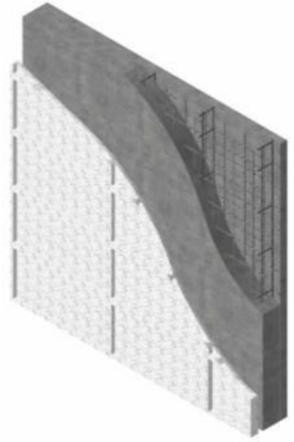
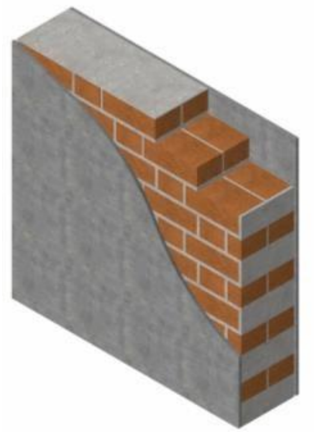
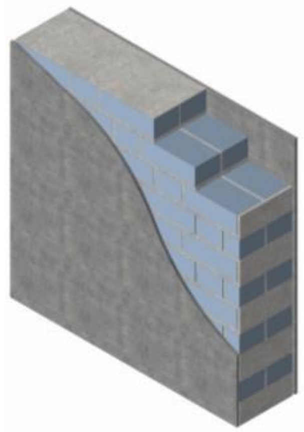
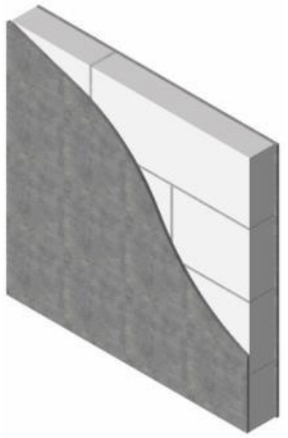
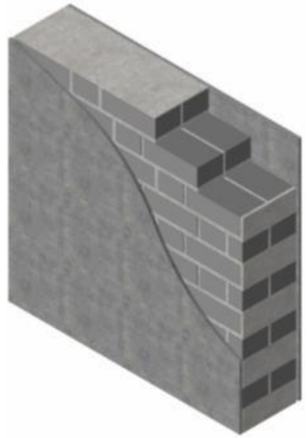
SOLID CONCRETE BLOCK



Case	Case 1	Case 1B 1	Case 1C 1	Case 1D 1	Case 1E 1
Shading			Without		
RETV	26.00	16.62	16.34	12.35	25.48
EPI	75.92	48.53	47.71	36.06	74.40
Comfort hours	4760 - 7627	4887-8599	4716-8608	1874-8760	4618-8009
Difference in cost	₹ -	₹ -79,50,926	₹ -66,03,988	₹ -76,08,377	₹ +61,12,630

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Existing Layout without Shading

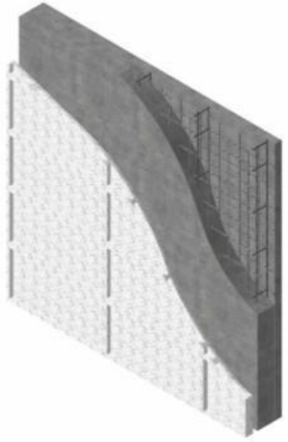
EXISTING RCC (MASCON)	BURNT CLAY BRICK	FLY ASH BRICK	AAC BLOCKS	SOLID CONCRETE BLOCK
				

Case	Case 1A2	Case 1B 2	Case 1C 2	Case 1D 2	Case 1E 2
Shading	With 0.6 m overhangs				
RETV	24.95	15.56	15.28	11.29	25.47
EPI	72.85	45.44	44.62	32.97	71.74
Comfort hours	4815-7683	5230-8657	5147-8670	2943-8760	4671-8042
Difference in cost	₹ +46,072	₹-79,04,854	₹ -65,57,916	₹-75,62,305	₹ +61,58,702

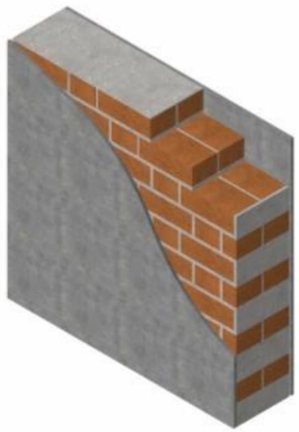
Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Re-Orientation (with shading)

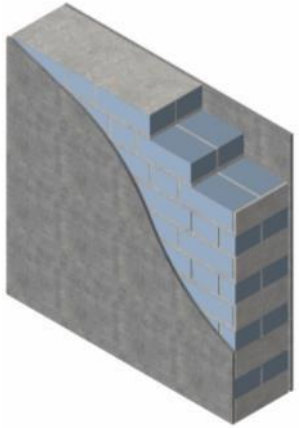
EXISTING RCC (MASCON)



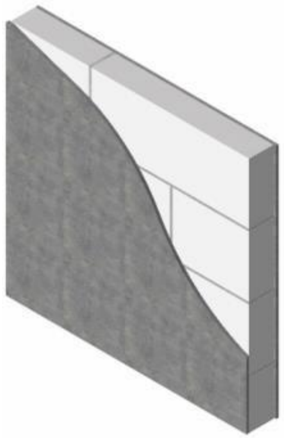
BURNT CLAY BRICK



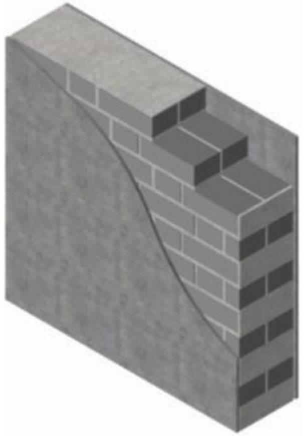
FLY ASH BRICK



AAC BLOCKS



SOLID CONCRETE BLOCK



Case	Case 2A 2	Case 2B 2	Case 2C 2	Case 2D 2	Case 2E 2
Shading	With 0.6 m overhangs				
RETV	23.57	14.47	14.20	10.33	23.06
EPI	68.82	42.25	41.46	30.16	67.34
Comfort hours	4904-7785	5432-8691	3132-8760	5358-8699	4819-8059
Difference in cost	₹ +46,072	₹-79,04,854	₹ -65,57,916	₹ -75,62,305	₹ +61,58,702

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Re-Orientation of Block, but without 100% FSI use

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

Re-Orientation of Block, with 100% FSI use (additional floor)

Source: Rawal, R., Shukla, Y., Patel, P., Desai, A., Asrani, S. (2021). Bridging the gap between Eco Niwas Samhita (ENS) code compliance and implementation: A Case Study of Affordable Housing. Centre for Advanced Research in Building Science and Energy (CARBSE), CRDF, CEPT University.

DAY 2

Tea Break

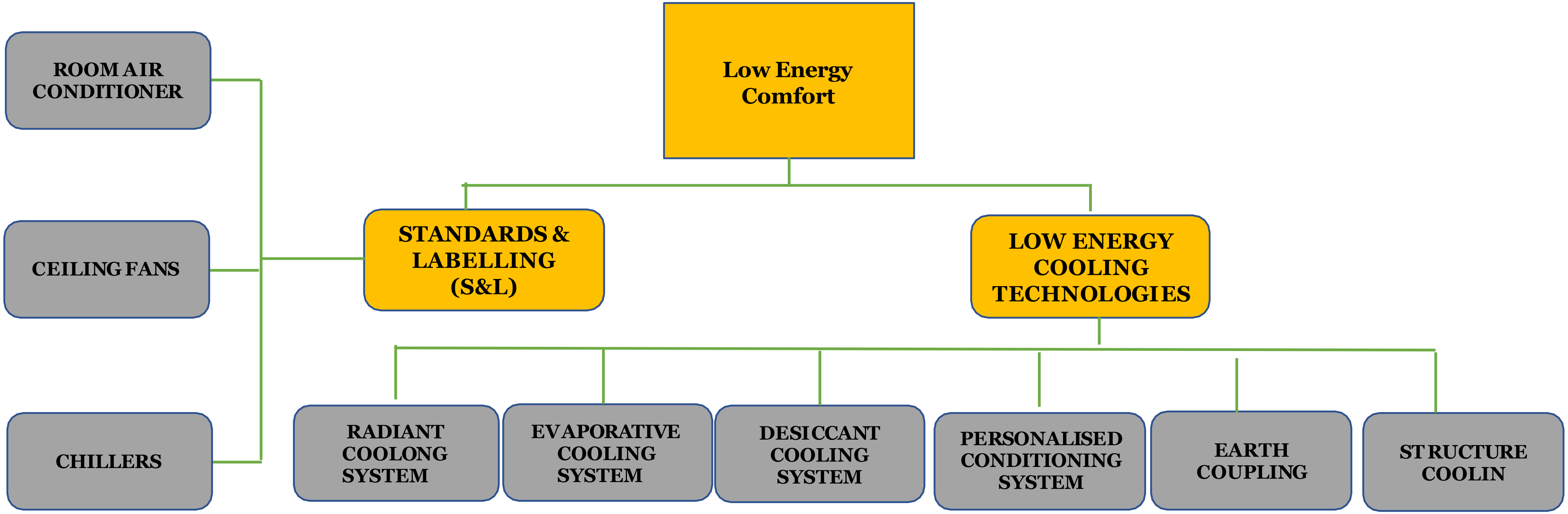
DAY 2

Session 6: Low Energy Cooling Technologies and Comfort

17

Categories of Low Energy Cooling Systems

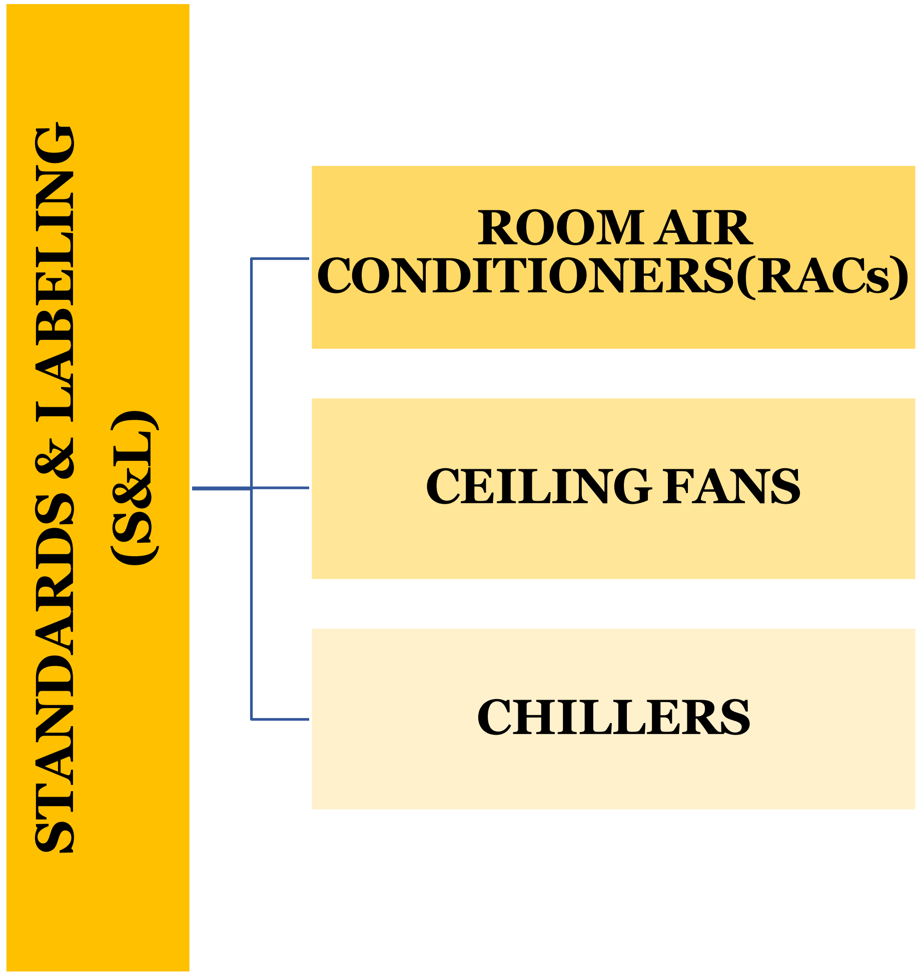
Low Energy Comfort System in Housing



Standards & Labeling (S&L)

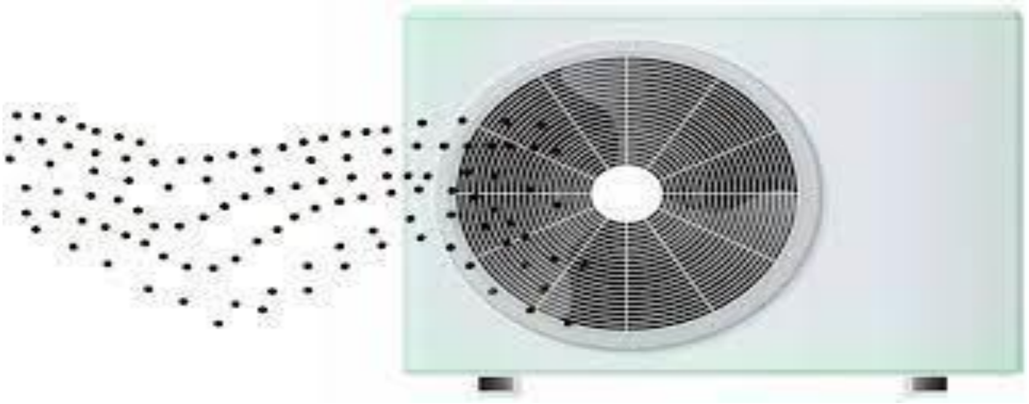
S&L assists consumers in making educated decisions about appliance energy usage and promotes the market penetration of energy efficient appliances and equipment. BEE established the S&L program in 2006.

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



Standards & Labeling (S&L)

1 - ROOM AIR CONDITIONERS (RACs):



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

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

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

Standards & Labeling (S&L)

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

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

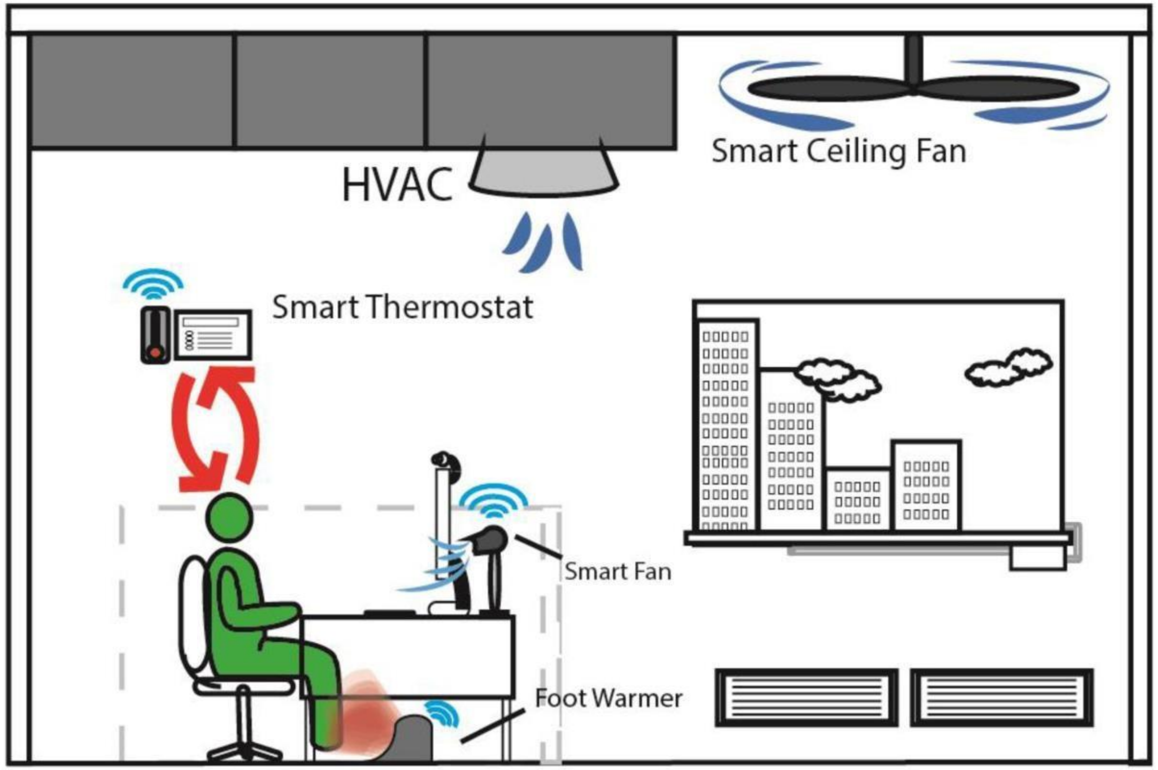
Standards & Labeling (S&L)

2 - CELING FANS:

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

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

Both the BIS and the BEE give ratings to fans.



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

- RADIANT COOLING SYSTEM
- EVAPORATIVE COOLING
- DESICCANT COOLING SYSTEM
- PERSONALISED CONDITIONING SYSTEM
- EARTH COUPLING
- STRUCTURE COOLING

Low Energy Cooling Technologies – Radiant Structural Cooling

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.

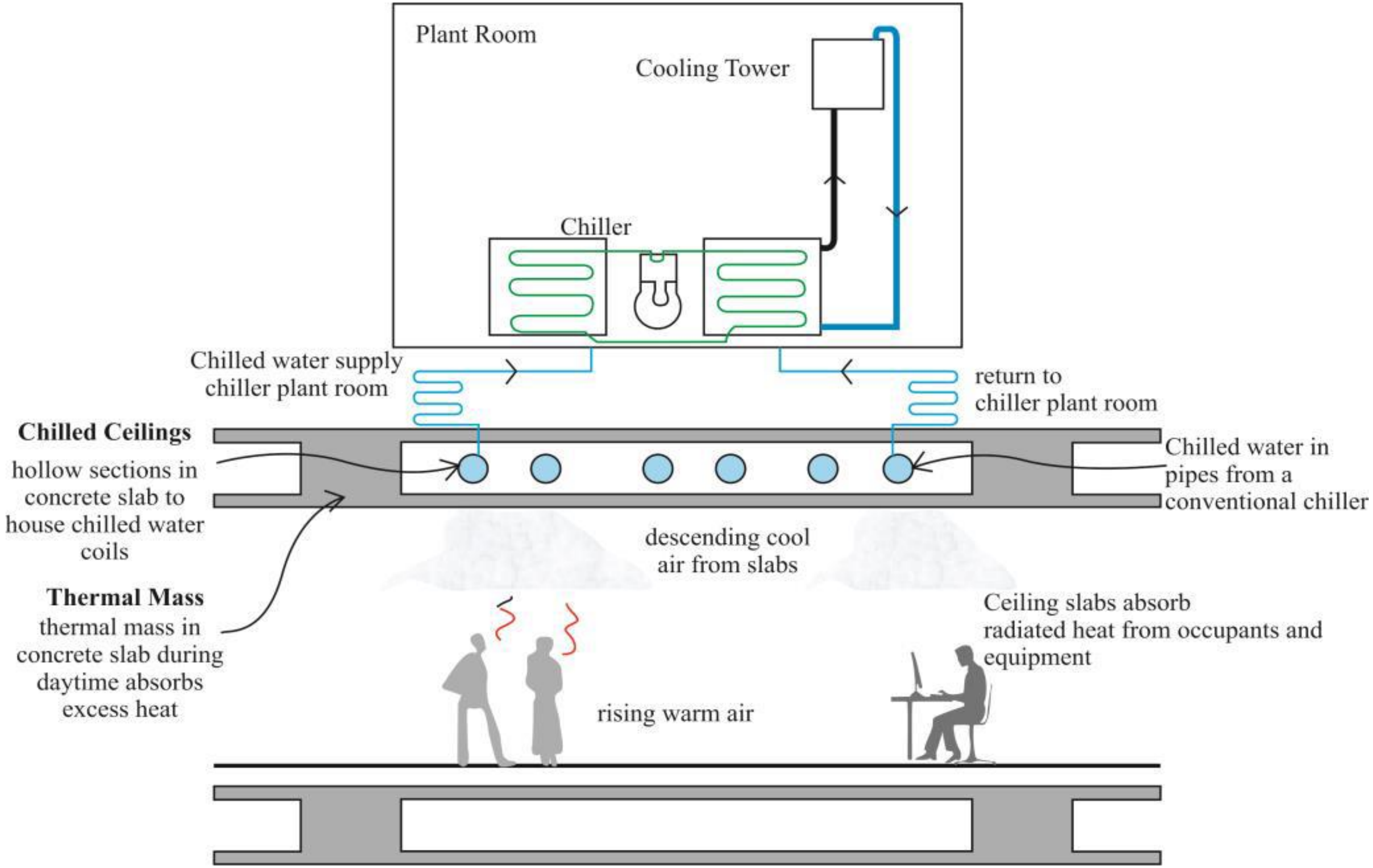
The technique makes advantage of water's far higher thermal capacity than air.

Unfavourable Factors

- No possibility of fresh air intake
- Low ceiling to floor height
- Poor insulation / no thermal mass

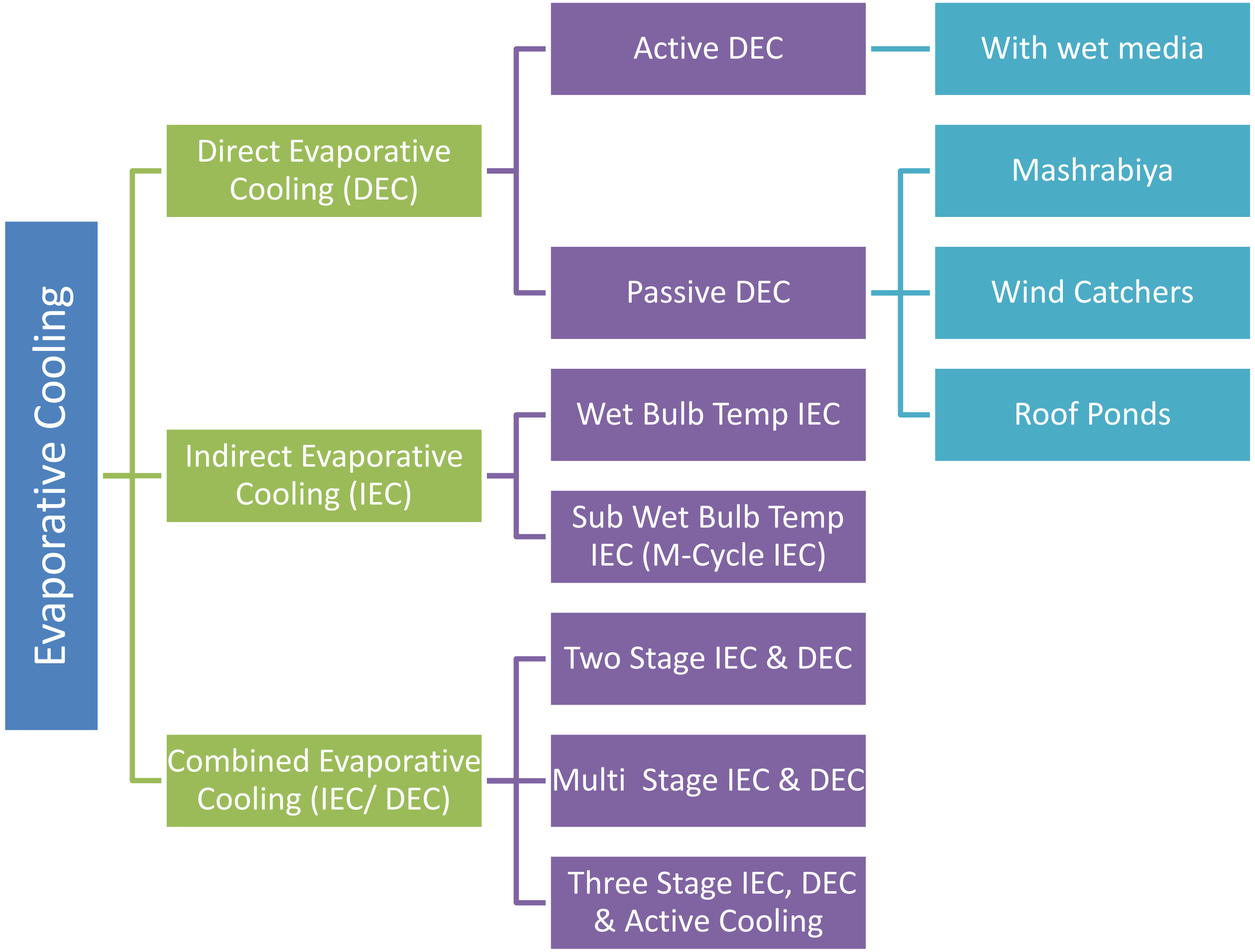
Favourable Factors

- Low Night time DBT
- Less and Periodic internal loads
- Uninterrupted electricity



Low Energy Cooling Technologies – Evaporative Cooling (and its variations)

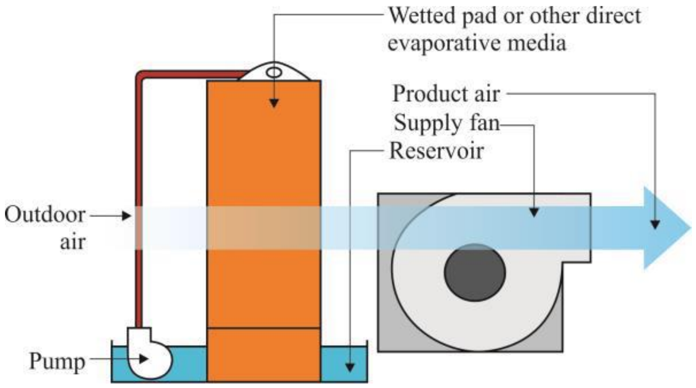
The evaporative cooling technology is based on heat and mass transfer between air and cooling water

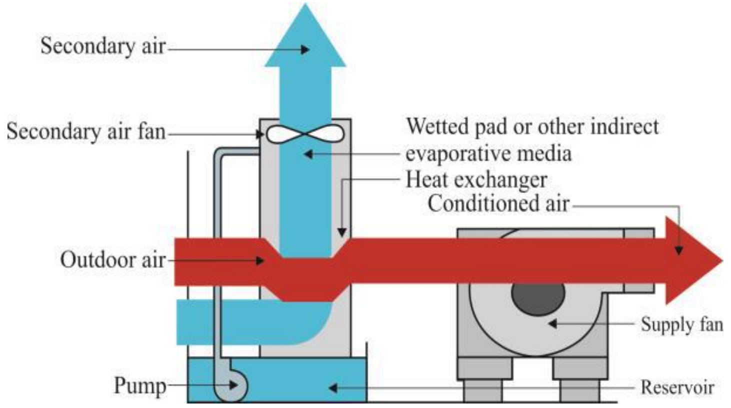


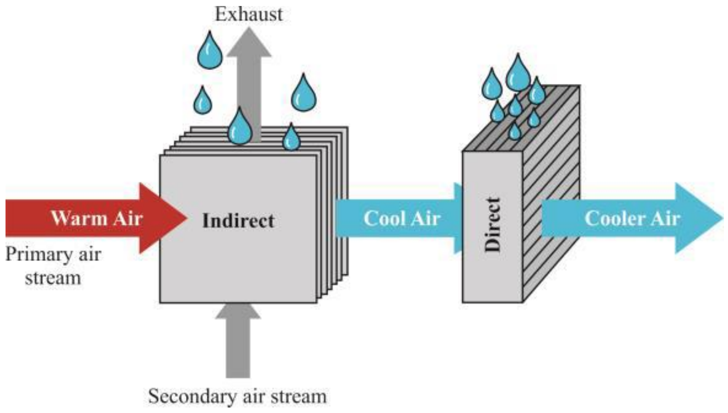
Low Energy Cooling Technologies – Evaporative Cooling (and its variations)

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

- Evaporative Cooling
  - Direct Evaporative Cooling (DEC
  - Indirect Evaporative Cooling (IEC)
  - Combined Evaporative Cooling (IEC/ DEC)







Source:Kanzari , M., Boukhanouf , R., & Ibrahim, H. (2013). Mathematical Modeling of a Sub Wet Bulb Temperature Evaporative Cooling Using Porous Ceramic Mat erials. Retrieved from https://www.researchgate.net/publication/267209957_Mathematical_Modeling_of_a_Sub Wet_Bulb_Temperature_Evaporative_Cooling_Using _Porous_Ceramic_Materials Condair.(2021, January 5). Direct vs. Indirect Evaporative Cooling: What's the Difference?Direct vs indirect evaporative cooling whats the difference. Retrieved April 16, 2022, from https://www.condair.com/humidifiernews/blog overview/direct vs indirect evaporative cooling whats the difference , ategroup . (n.d.). Evaporative cooling system: Indirect direct evaporative cooler. A.T.E. India. Retrieved April 16, 2022, from https://www.ategroup.com/hmx/why evaporative/

Low Energy Cooling Technologies – Night Cooling by Natural Ventilation

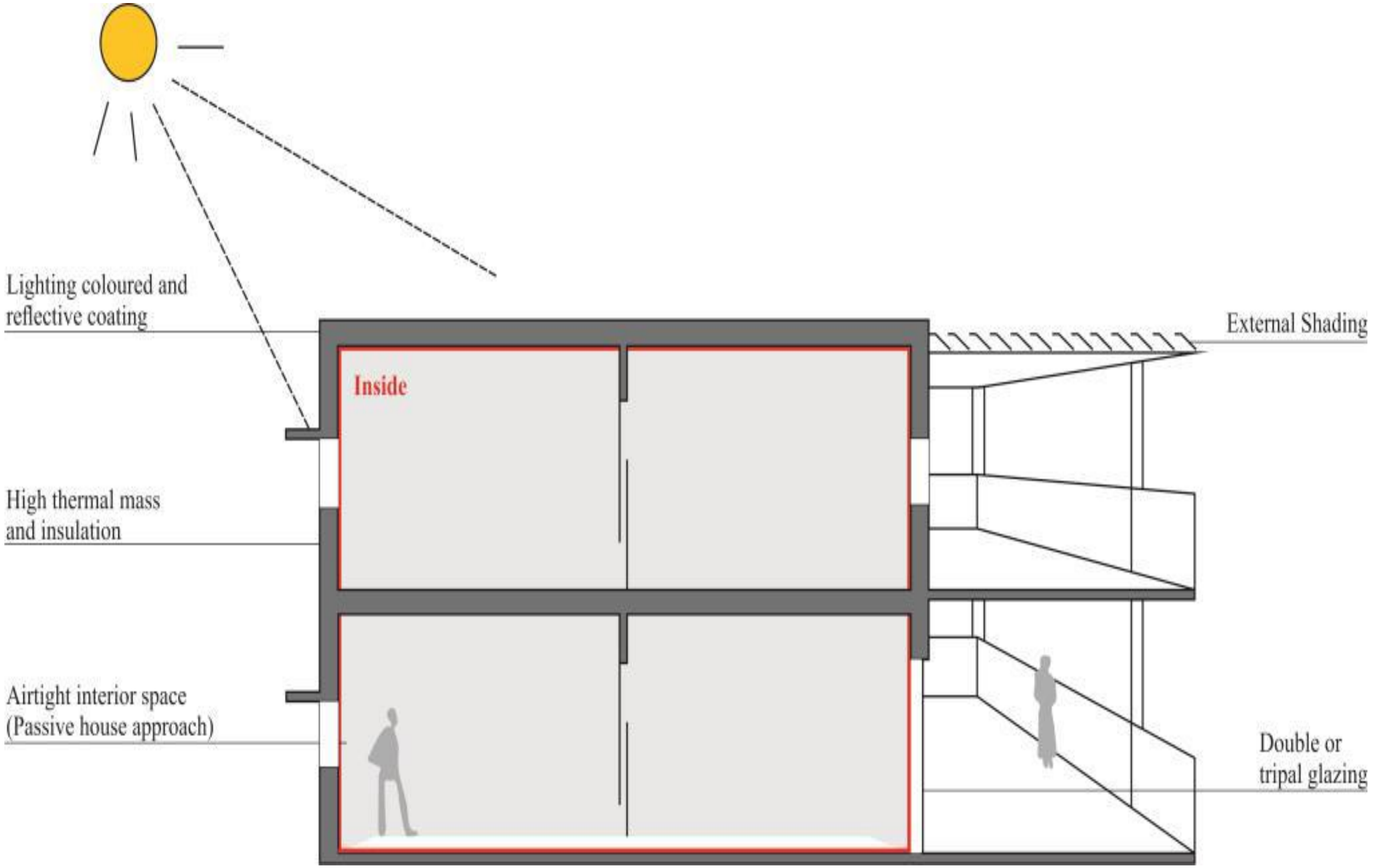
Good Air Contact with Thermal Mass, Unobstructed Air Flow Paths.

Unfavourable Factors

- High day/ night time humidity
- External pollution/ noise
- Deep plan floor plates Displacement ventilation

Favourable Factors

- Low Night time DBT
- Less and Periodic internal loads
- Uninterrupted electricity



Low Energy Cooling Technologies – Night Cooling by Mechanical Ventilation

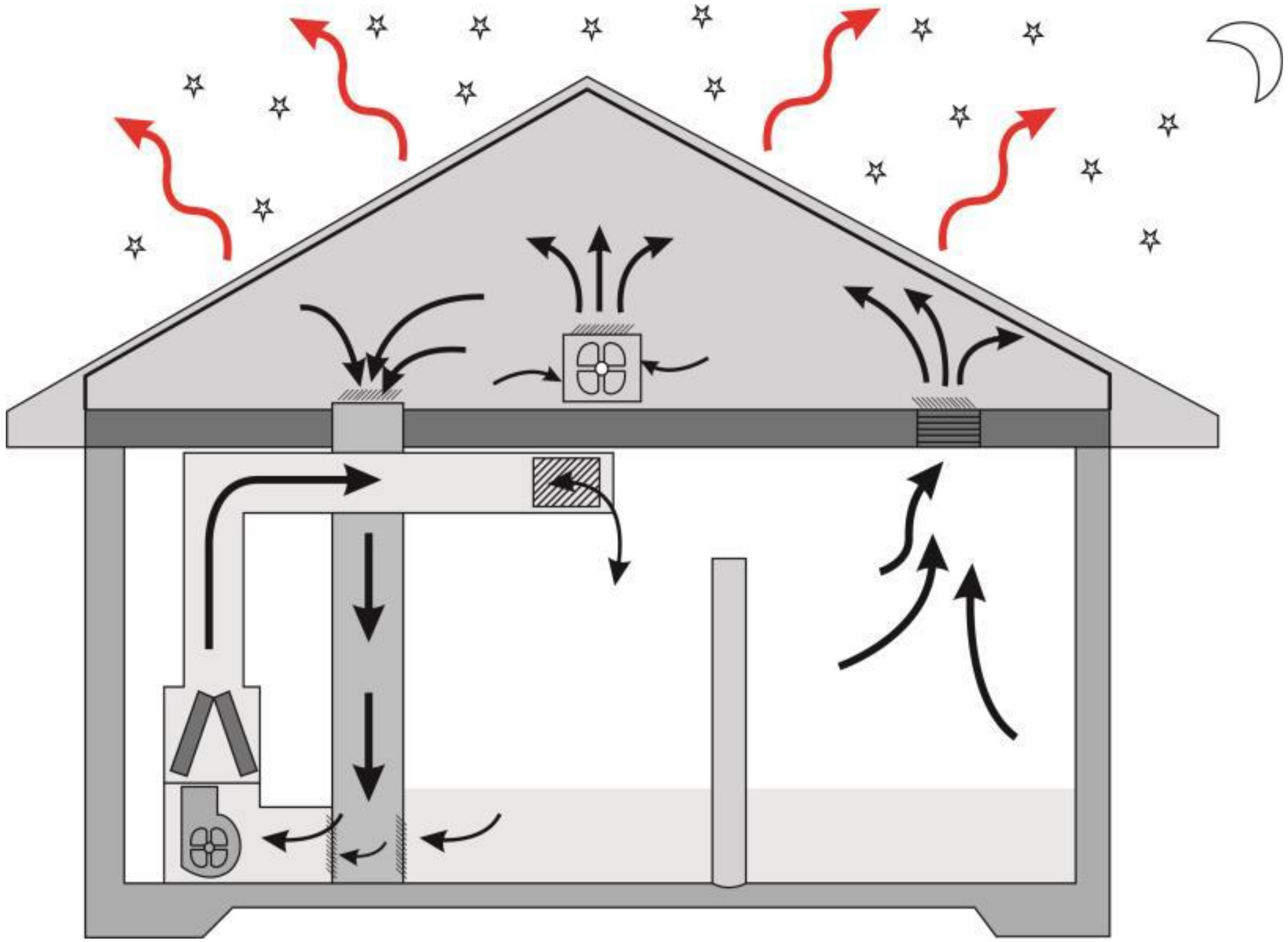
Highly efficient, low noise fans and low-pressure drop needed, night cooling for high mass can offset~20-30 W/m2 heat gains.

Unfavourable Factors

- No possibility of fresh air intake
- Low ceiling to floor height
- Poor insulation/ no thermal mass

Favourable Factors

- Low Night time DBT
- Less and Periodic internal loads
- Uninterrupted electricity



Low Energy Cooling Technologies – Dessicant Cooling

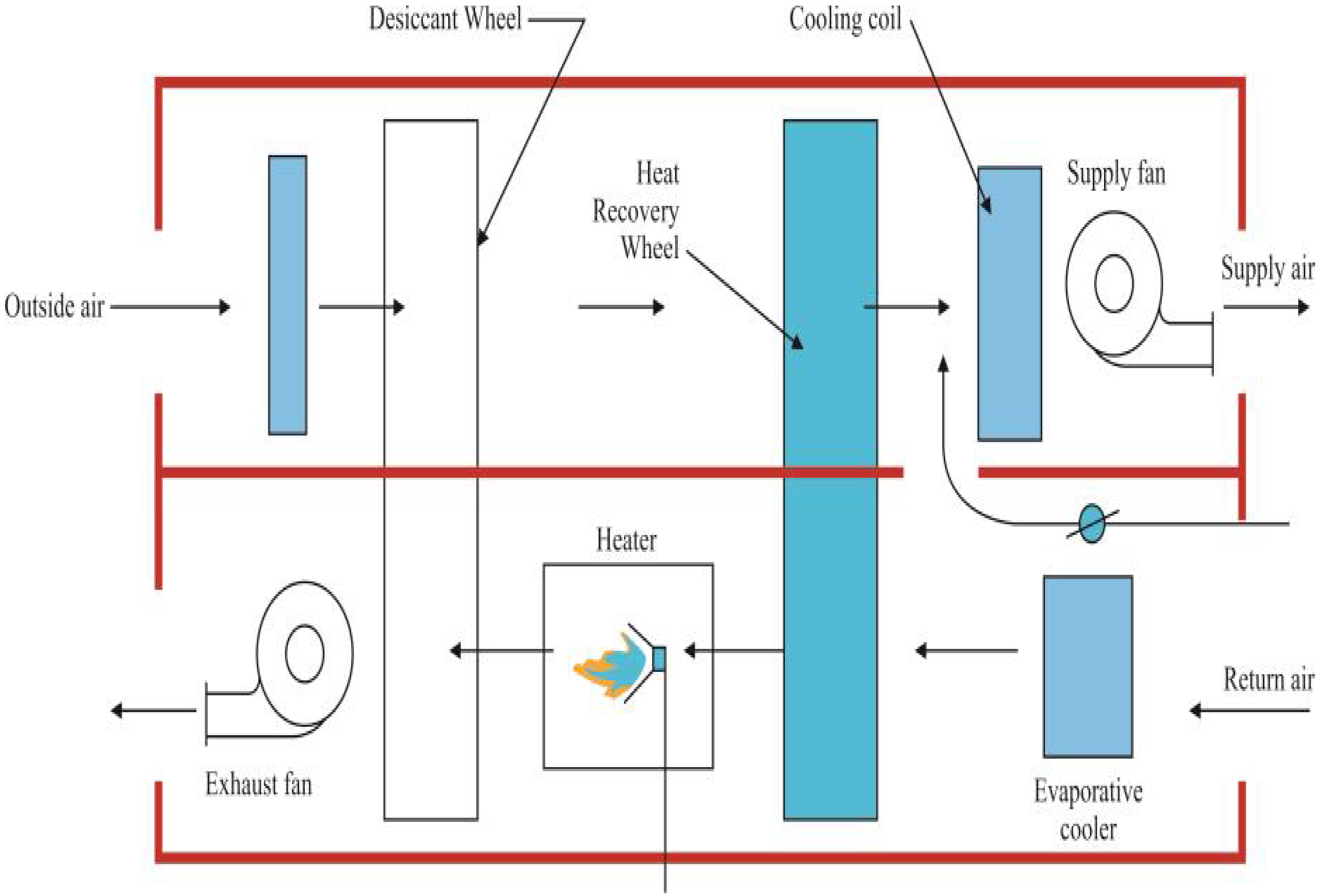
Works well alongside Night Cooling and Displacement Ventilation

Unfavourable Factors

- Works well in Dry Climate
- Need precision temp and humidity conditions

Favourable Factors

- Waste Heat or Affordable Thermal source
- Minimal Electrical Consumption



Low Energy Cooling Technologies – Displacement Ventilation

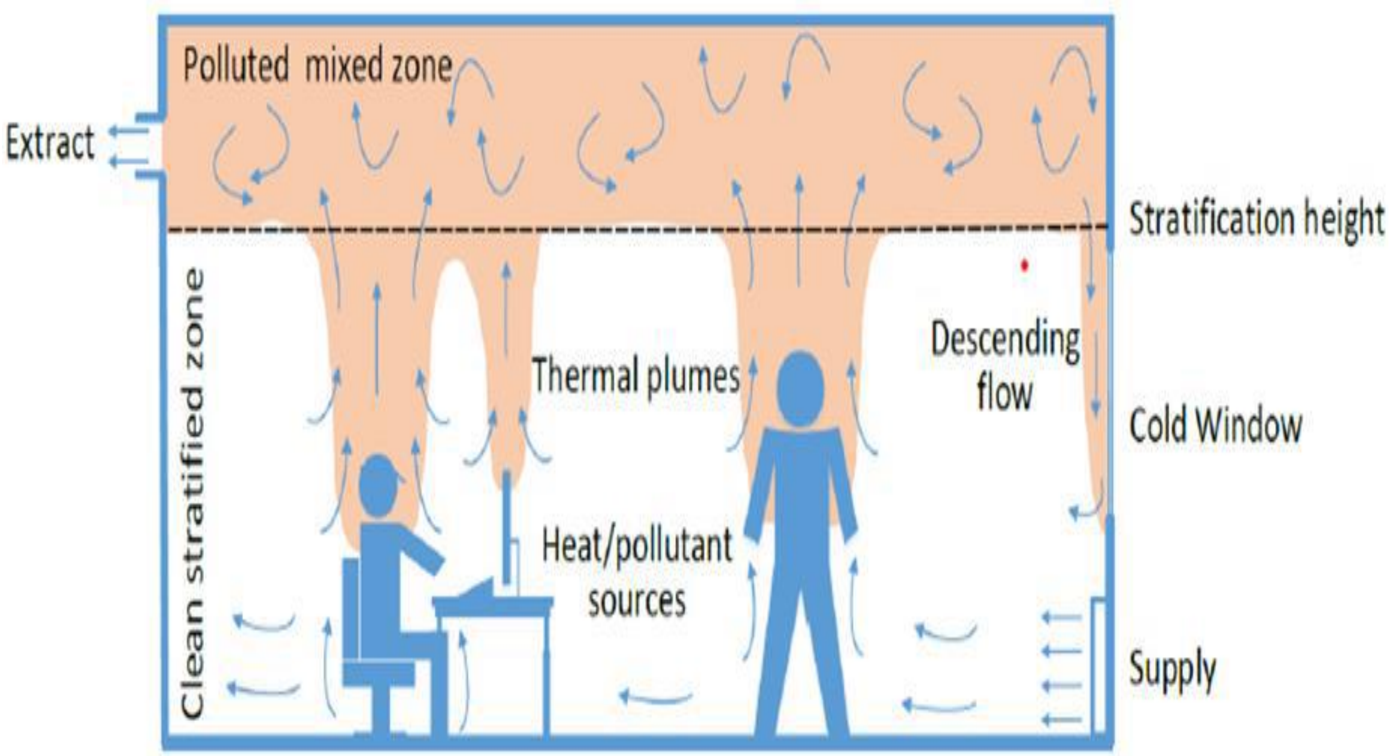
Ideal air supply at 18 °C, Vertical temperature gradient <1.5K

Unfavourable Factors

- High airflow
- May result in noise
- High ceiling needed
- Needs low velocity terminals at a low level

Favourable Factors

- Surface temp at heat source >35°C



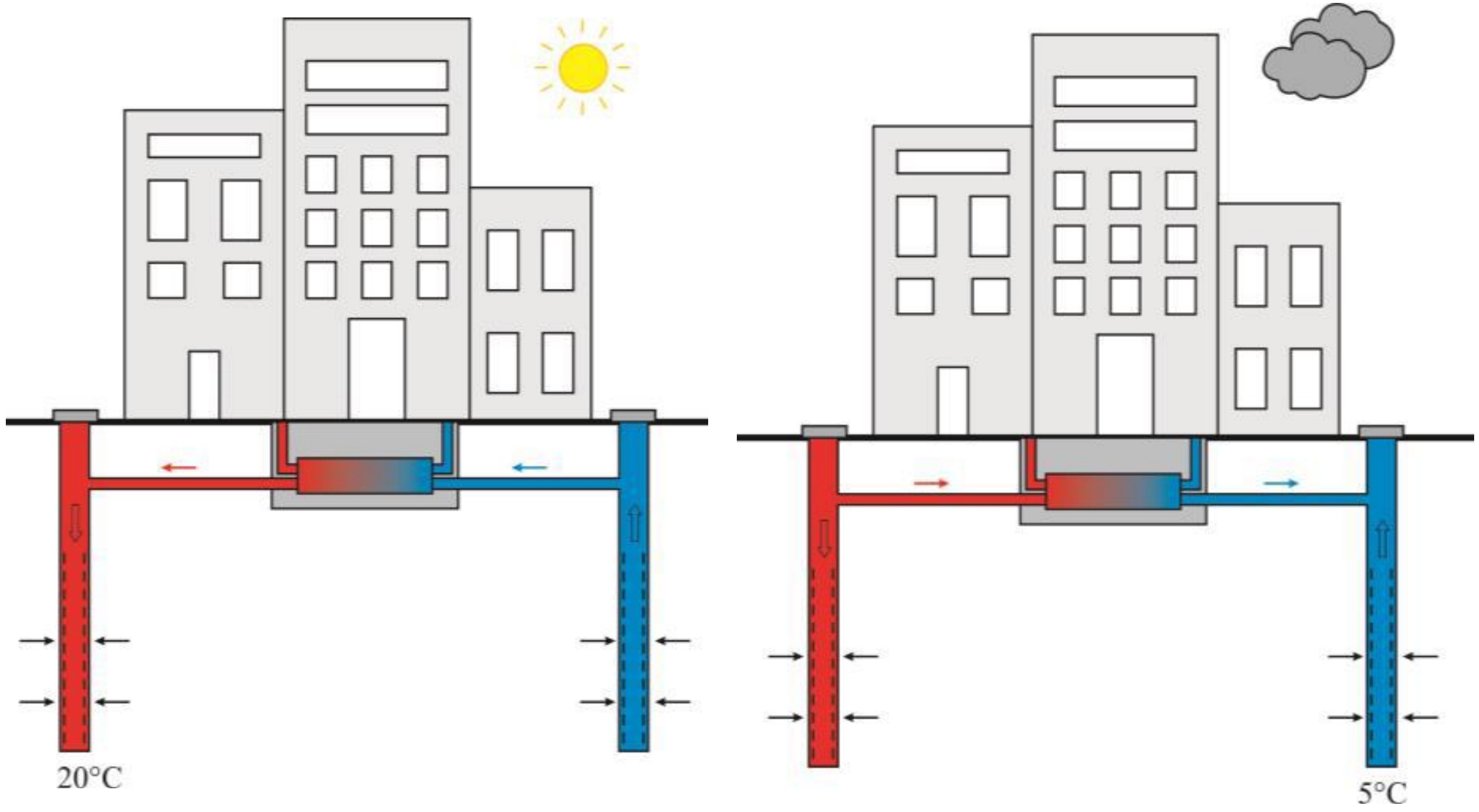
Low Energy Cooling Technologies – Ground and Aquifer Cooling

Unfavourable Factors

- Rock / Solid ground
- Need RH control
- Slow response time

Favourable Factors

- If ground temp below 12°C
- Use earth as sink, possible to use soil above
- Flowing water may help



Source: Schüppler, S., Fleuchaus, P., & Blum, P. (2019). Techno-economic and Environmental Analysis of an aquifer thermal energy storage (ATES) in Germany. Geothermal Energy, 7(1). https://doi.org/10.1186/s40517-019-0127-6

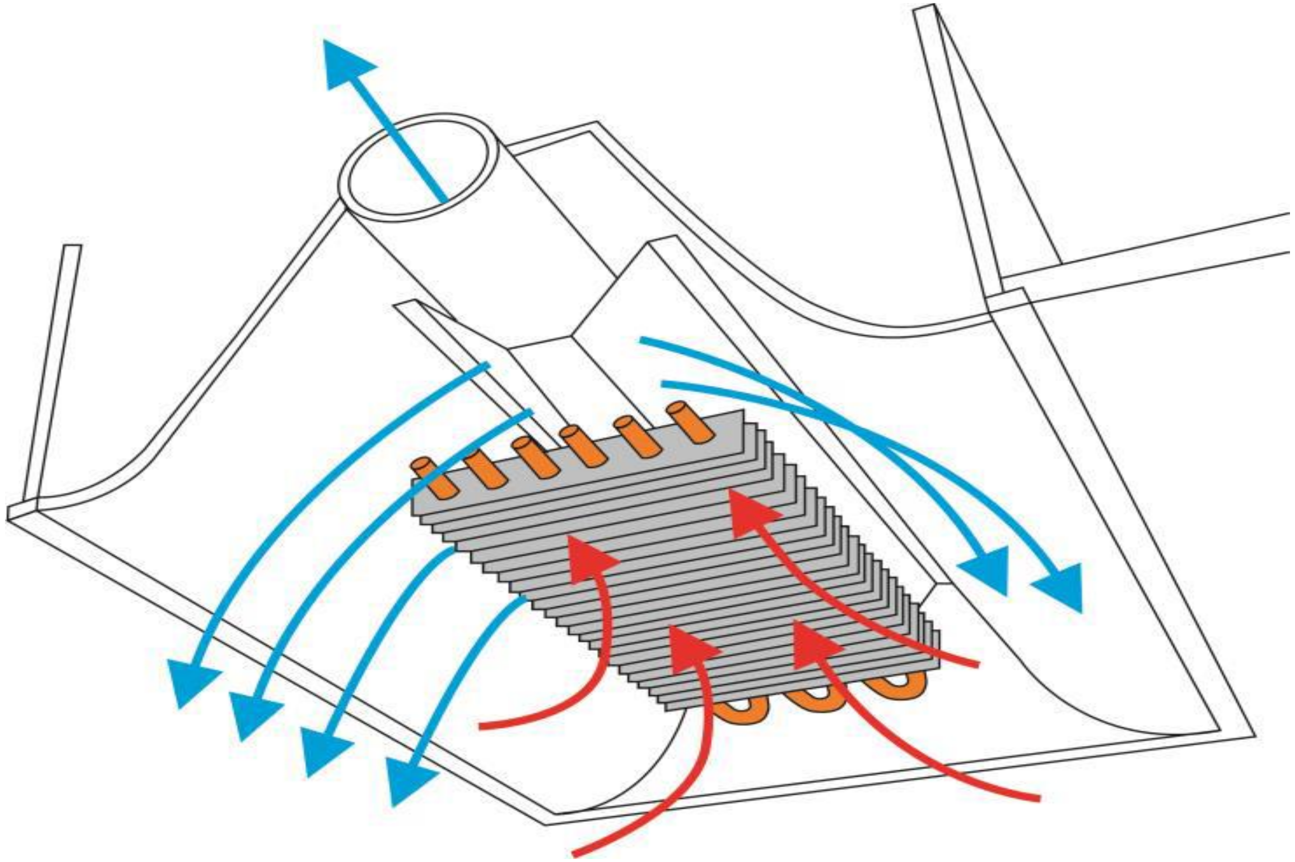
Low Energy Cooling Technologies – Chilled Ceiling and Beams

Unfavourable Factors

- Dew Point temperature needs control
- Needs air exchange systems
- Latent load management

Favourable Factors

- Low energy
- Highly efficient
- Can manage sensible loads well



Source: Source: Ehrlich, B. (2010, March 31). Active Chilled Beams: Saving Energy and Space. Retrieved from https://www.buildinggreen.com/product review/active chilled beams saving energy and space

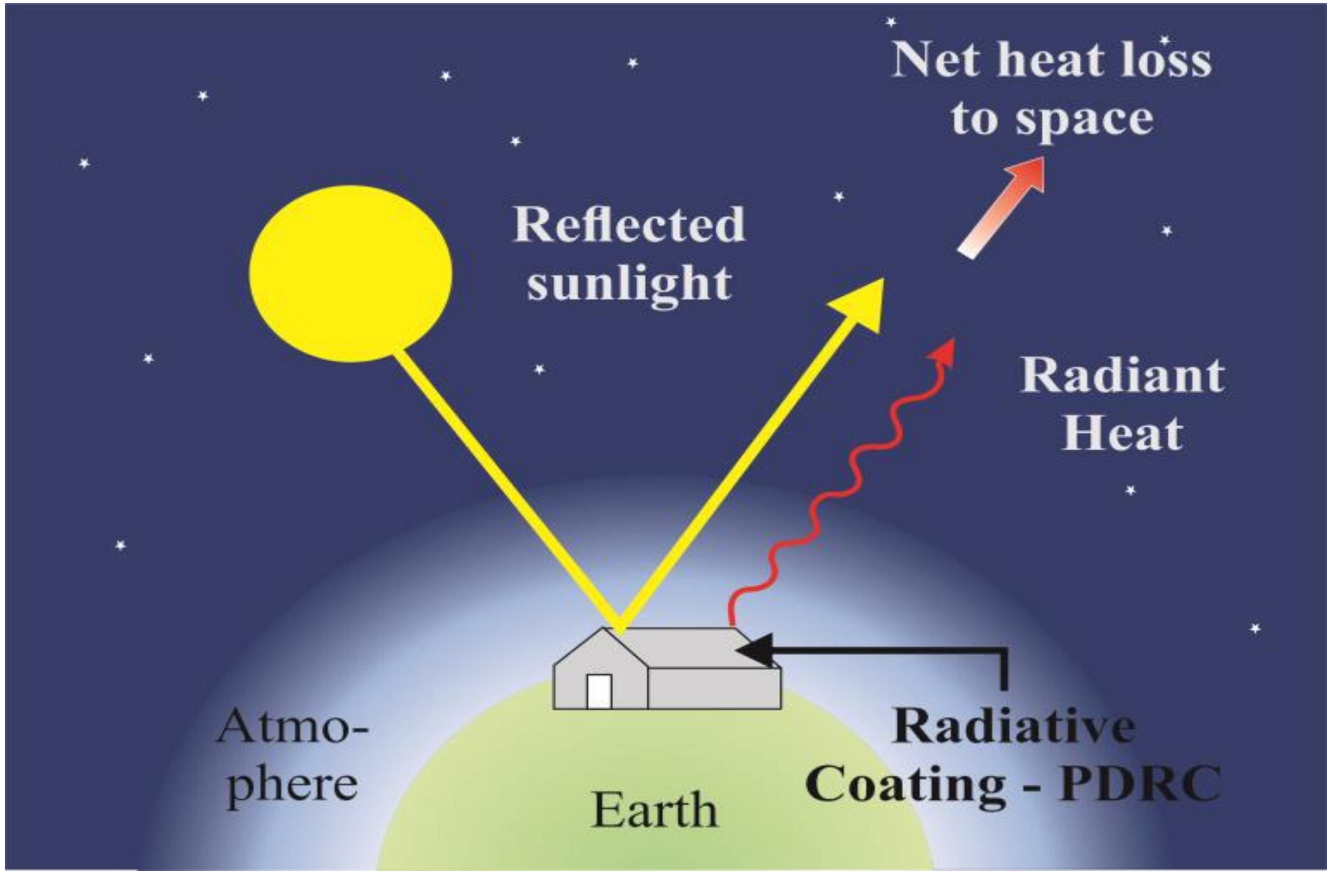
Low Energy Cooling Technologies – Radiative Cooling

Unfavourable Factors

- Sky view factor
- Pollution and PM in the air
- Heat Gain and losses should be calculated

Favourable Factors

- Heat Transfer through radiation is efficient
- Deep Sky is a heat sink
- Manage sensible loads very well



Source: Source: Yang, Y., & Zhang, Y. (2020). Passive daytime radiative cooling: Principle, application, and economic analysis. MRS Energy & Sustainability, 7(1). https://doi.org/10.1557/mre.2020.18

18

Rating Steps & Standards

Steps for Rating as per Standards

1. Measurement of DBT, WBT, Pressure
2. Derivation of Enthalpy, Sp. Vol., Rel. Humidity (using Psychometric tables)
3. Calculation of Flow Rate of Air
4. Determining Total Cooling Capacity
5. Calculating Sensible Cooling Capacity
6. Latent Cooling Capacity = Total Cooling Capacity – Sensible Cooling Capacity
7. Calculation of Dehumidification Capacity
8. Determination of EER for the test Unit

Low Energy Key Reference Standards

Standard – AHRI 340/360	• Performance testing of commercial and industrial unitary air conditioning and heat pump equipment (up to 65, 000 Btu/h)
Standard – ASHRAE 37	• Performance testing of electricity driven unitary air conditioning equipment (less than 65, 000 Btu/h)
Standard – ASHRAE 116	• Determining seasonal efficiency of unitary air conditioning equipment
Standard – ASHRAE 16	• Performance testing of room air conditioners and packaged terminal units
Standard – IS 1391-1	• Performance testing of room air conditioners – unitary air conditioners (from 6, 000 Btu/h to 35, 000 Btu/h)
Standard – IS 1391-2	• Performance testing of room air conditioners – split air conditioners (from 12, 000 Btu/h to 35, 000 Btu/h)
Standard – AHRI 1230	• Performance testing of variable refrigerant systems (VRF) and heat pump equipment (from 12, 000 Btu/h to 65, 000 Btu/h)
Standard – AHRI 210/ 240	• Performance testing of unitary air conditioning and heat pump equipment (capacities less than 65, 000 Btu/h)

19

Case Studies

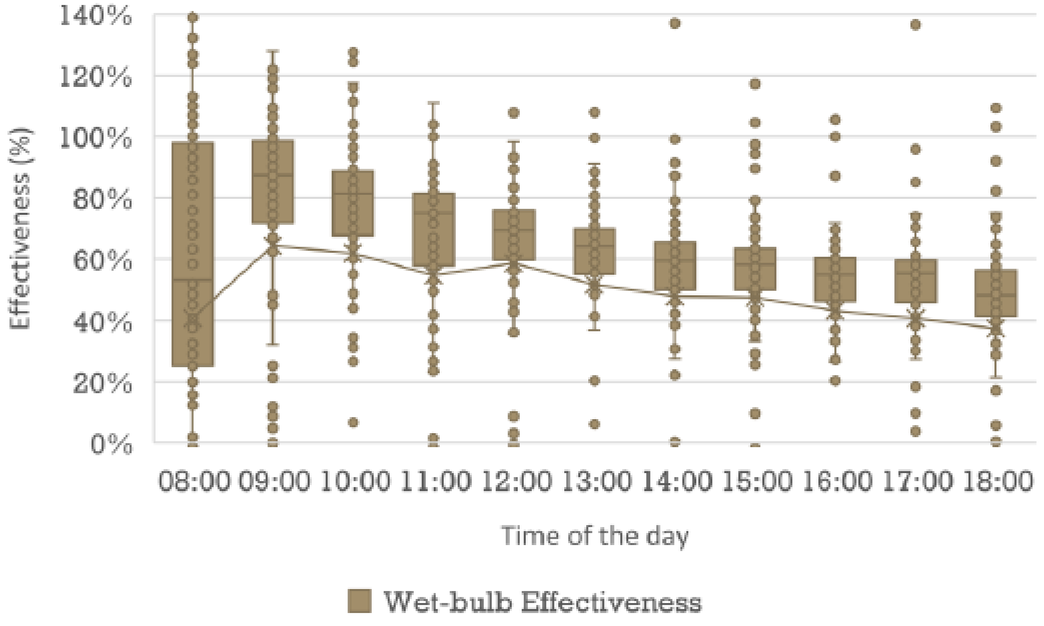
Case Studies

Location: Nadiad, Gujarat
System type: 1 DECs & 1 IDECs
System Capacity: 30,000 CFM

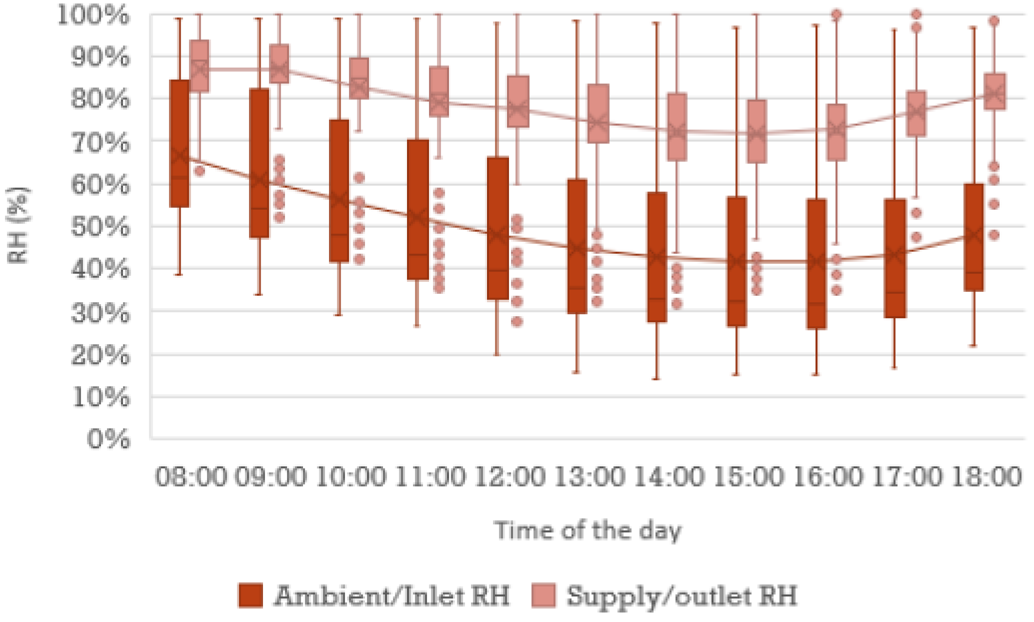
Location: Ahmedabad, Gujarat
System type: 4 – DECs
System Capacity: 30,000 CFM

Location: Gandhinagar, Gujarat
System type: 2 DECs & 1 PDECs
System Capacity: 20,000 CFM

Results of Case Study 1



Graph showing outside and inside DBT range from July to Dec for operating hours



Graph showing outside and inside RH range from July to Dec for operating hours

A maximum Delta-T of 5-6 °C and Delta-RH of 30-35% is observed from 12:00 to 6:00 PM.

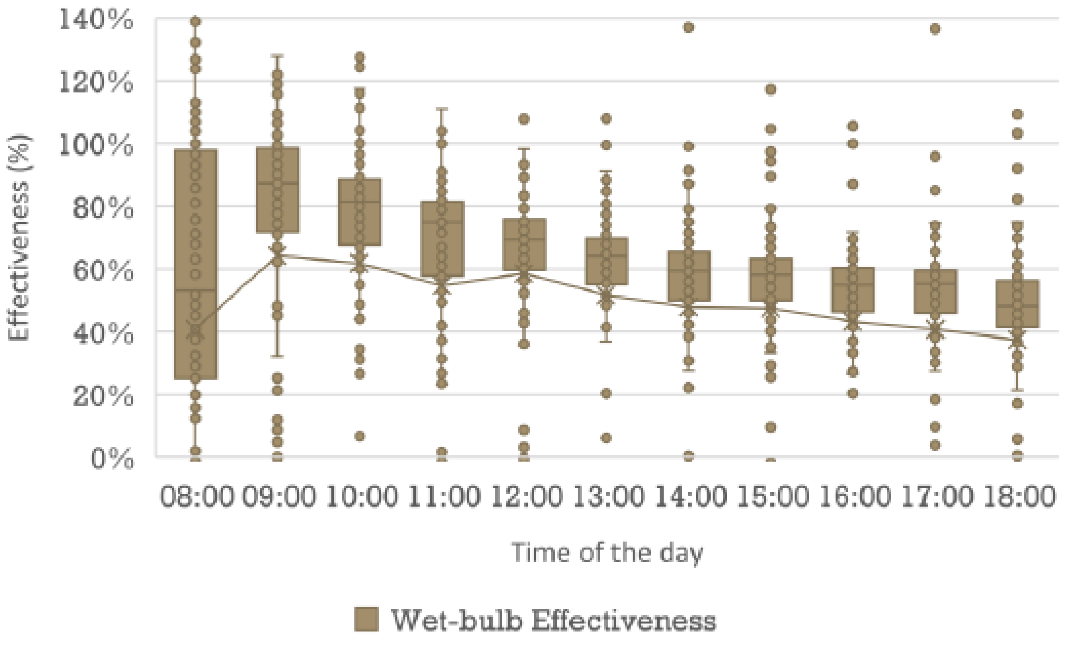
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

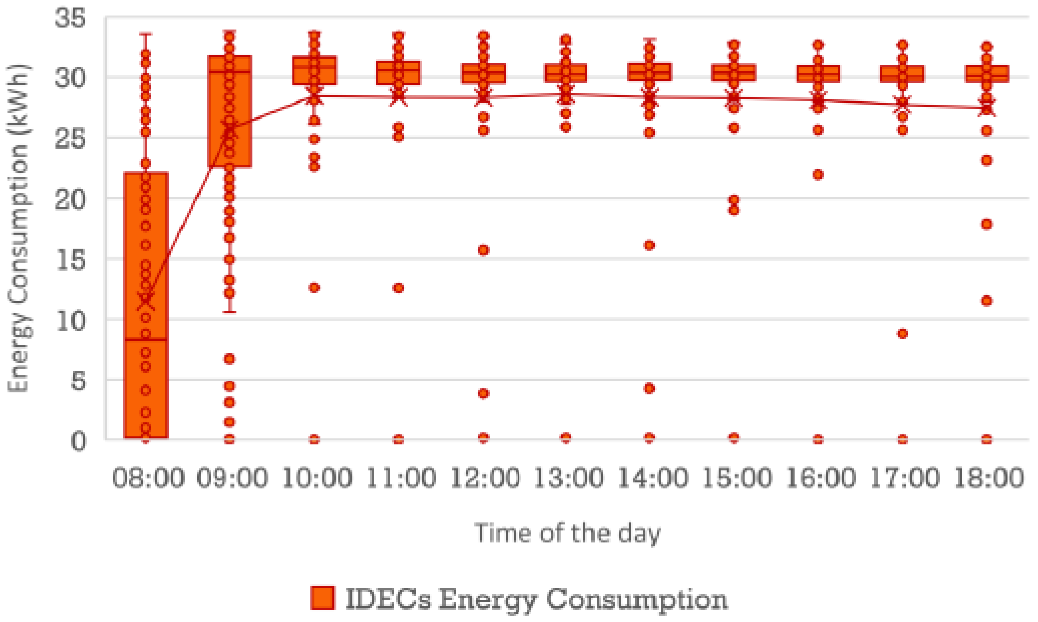
Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

Results of Case Study 1



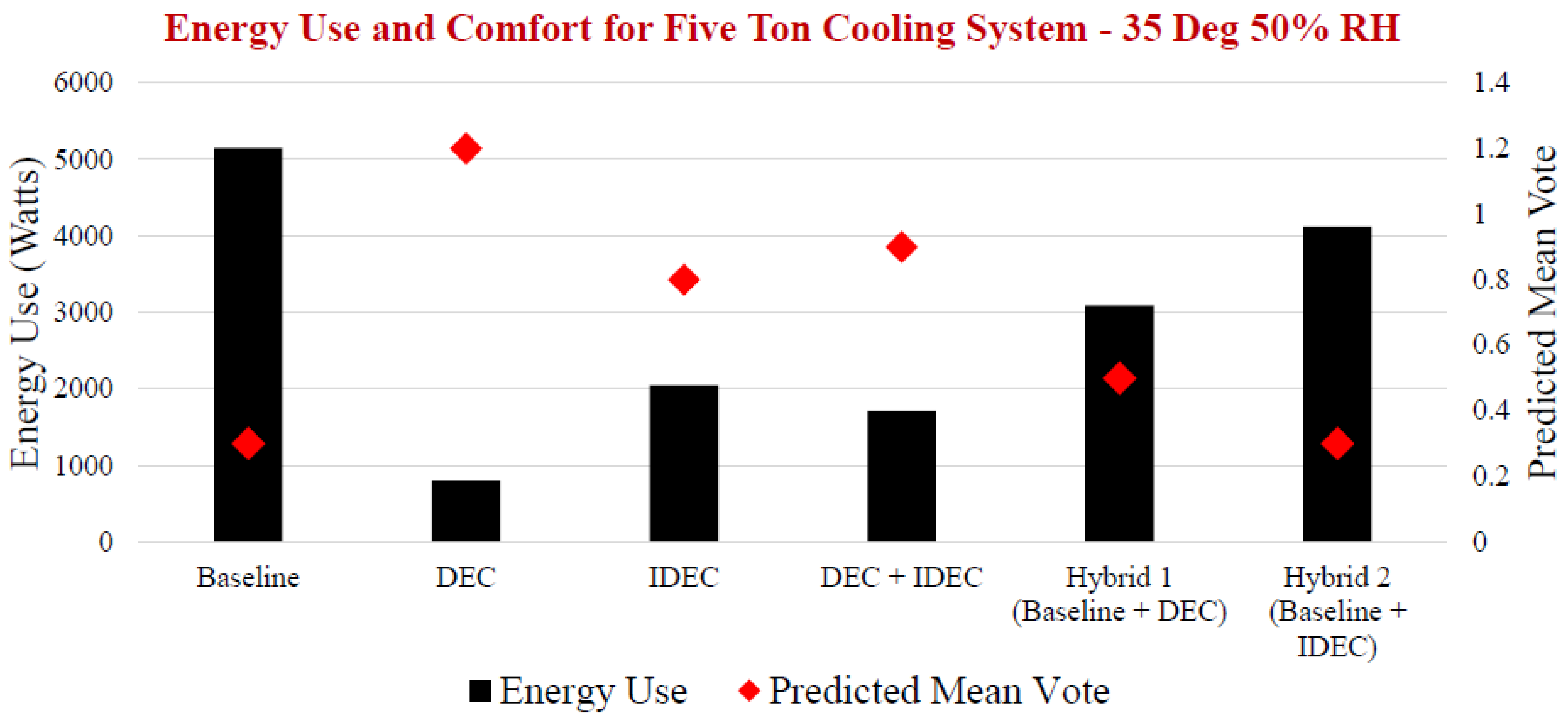
Graph showing Wet Bulb Effectiveness range from July to Dec for operating hours



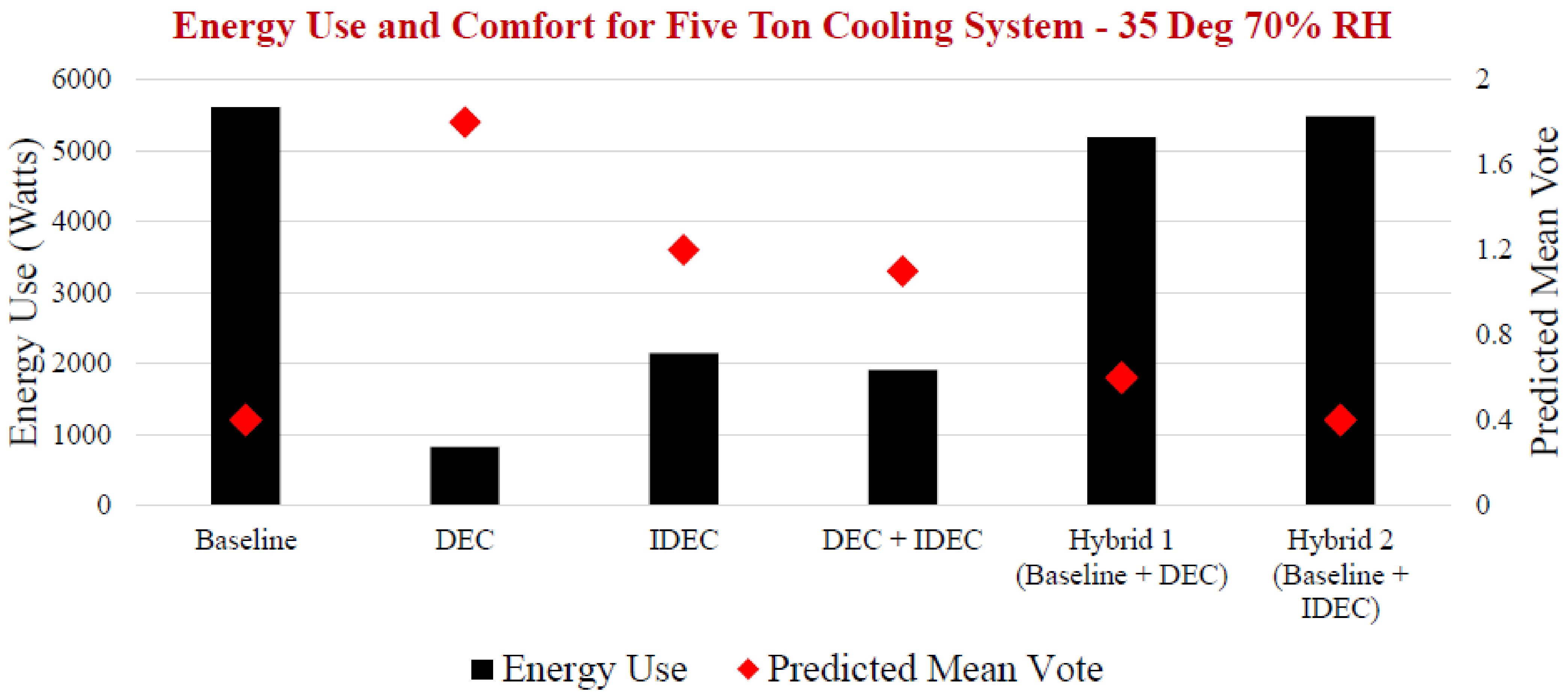
Graph showing energy consumption range from July to Dec for operating hours

The system is taking around one hour for stabilization. Energy consumption varies from 30-33 kWh, whereas the WBE varies from 25-100%.

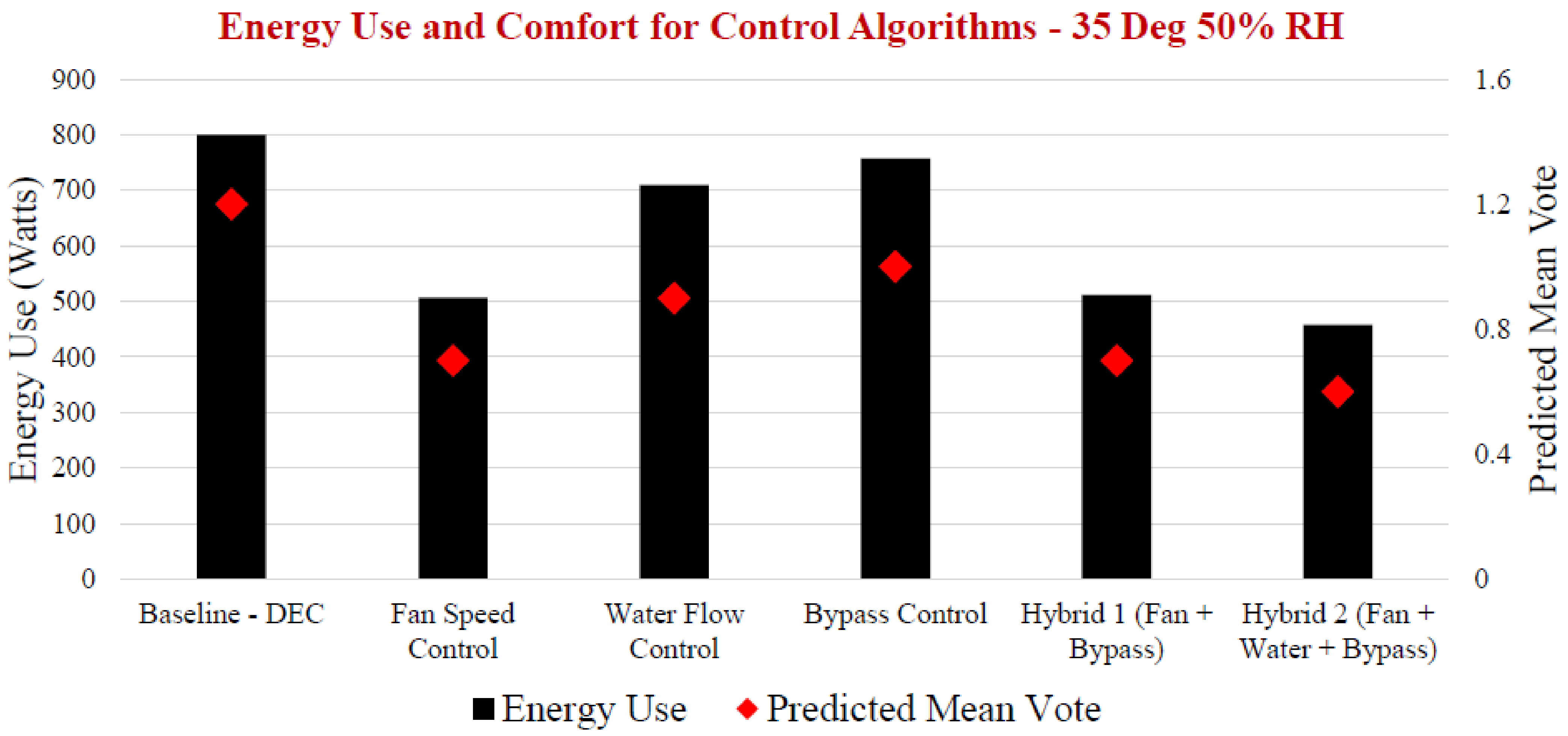
Results of Comparative Study: Hot Dry Climate



Results of Comparative Study: Hot Dry Climate



Results of Comparative Study: Hot Dry Climate



Results of Comparative Study: Conclusion

Smart control algorithms reduce energy use by 10 - 25% compared to current operational practices

- Comparison is performed with on/off low energy cooling systems
- Fan speed modulation significantly reduces power consumption especially when cooling needs in the space are low

Smart control increases comfort by 0.5 to 1.0 PMV

- Increased air velocity in the space further improves heat loss
- Maintains sensible heat dissipation of Manikin but needs to avoid the draft
- Humidity control of low energy cooling system is effective

Hybrid systems reduce energy consumption by 30 - 40% due to capacity reduction of the baseline system and maintain comfort throughout the year

- Smart control algorithms very suitable for control of hybrid systems

DAY 2

Lunch Break

DAY 2

Session 7: Building Codes

20

Building Codes - IMAC & ASHRAE

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

Building Ventilation Type

- Naturally Ventilated (NV)
- Mixed Mode (MM)
- Air Conditioned (A/C)

IMAC – Indian Model for Adaptive Comfort

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

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

IMAC – Indian Model for Adaptive Comfort

Naturally Ventilated Buildings

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

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

Acceptability range for naturally ventilated buildings is ±2.38°C

IMAC – Indian Model for Adaptive Comfort

Mixed Mode Ventilated Buildings

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

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

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

IMAC – Indian Model for Adaptive Comfort

AC Buildings – Air Temperature based Approach

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

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

ASHRAE 55

Human Comfort Range

Most Humans are comfortable under this conditions

- **Winters**
  - 68°F to 76°F
  - 60% to 30% RH
- **Summer**
  - 74°F to 80°F
  - 60% to 30% RH

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.

General Requirements & Standard Conditions of ASHRAE 55

The standards and conditions that must be completed in order to comply with ASHRAE 55 are defined in sections 4 and 5. The criterion must be applied to the specific space being evaluated, the inhabitants who will be inhabiting the area, locations within that space if not the entire space, and any outlier occupants, according to general requirements (i.e., children, disabled persons, elderly persons, etc.).

Because satisfying everyone in a given place is impossible owing to unknown differences, the mandatory requirements that must be met to comply with ASHRAE standard 55 exist in a range of values (physiologically and psychologically). As a result, ASHRAE 55 specifies a certain percentage of occupants as acceptable, as well as the thermal environment values associated with that number.

Needed Thermal Comfort Compliance Documentation

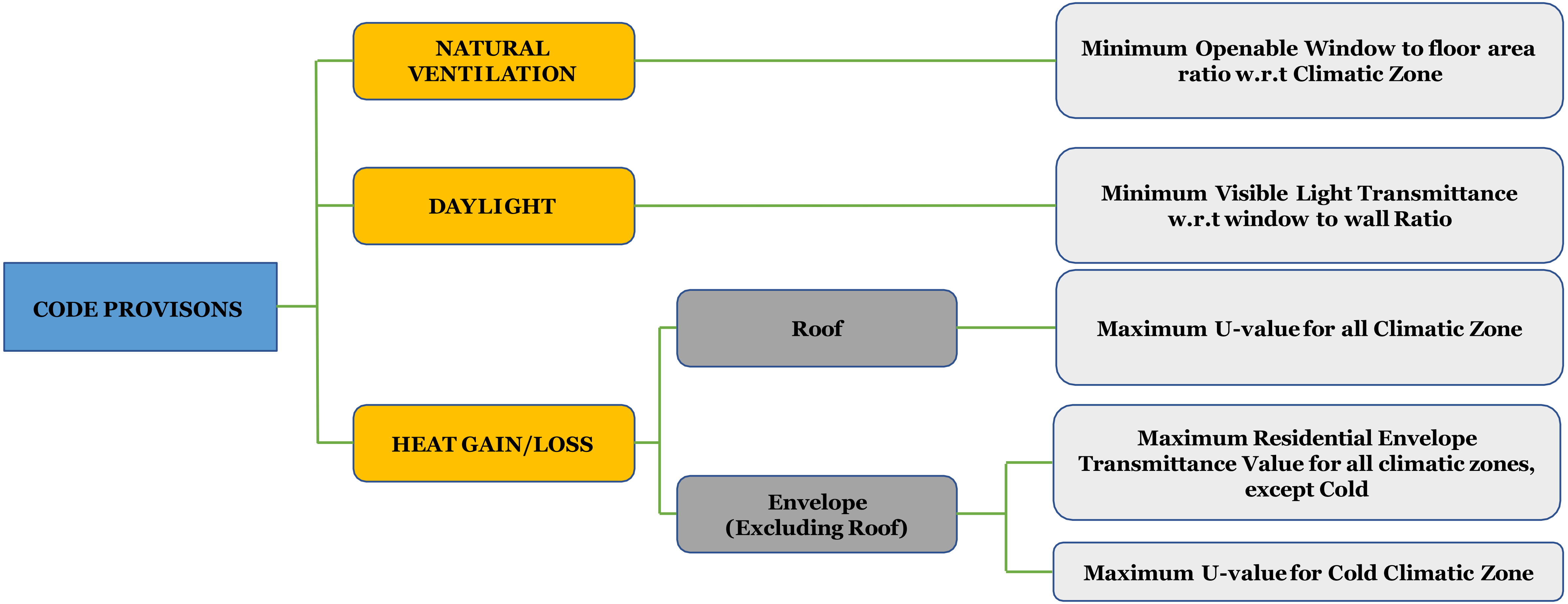
Except in the case of naturally ventilated areas, all of the following documentation is required to comply with ASHRAE:

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.

21

Building Codes – Eco Niwas Samhita 2018 & 2021 and Code Provisions

Code Provisions by Eco Niwas Samitha for Thermal Comfort in Affordable Housing



SR.NO.	CODE PROVISONS
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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

Openable window to floor area ratio (wfr):

EQUATION FOR WFR

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

Where,

WFR	Openable Window to Floor Area Ratio
$A_{Openable}$	Openable area (m^2); 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_{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

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.

EQUATION FOR VLT

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

VISIBLE LIGHT TRANSMITTANCE (VLT):

MINIMUM VISIBLE LIGHT TRASNSMITTANCE (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

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building. Limiting the U_{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_{roof} value of 1.2 W/m² K.

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

EQUATION FOR U_{roof}:

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

U_{roof}	**Thermal Transmittance of Roof (W/M².K)**
A_{roof}	Total Area of the Roof (m²)
U_i	Thermal Transmittance values of different roof constructions (W/m² .K)
A_i	Areas of different Roof Constructions (m²)

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

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/m² .

RETV formula takes into account the following:

- 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.)

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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

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

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

RETV EUQATIONS TERMS

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

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

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

- 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 $W/m^2.K$

EQUATION FOR $U_{envelope,cold}$:

$$U_{envelope,cold} = \frac{1}{A_{envelope}} \sigma_{i=1}^{n}(Ui \times Ai)$$

$U_{envelope,cold}$	**thermal transmittance of building envelope (except roof) for cold climate ($W/m^2.K$)**
$A_{envelope}$	envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors)
U_i	thermal transmittance of different opaque and non-opaque building envelope components ($W/m^2.K$)
A_i	area of different opaque and non-opaque opaque building envelope components (m^2)

Eco – Niwas Samhita 2021 Scope

The Code Applies to

Residential buildings built on a plot area of ≥ 500 m²

Residential part of ***Mixed land-use building*** projects, built on a plot area of ≥ 500 m².

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

Prescriptive Method

Compliance Mandatory +

Point System Method

Additional Score

- Minimum Points
- Additional Points
- 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

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	

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

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

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

Affordable Housing Projects:
- for Affordable houses 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 Based System

POINT BASED SYSTEM

- ANNUAL EPI
- ANNUAL EPI NORMALISE BY SERVICE LIFE
- LIFE CYCLE COST

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

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%.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Prescriptive Method

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

Common Areas	Maximum LPD (W/m²)	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/m²)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

Prescriptive Method

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

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

Point System Method

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

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

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

Thermal Transmittance of Roof	
Minimum: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m2·K.	Up to 4 Points
Additional: 1 Point for every reduction of 0.23 W/m2·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).	Maximum 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/m2.	44 Points
For RETV less than 15 and upto 12 W/m2, score will be calculated by following equation: 74 – 2 x (RETV) (@ 2 points per RETV reduction)	Up to 50 Points
Additional: For RETV less than 12 and upto 6 W/m2, score will be calculated by following equation: 110 – 5 x (RETV) (@ 5 points per RETV reduction)	Up to 80 points
Additional: For RETV less than 6 W/m2	80 Points

Point System Method

2 – Common Area and Exterior Lighting (9 Points)

Common Areas	Maximum LPD (W/m²)	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/m²)
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

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

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

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

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

7 – Comfort Systems (50 Points) – Ceiling Fans

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

Point System Method

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

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

Point System Method

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

9 – Solar Photo Voltaic (10 Points)

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

22

ENS Compliance Tools

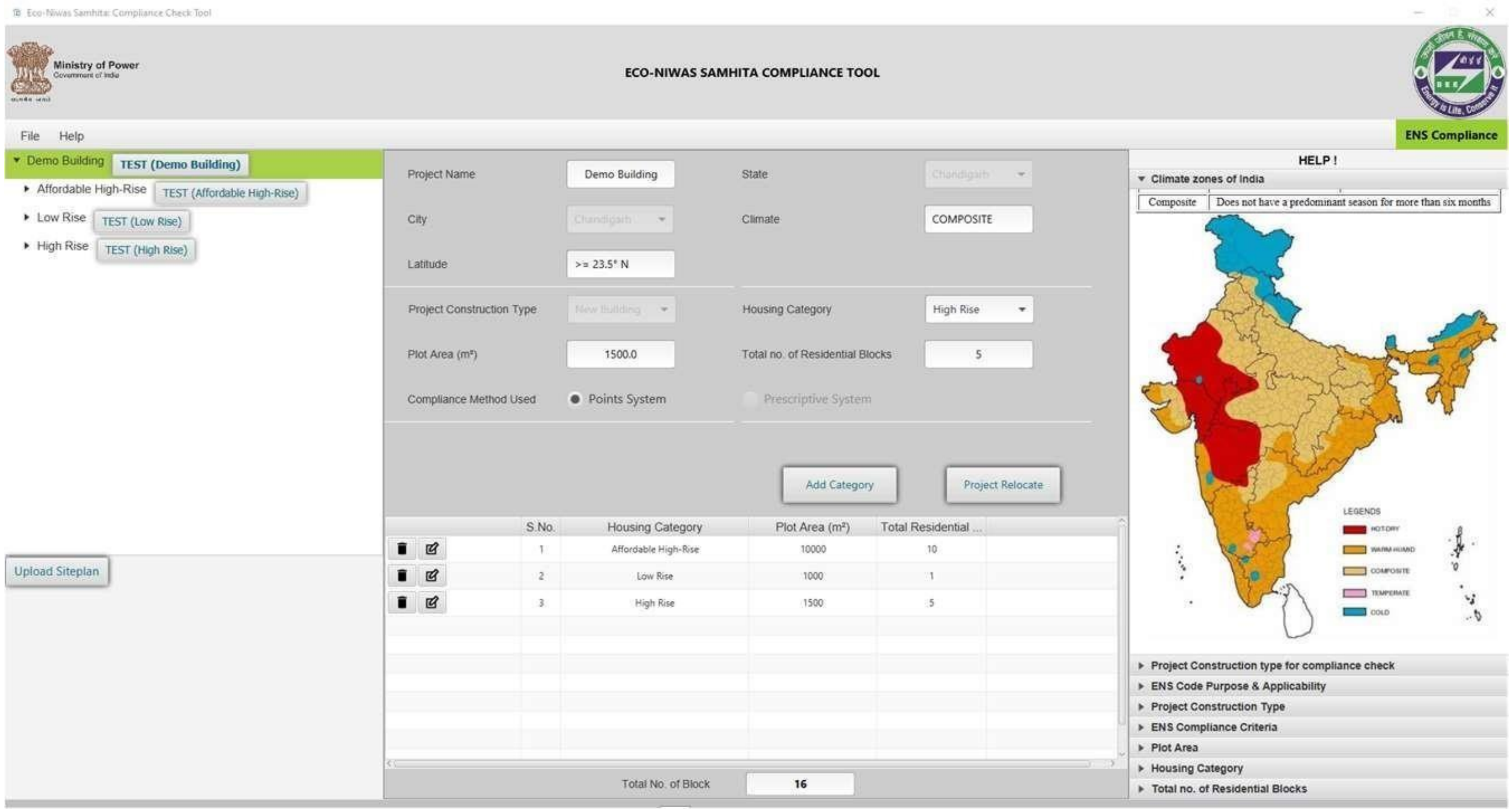
Introduction

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

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

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

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



ENS Compliance Tools Key Features

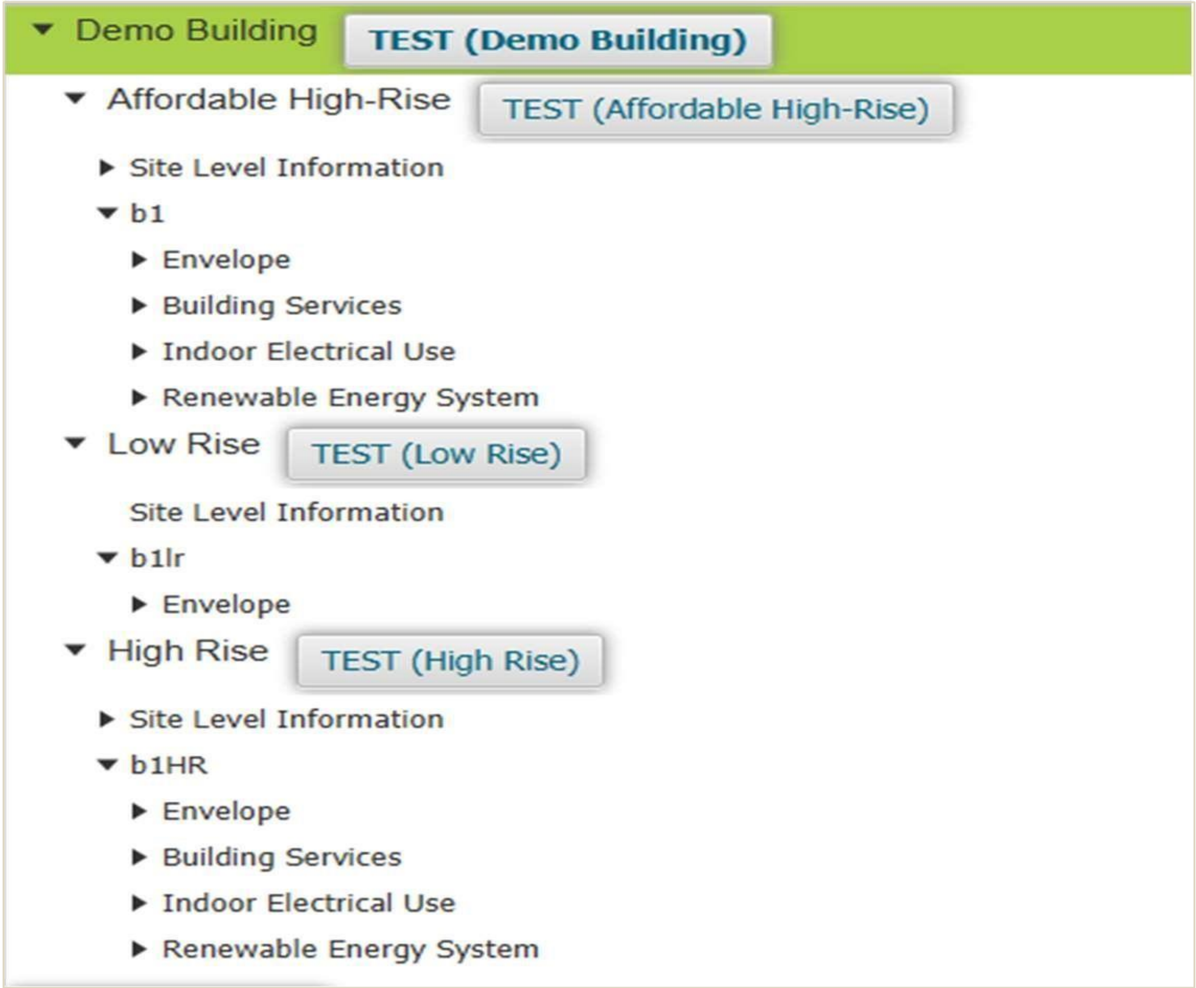
- Provisionsfor multiple housing category addition for compliance evaluation

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

Total No. of Block: 16

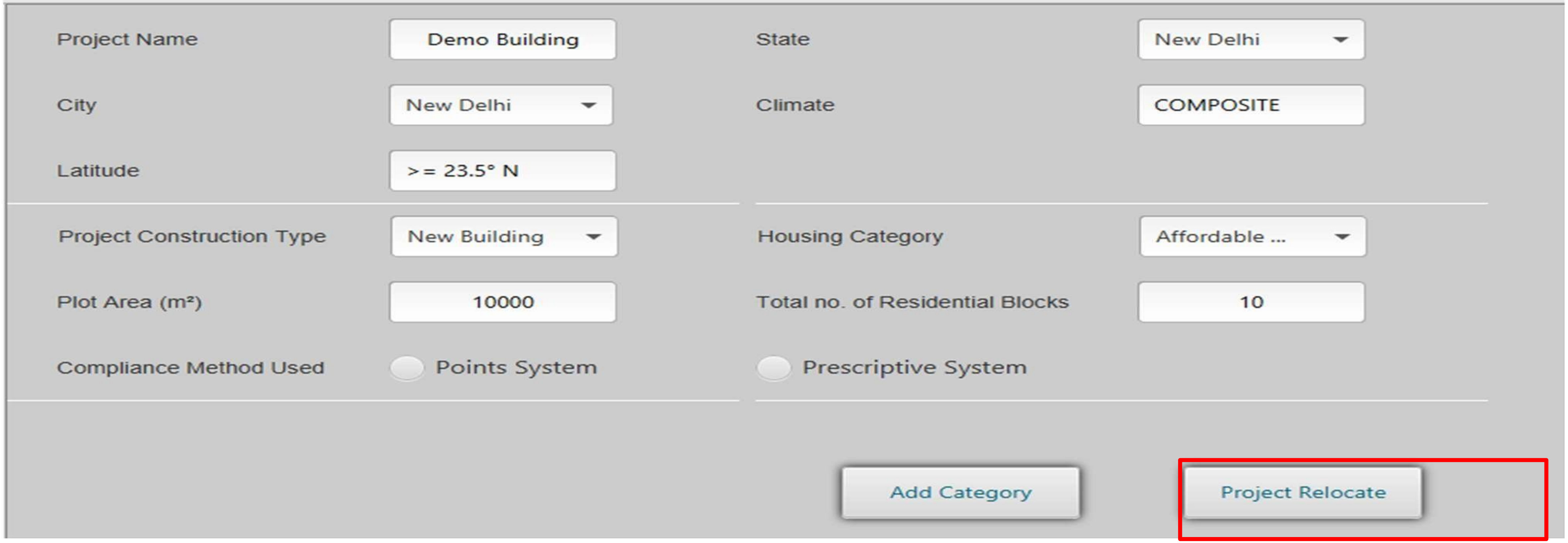
ENS Compliance Tools Key Features

- Easy to navigate tree-view structure



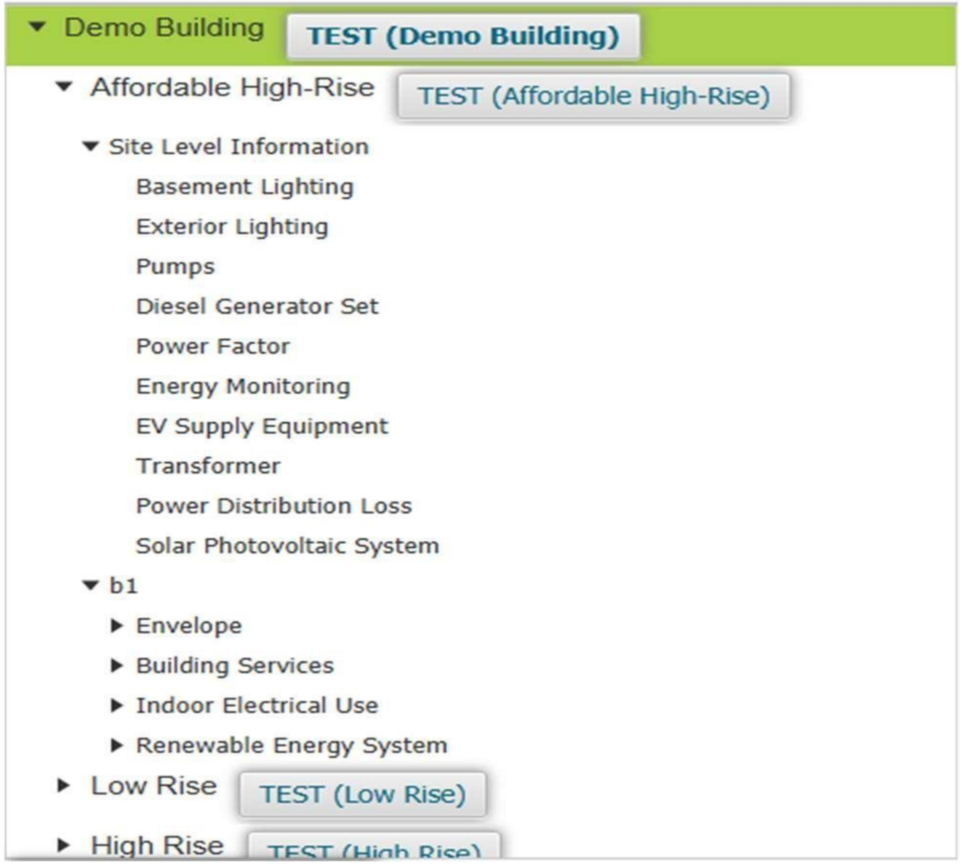
ENS Compliance Tools Key Features

- Project relocation feature for multiple domainuse

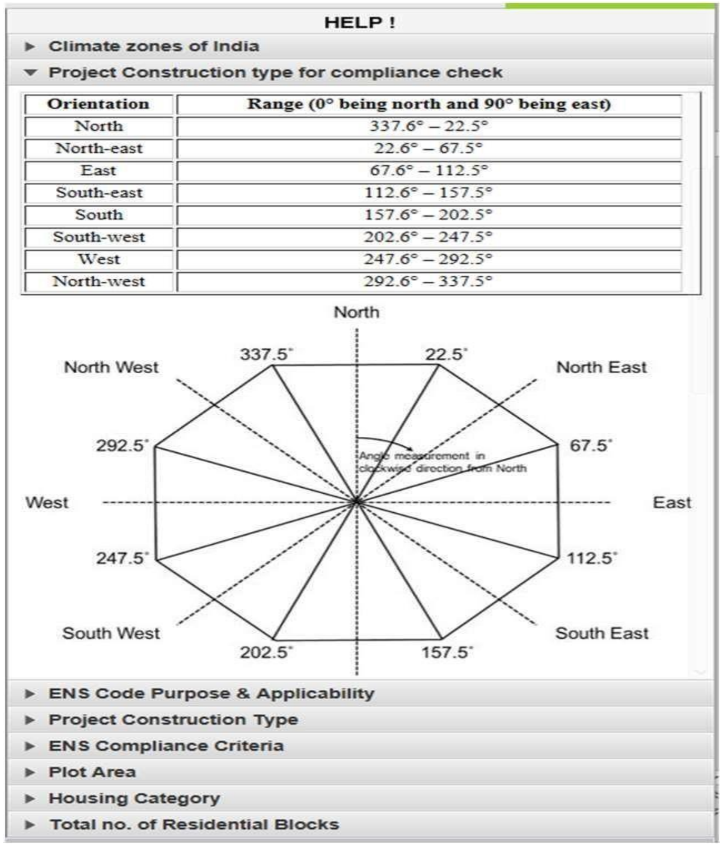


ENS Compliance Tools Key Features

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



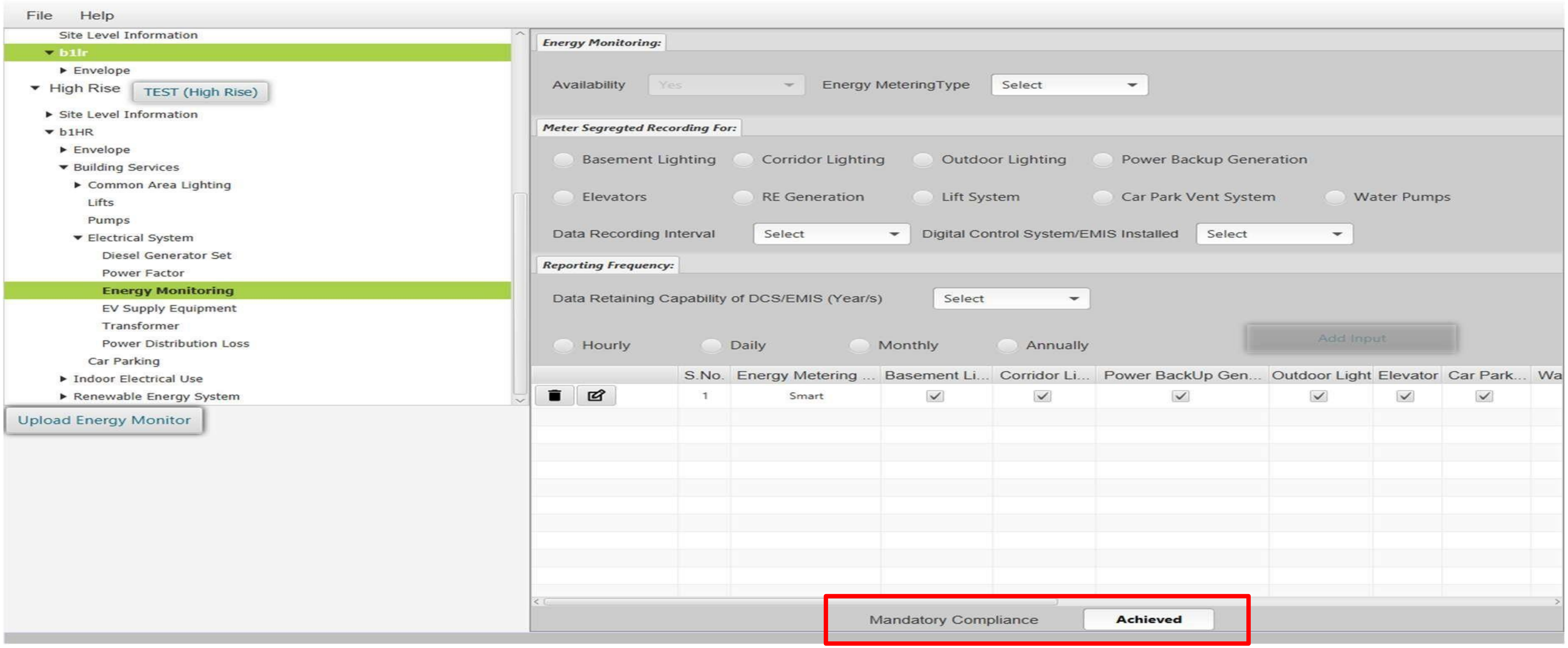
- Comprehensive help panel on each form for easy user referencing



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°

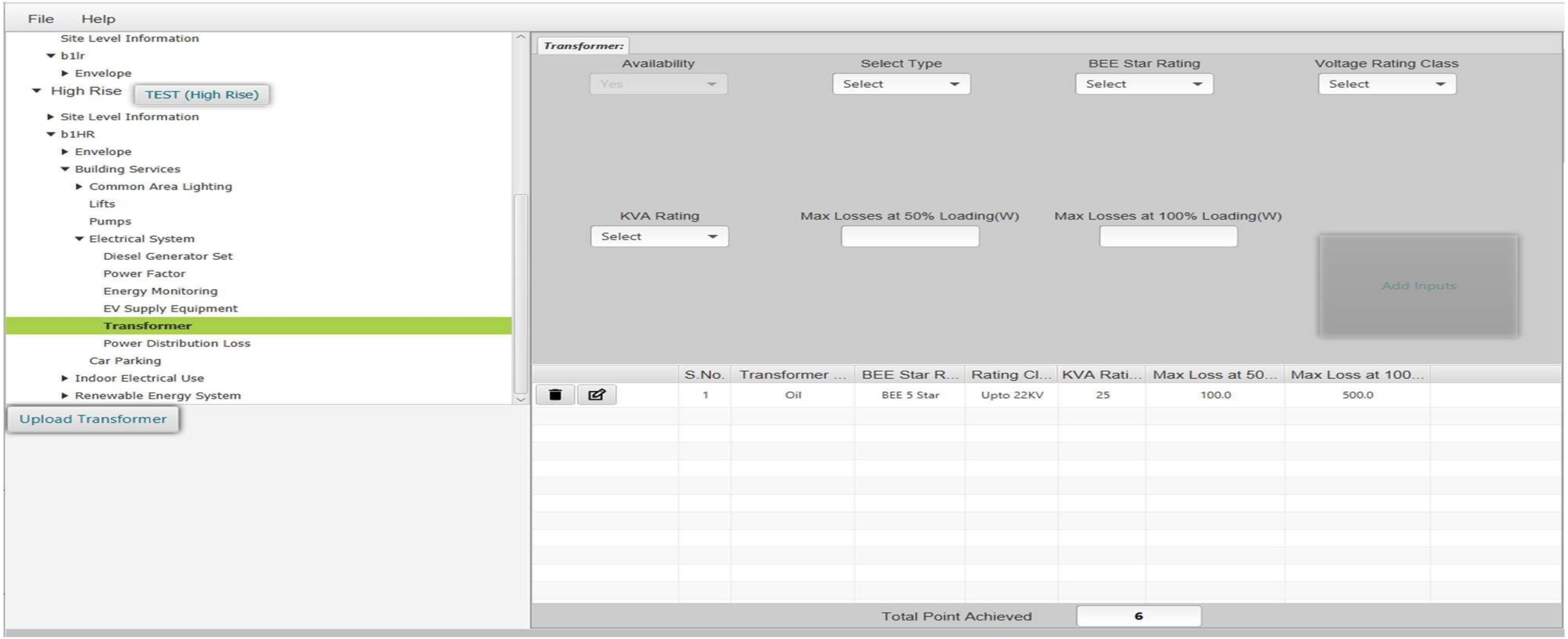
ENS Compliance Tools Key Features

- Component level display for mandatory provisions and pointsachieved



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

ENS Compliance Tools Key Features



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

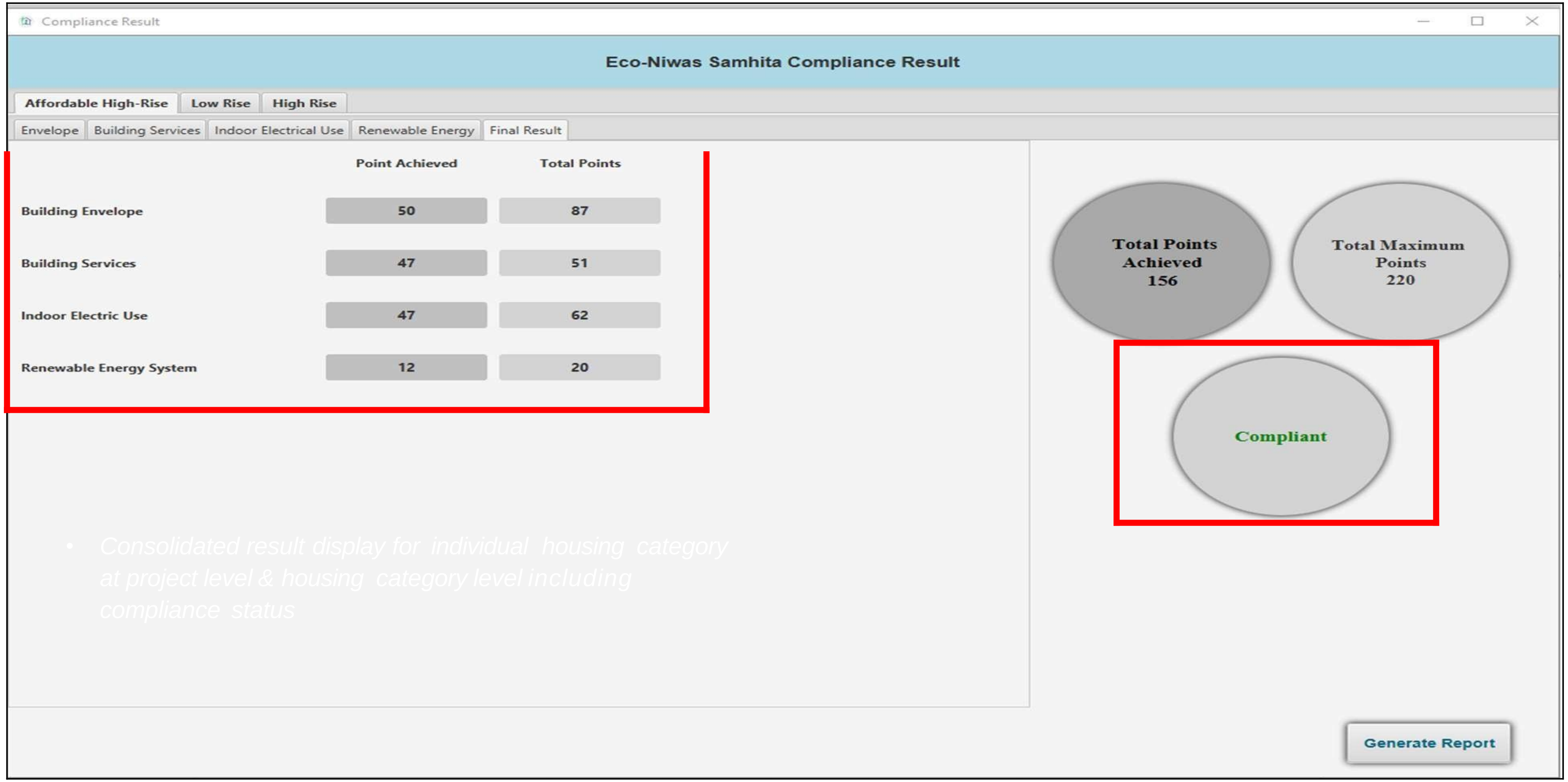
प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ENS Compliance Tools Key Features



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

ENS Compliance Tools Key Features

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

Eco-Niwas Samhita: Compliance Check Report

ECO-NIWAS SAMHITA (ENS) COMPLIANCE EVALUATION REPORT

Project Information

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

Housing Category Information

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

Eco-Niwas Samhita: Compliance Check Report

Consolidated Compliance Status of the Project:

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

Eco-Niwas Samhita: Compliance Check Report

1. Affordable High-Rise : Compliance Result

1.1. Building Envelope:

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

1.2. Building Services:

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

1.3. Indoor Electrical End Use:

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

1.4. Renewable Energy System:

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

DAY 2

Tea Break

DAY 2

Session 8: Green Building & Green Measures

23

Green Building & Green Measures

What is Green Building?

- A 'green' building is a building that, in its **design, construction or operation, reduces or eliminates negative impacts**, and **can create positive impacts**, on our climate and natural environment.
- Green buildings preserve precious natural resources and improve our quality of life.

The Benefits

Environmental Benefits

- Protect Biodiversity & ecosystems
- Improve air and water quality
- Reduce Water streams
- Conserve natural resources

Economic Benefits

- Reduce operating cost
- Tax incentives and subsidies for green buildings and renewable energy concepts
- Create, expand and shape markets for green product and services
- Improve Occupant Productivity

Social Benefits

- Enhance occupant comfort & health
- Heighten aesthetic qualities
- Minimize strain on local infrastructure
- Improve overall quality of life

Green buildings & the Sustainable Development Goals

Goals of Green Buildings

Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of buildings on the environment and human health.

It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off.

Many other techniques, such as using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water, are used as well. While the practices, or technologies, employed in green building are constantly evolving and may differ from region to region, there are fundamental principles that persist from which the method is derived:

Goals of Green Buildings

- Life Cycle Assessment (LCA)
- Setting & Structure define efficiency
- Energy Efficiency
- Water Efficiency
- Material Efficiency
- Waste Reduction

Life Cycle Assessment (LCA)

LCA can help avoid a narrow outlook on

Concerns:
- Environmental
- Social
- Economic

- extraction of raw materials through materials processing
- Manufacture
- Distribution
- Use
- Repair & Maintenance
- Disposal or recycling

by assessing a full range of impacts associated with all the stages of a process from cradle-to-grave

Impacts taken into account include (among others)

- Embodied Energy
- Global Warming Potentials
- Resources Use
- Air Pollution
- Water Pollution
- Waste

Setting & Structure Design Efficiency

The foundation of any construction project is rooted in

Concept Stage

The concept stage, in fact, is one of the major steps in a project life cycle, as it has the largest impact on cost and performance. In designing environmentally optimal buildings, the objective is to minimize the total environmental impact associated with all life-cycle stages of the building project. However, building as a process is not as streamlined as an industrial process, and varies from one building to the other, never repeating itself identically

Design Stage

In addition, buildings are much more complex products, composed of a multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable may affect the environment during all the building's relevant life-cycle stages.

Energy Efficiency

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment

To reduce operating energy use, high-efficiency windows and insulation in walls, ceilings, and floors increase the efficiency of the building envelope, (the barrier between conditioned and unconditioned space). Another strategy, passive solar building design, is often implemented in low-energy homes

Designers orient windows and walls and place awnings, porches, and trees to shade windows and roofs during the summer while maximizing solar gain in the winter

In addition, effective window placement (day lighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs.

Water Efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself.

To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site.

The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing.

Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation.

Waste-water may be minimized

by utilizing water conserving fixtures such as

ultra-low flush toilets

low-flow shower heads.

Bidets help eliminate the use of

toilet paper

Reducing Sewer Traffic

increasing possibilities of re-using water on-site

The use of non-sewage and greywater for on-site use such as site-irrigation will minimize demands on the local aquifer.

Material Efficiency

Building materials

typically considered to be 'green' include

lumber from forests that have been certified to a third-party forest standard, rapidly renewable plant materials like

- bamboo and straw
- insulating concrete forms
- dimension stone,
- recycled stone
- recycled metal

and other products that are

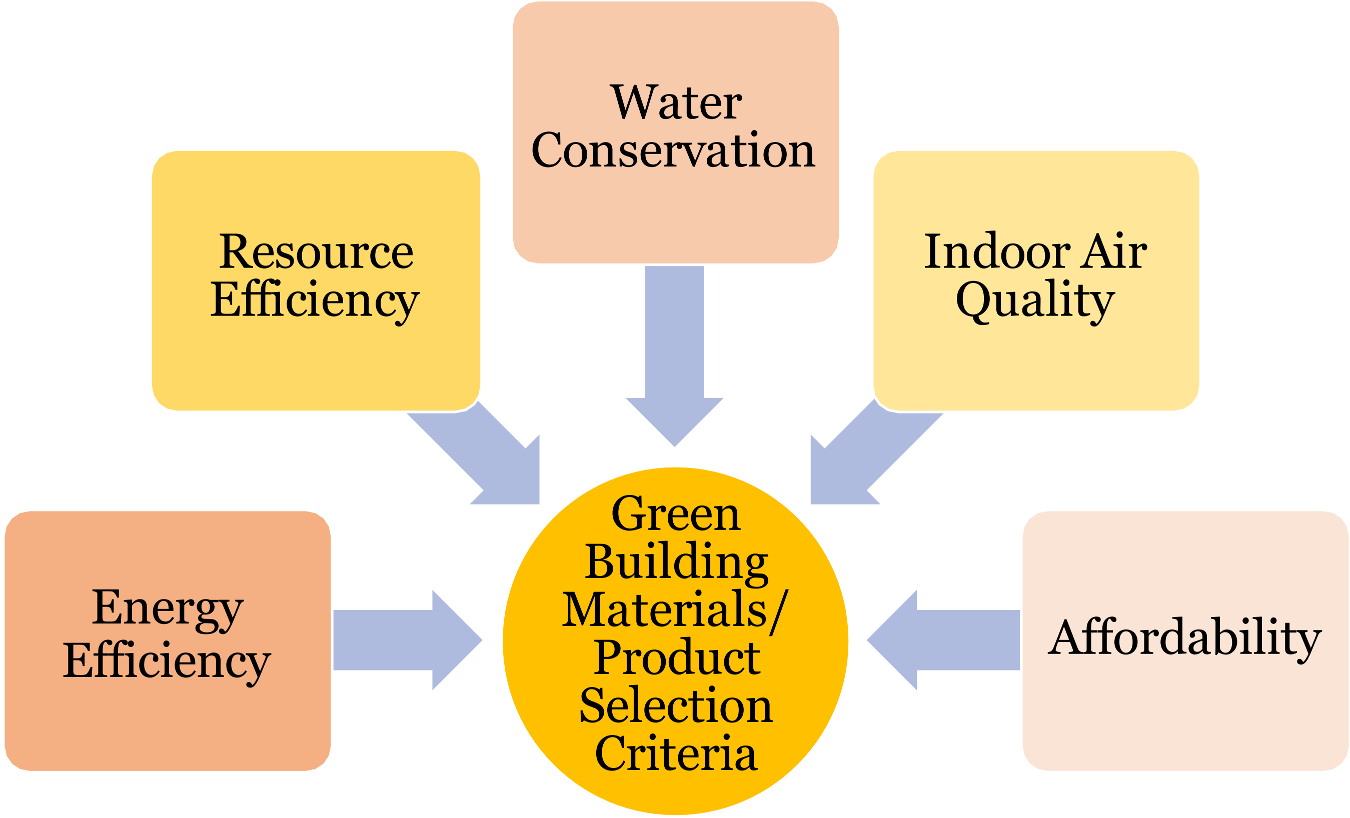
- Non Toxic
- reusable
- renewable, and/or recyclable

The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation

Where possible, building elements should be manufactured off-site and delivered to site, to maximize benefits of off-site manufacture including minimizing waste, maximizing recycling (because manufacture is in one location), high quality elements, better OHS management, less noise and dust.

Green Building Materials

Selection criteria like what is presented below was also used for the East End Project as identified in the Review of Construction Projects Using Sustainable Materials.



Green Building Materials - Resource Efficiency

Resource Efficiency

Recycled Content	Products with identifiable recycled content, including postindustrial content with a preference for post consumer content
Natural, plentiful or renewable	Materials harvested from sustainably managed sources and preferably have an independent certification (e.g., certified wood) and are certified by an independent third party
Resource efficient manufacturing process	Products manufactured with resource-efficient processes including reducing energy consumption, minimizing waste (recycled, recyclable and or source reduced product packaging), and reducing greenhouse gases.
Locally Available	Building materials, components, and systems found locally or regionally saving energy and resources in transportation to the project site.
Reusable or Recyclable	Select materials that can be easily dismantled and reused or recycled at the end of their useful life.
Recycle or Recyclable Product packaging	Products enclosed in recycled content or recyclable packaging.
Durable	Materials that are longer lasting or are comparable to conventional products with long life expectancies

Salvaged, refurbished, or remanufactured: Includes saving a material from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product

Green Building Materials - Indoor Air Quality (IAQ)

Indoor Air Quality (IAQ)

Low or non-toxic	Materials that emit few or no carcinogens, reproductive toxicants, or irritants as demonstrated by the manufacturer through appropriate testing.
Minimal Chemical Emission	Products that have minimal emissions of Volatile Organic Compounds (VOCs). Products that also maximize resource and energy efficiency while reducing chemical emissions
Low-VOC Assembly	Materials installed with minimal VOC-producing compounds, or no-VOC mechanical attachment methods and minimal hazards
Moisture Resistant	Products and systems that resist moisture or inhibit the growth of biological contaminants in buildings.
Healthfully maintained	Materials, components, and systems that require only simple, non-toxic, or low-VOC methods of cleaning
Systems or equipment	Products that promote healthy IAQ by identifying indoor air pollutants or enhancing the air quality.

Green Building Materials - Indoor Air Quality (IAQ)

Materials, components, and systems that help reduce energy consumption in buildings and facilities

Energy Efficiency can be maximized by utilizing materials and systems that meet the following criteria:

Water Conservation can be obtained by utilizing materials and systems that meet the following criteria:

Products and systems that help reduce water consumption in buildings and conserve water in landscaped areas

Affordability can be considered when building product life-cycle costs are comparable to conventional materials or, are within a project-defined percentage of the overall budget.

Green Building Materials – Three Basic Steps of Product Selection

Three Basic Steps of Product Selection

Research

This step involves gathering all technical information to be evaluated, including manufacturers' information such as Material Safety Data Sheets (MSDS), Indoor Air Quality (IAQ) test data, product warranties, source material characteristics, recycled content data, environmental statements, and durability information

In addition, this step may involve researching other environmental issues, building codes, government regulations, building industry articles, model green building product specifications, and other sources of product data. Research helps identify the full range of the project's building material options.

Evaluation

This step involves confirmation of the technical information, as well as filling in information gaps. For example, the evaluator may request product certifications from manufacturers to help sort out possible exaggerated environmental product claims.

Evaluation and assessment is relatively simple when comparing similar types of building materials using the environmental criteria, e.g., a recycled content assessment between various manufacturers of medium density fiberboard is a relatively straightforward "apples to apples" comparison

However, the evaluation process is more complex when comparing different products with the same function. Then it may become necessary to process both descriptive and quantitative forms of data.

Selection

This step often involves the use of an evaluation matrix for scoring the project-specific environmental criteria. The total score of each product evaluation will indicate the product with the highest environmental attributes. Individual criteria included in the rating system can be weighted to accommodate project-specific goals and objectives

Materials are the stuff of economic life in our industrial world. They include the resource inputs and the product outputs of industrial production. How we handle them is a major determinant of real economic efficiency, and also has a major impact on our health and the health of the natural environment

Green Building Materials – Elements of Material Solutions in Building

Elements of Material Solutions in Buildings

Element	Description
Materials use avoidance	this includes scrutiny of consumption needs themselves—do we really need to build this?—and voluntary simplicity. It includes a focus on selling services, rather than products. It also includes the redesign of products, buildings and settlements to dispense with superfluous materials. The great efficiencies resulting from ecological urban design and mixed use development are in this category.
Increased intensity of product use	All kinds of sharing are included here, and thus there is some overlap with category #1. Cohousing developments with shared facilities, for example, can substantially reduce the volume of materials use.
Extended Product Life	Repair, reuse and remanufacturing are in this category, and in building there is vast potential for deconstruction (the disassembly of buildings) and the reuse of building materials. One step further is the design of buildings to be easily changed, repaired and disassembled.
Materials recovery or recycling	This tends to require more energy, but some form of recycling will be ultimately necessary for every material at a point in its life cycle, no matter how durable, reused, or shared it has been.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

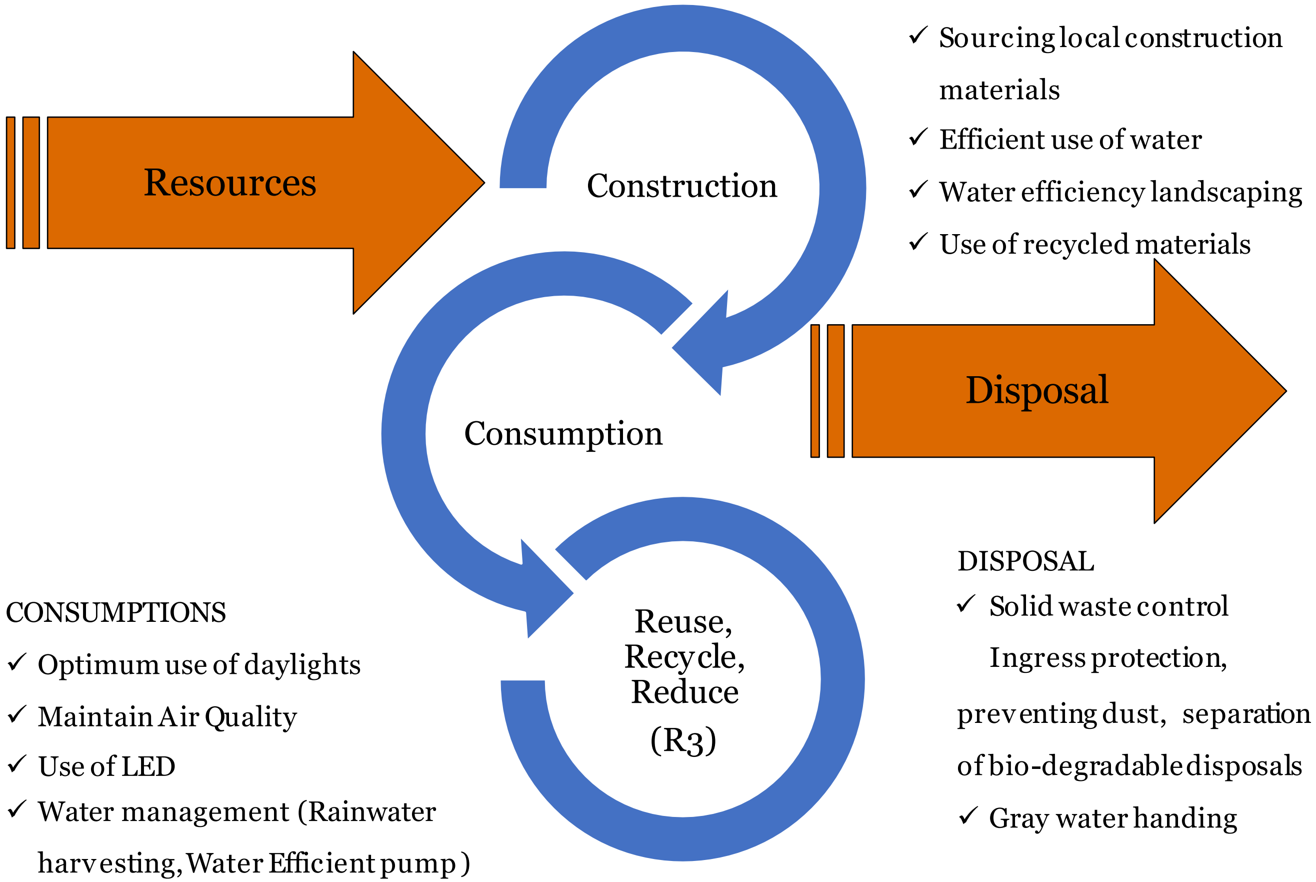
प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Life Cycle of Green Building



CONSTRUCTION

- ✓ Sourcing local construction materials
- ✓ Efficient use of water
- ✓ Water efficiency landscaping
- ✓ Use of recycled materials

CONSUMPTIONS

- ✓ Optimum use of daylights
- ✓ Maintain Air Quality
- ✓ Use of LED
- ✓ Water management (Rainwater harvesting, Water Efficient pump)

DISPOSAL

- ✓ Solid waste control
  Ingress protection, preventing dust, separation of bio-degradable disposals
- ✓ Gray water handing

GREEN RATING SYSTEMS

LEED — Leadership in Energy & Environmental Design

GRIHA

Indian Green Building Council
Greening India since 2001

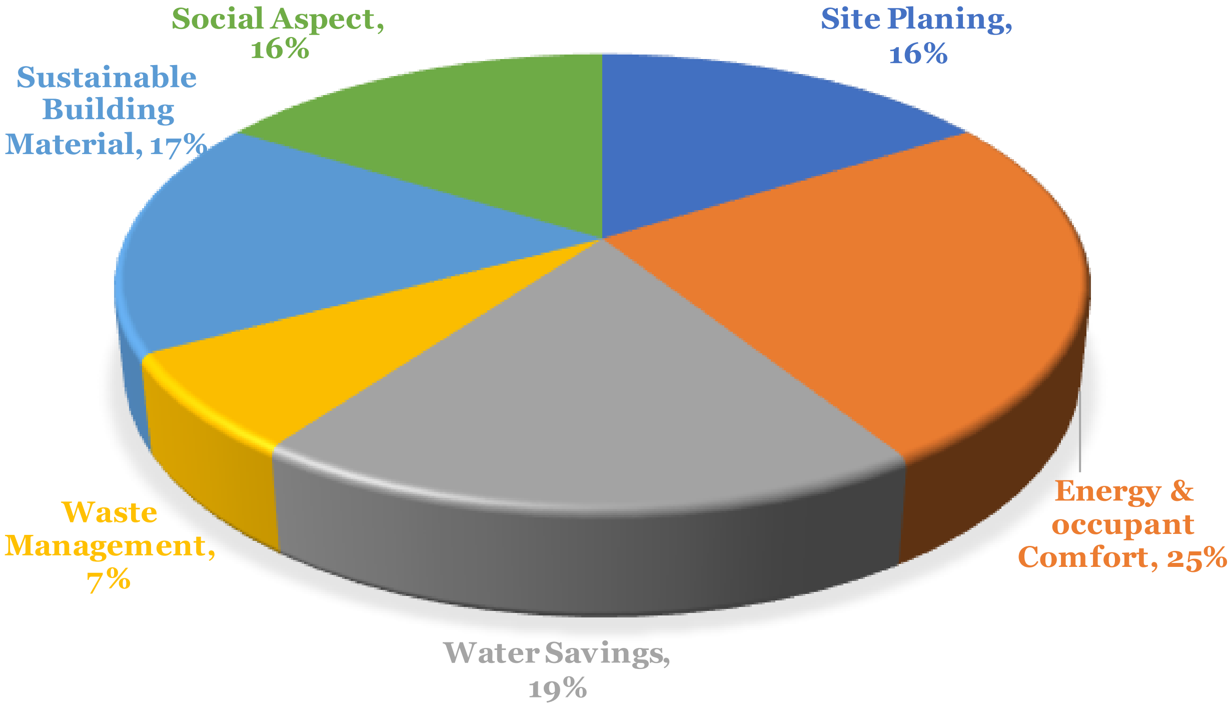
GEM
Green and Eco-friendly Movement
Care for the Mother Earth

Edge

Features that can make an Affordable building 'GREEN'

- **Site Planning**
- **Energy and Occupant Comfort**
- **Water Saving**
- **Waste Manageme nt**
- **Sustainable Building Material**
- **Social Aspect**

GRIHA Rating System: AFFORDABLE HOUSING



POINT WEIGHTAGES

Rating Thresholds	Rating
86 and above	5 Star
71-85	4 Star
56-70	3 Star
41-55	2 Star
25-40	1 Star

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Site Planning

1

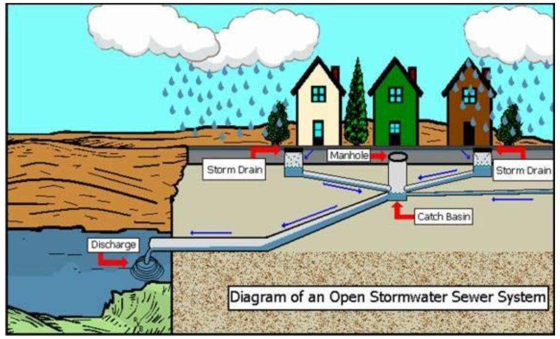
Climate Type	Passive Design Strategies
	Solar Chimney/ Wind Tower
	Courtyards
	Roof Pond for Evaporative Cooling
	Reduce Solar Access
	Building/ Site planning to increase cross ventilation (layout of windows in the rooms and building for wind flow)
	Cavity Walls/ Thermal mass to reduce heat gain/loss
	Dense vegetarian cover to moderate micro-climate
	Design accordingly site slope
	Light Shelves
	Internal distribution of spaces to be carried out such that buffer spaces like store rooms, staircases , toilets etc are located on the eastern and western facades
	Cool roofs in the form of vegetated roof/ terrace gardens/ roof ponds

Site Planning

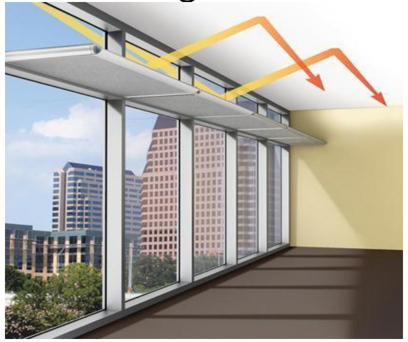
Vegetated Roof

SRI Coating

Grass pavers (https://greenroutesolutions.com/)



Strom water management (https://www.thewatertreatments.com)



Light Shelves (https://www.designingbuildings.co.uk/)

Mosaic tiles (https://www.dreamstime.com/

Design to mitigate -UHIE

- SRI Coating, Grass pavers

Landscape preservation

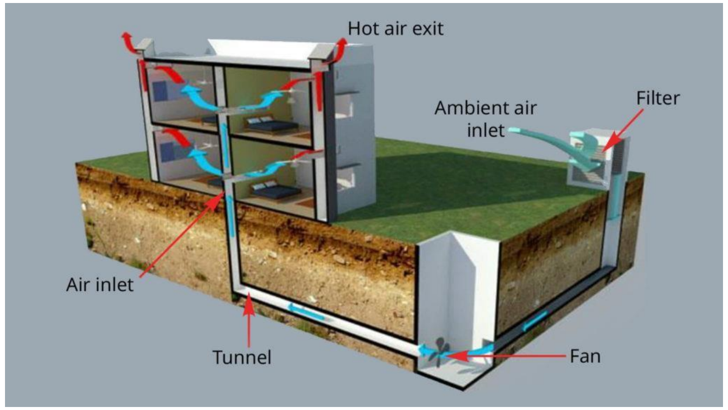
- Protection mature trees

Strom Water management

Reduction in air and soil pollution

Energy & Occupant Comfort

Envelope Thermal Performance	• Peak Heat Gai Factor (W/Sq.m) • Peak Cooling Load (W/Sq.m)
Occupants visual comfort (Daylight)	• UDI • Daylight Extent factor as per ECBC
Efficient Lighting	• Minimum luminous efficacy 75 lumen/Watt • **100% outdoor lighting**
Energy Efficient Equipments	• At least BEE 3 Star Motor & Transformers
Renewable Energy	• 1kWp per 500 sq.m
Energy Metering	• Dedicated energy meter in each DUs



Earth Air System
https:/

BEE Star ratings

Water Savings

Efficient use of water during construction	• Gunny Bag/hessian cloth and ponding for curing • Additives • Use of treated wastewater/ captured rainwater
Optimizing the Building & Landscape water demand	• **20% reduction w.r.t base case** • Reduce the total landscape water requirement(Sprinkler Irrigation, Drip irrigation)
Water Reuse	• Sewage Treatment Plant • Reuse of treated and rain water
Water Metering	• **Installation of the water meter** • Sub-water meter in each DUs

GUNNY Bags (https://blog.fabricuk.c

Water meter (https://www.nobroker.in/)

Sprinkler

Waste Management

Construction Waste Management

- Waste management plan as per 'Construction and Demolition Waste Management Rules, 2016

Post Construction Waste Management

- Compliance with Solid Waste Management Rules, 2016
- Collection & Segregation (multi-coloured bins)
- Safe & hygienic storage
- Safe recycling
- Treating organic waste (biogas/manure) (>100kg/day)

https://www.nbmcw.com/

150 million tonnes of construction and demolition (C&D) waste every year. (2019) Recycling capacity is a about 6,500 tonnes per day (TPD) -- just about 1 per cent.*

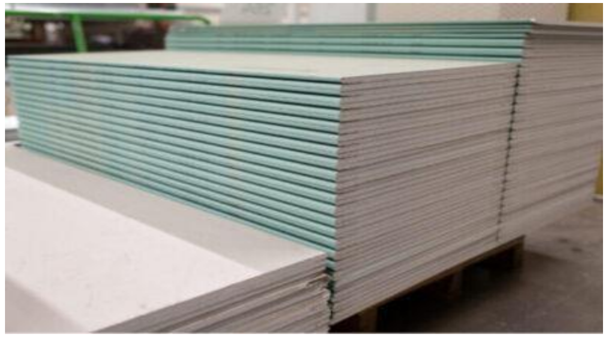
*https://www.cseindia.org/

Sustainable Building Materials

Reduction in environmental impact of construction (Building Structure)	• Use of BIS recommended waste materials (OPC, aggregate, sand) • Use of recycled materials (Steel frame, polystyrene components, Gypsum panels) • Embodied energy calculation
Use of low environmental impact materials in building interiors	• Stones from India • Composite wood based product • FSC Chain of custody certified products • Products with 5% recycled content
Use of recycled content in roads and pavements	• 8% (min) as per CPRI and IRC Guidelines
Low VOC paints, adhesives, sealants and composite wood products	• VOC limit (g /litre) specified
Zero ODP materials	• CFC, HCFCs free from Building insulation , HVAC & refrigeration equipment and fire fighting system

Portland Slag Cement, commonly known as PSC
Up to 45- 50% slag, 45% – 50% clinker, and 3-5% gypsum

Compacted EPS Blocks



Gypsum Board
(https://www.boardandwall.com/)

Social Aspects

Facilities for construction workers	• Compliance with NBC 2016 Safety norms • Drinking water, hygienic working & living condition
Universal Accessibility	• Measure to provide barrier free facilities for Specially abled persons and elderly persons
Proximity of Transport and basic Services	• With in 500 metre transportation facilities • Health Care, Education, Socio culture, market, sports, recreation, Bank (ATM) – 800 metre preferred
Environmental Awareness	• Awareness tools (Brochure, poster etc.)
Tobacco Smoke Control	• Zero exposure of non-smoking occupants
Water Quality	• Conform to IS 10500-1991
Provision to access clean sources of Cooking Fuel	• Basic infrastructure for PNG & LPG connection

Ramp for physically handicapped

DAY 2

Q & A Session

DAY 2

Vote of Thanks

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

THANK YOU