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

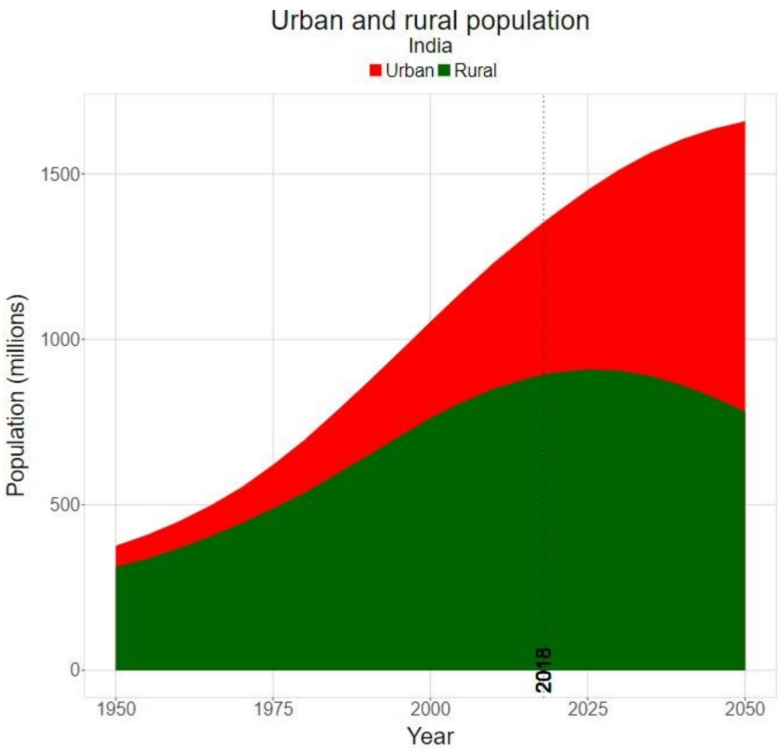
CLIMATE SMART BUILDINGS

Training #25 (RACHNA 2.0) : 1 Day Training Program at Infocity Club & Resorts, Gandhinagar

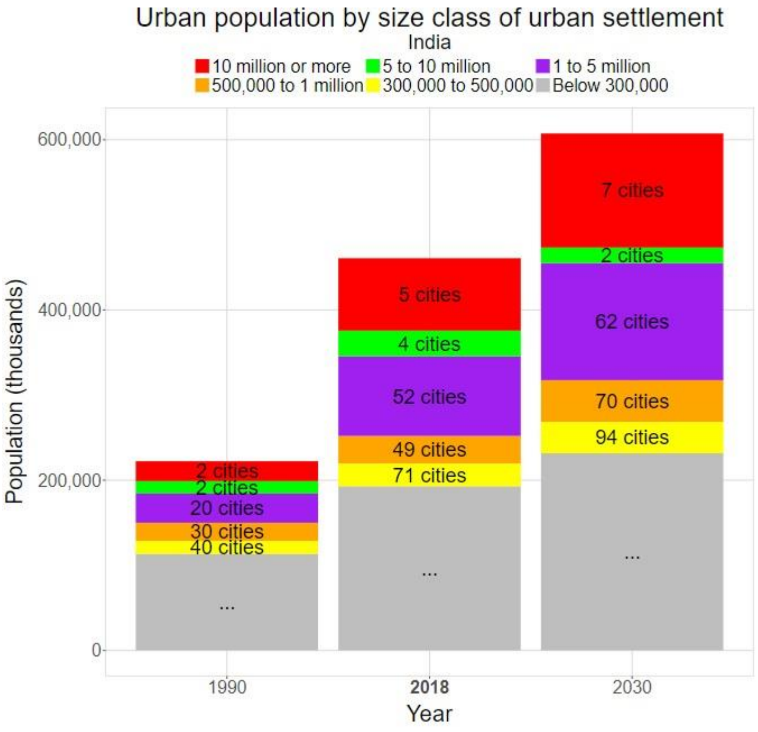
01

INTRODUCTION

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

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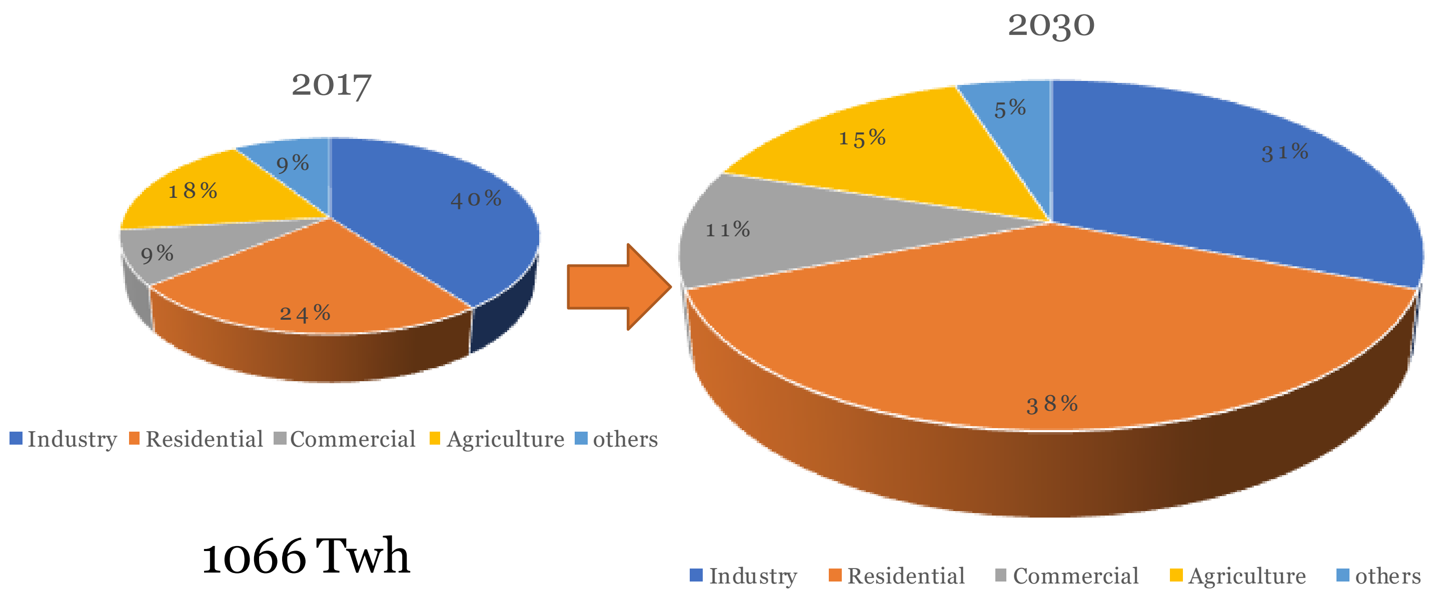
Energy demand with Rapid Urbanization



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.

MoHUA Initiates for Urban Transformation

1. SMU (U)
2. PMY (U)
3. DAY - NULM
4. HRIDAY
5. AMRUT
6. Smart City
7. Transport

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.

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

Pradhan Mantri Awaas Yojana-Gramin
प्रधान मंत्री आवास योजना - ग्रामीण

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	Slum rehabilitation of Slum dwellers with participation of private developers using Land as a resource

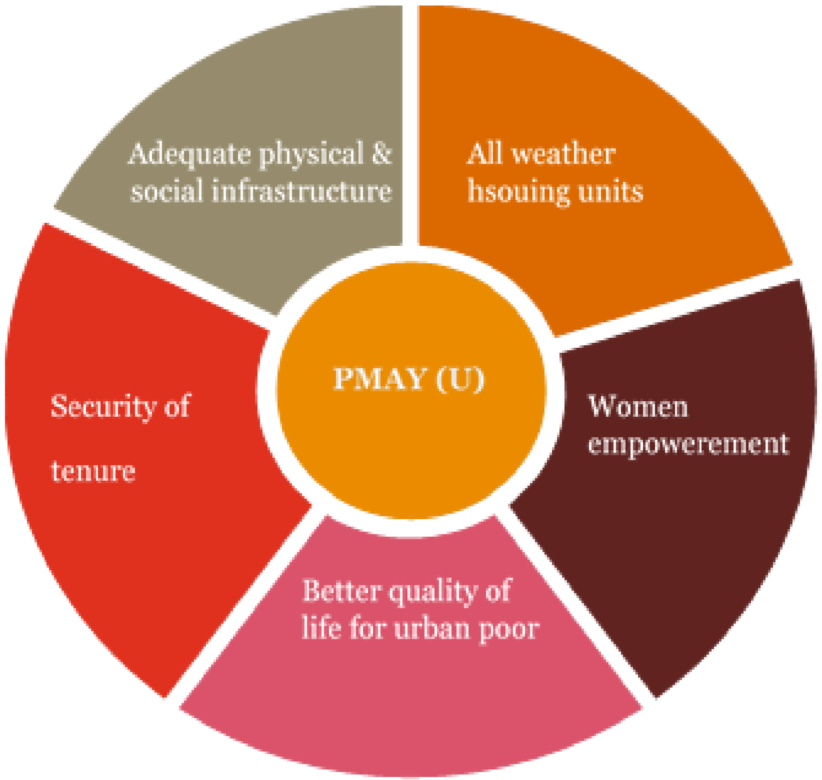
Project Objectives

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)**

Problems addressed through cafeteria approach by mission



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)

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Ministry of Housing and Urban Affairs
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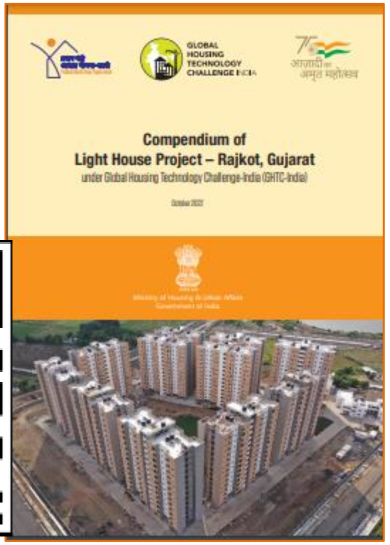
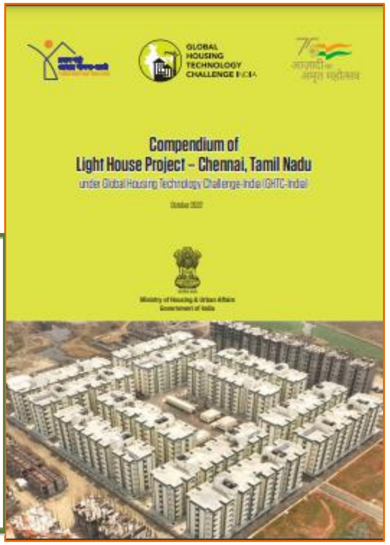
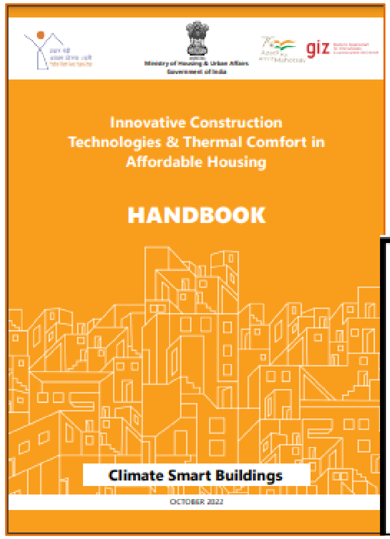
Book Launches by MoHUA under GHTC India Challenge

Compendium of Light House Project Rajkot

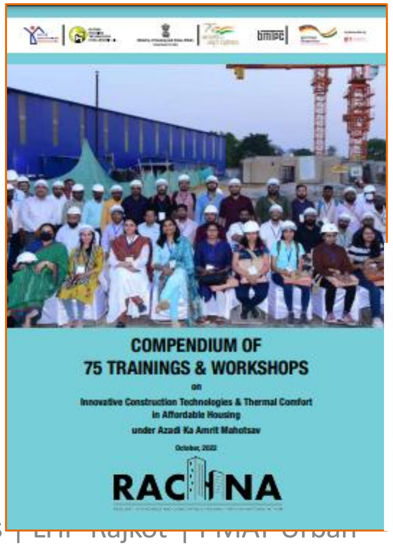


Compendium of Light House Project Chennai





Handbook on Innovative Construction Technologies & Thermal Comfort



Compendium of 75 Trainings & Workshops under RACHNA

Climate Smart Buildings Programme (ICEN-CSB)

Government of India/ MoHUA

+

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

→ **ICEN-CSB**

Affordable

Climate Smart Building

Climate Resilient

Thermal Comfortable

Key features of a CSB

Reduce the demand for air-condition by 30-40%	Curtail 30 metric tones 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

High Tea & Networking

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 greening 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

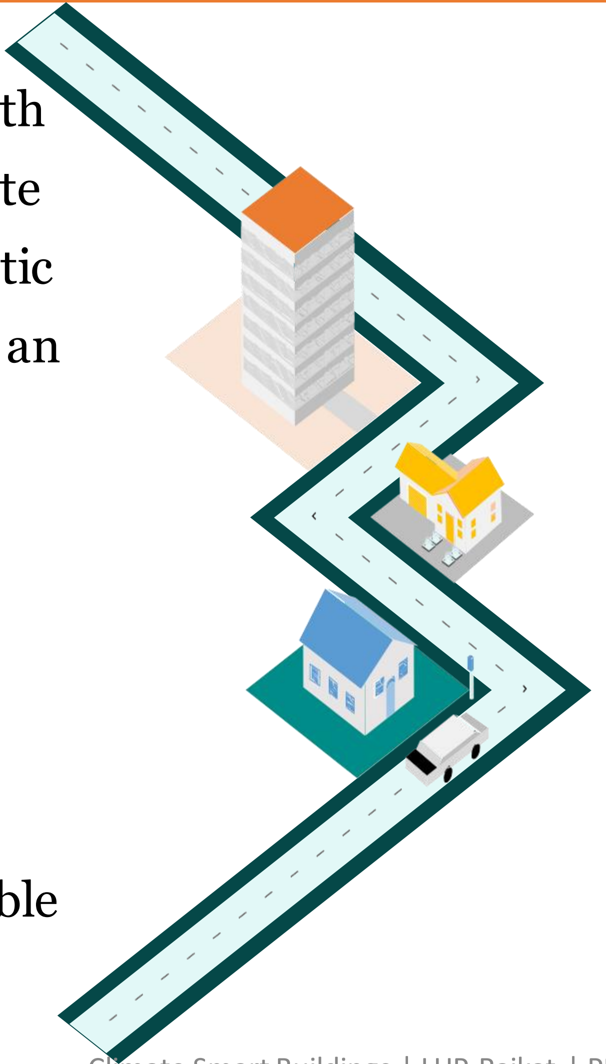
Outcome

- 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

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Features of LHP

Definition	Minimum Size of houses	Available on-site facilities	Design	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	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	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		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

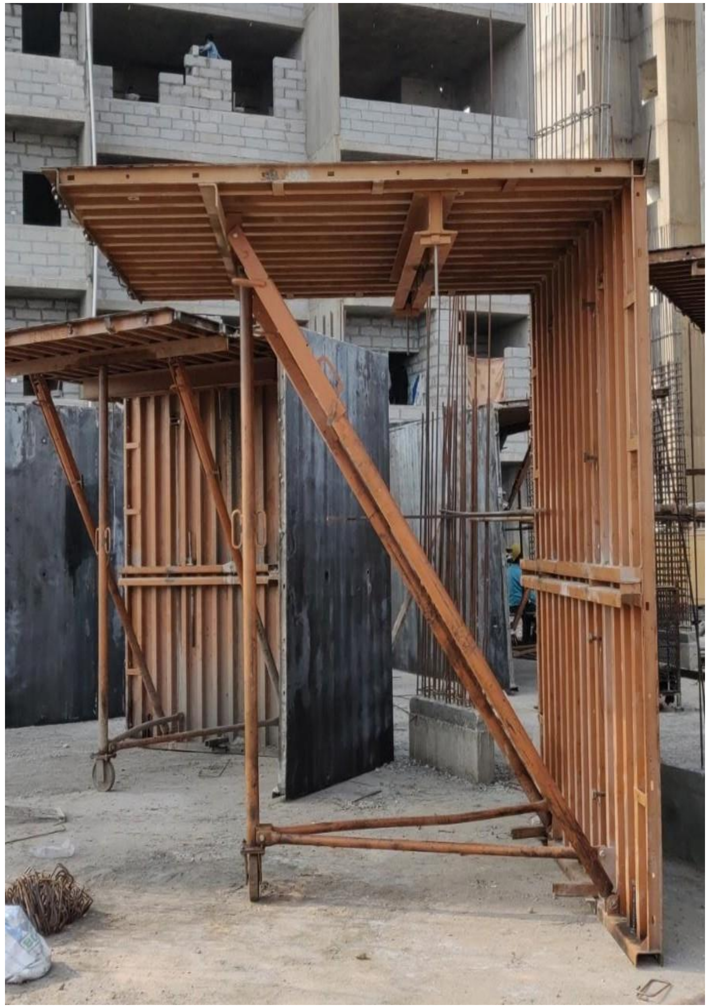
- Designed as per the dimensional requirements mandated in the National Building Code (NBC) 2016.
- Design in concurrence with existing centrally sponsored schemes and Missions such as Smart Cities, AMRUT, Swachh Bharat (U), National Urban Livelihood Mission (NULM), Ujjwalla, Ujala, Make in India, etc.
- 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 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.

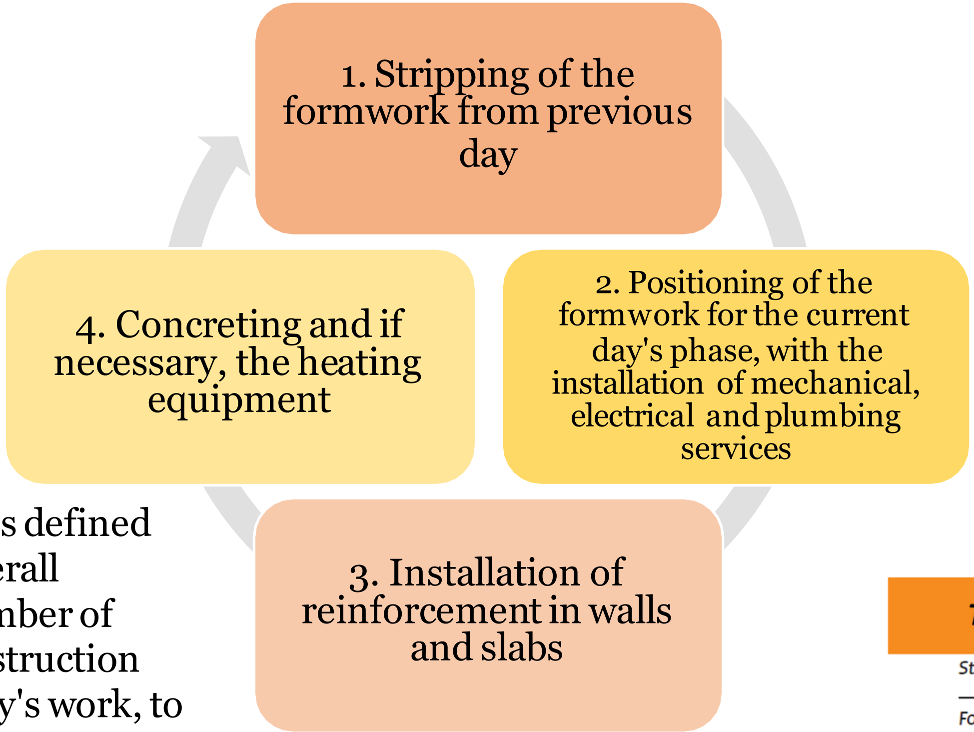
Tunnel forms allow walls and slabs to be cast in one day through several phases to the structure. The programme and the amount of floor area that can be poured in one day define the phasing. The task to be done each day is defined by the 24-Hour cycle. In the morning, the formwork is set up for the day's 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.

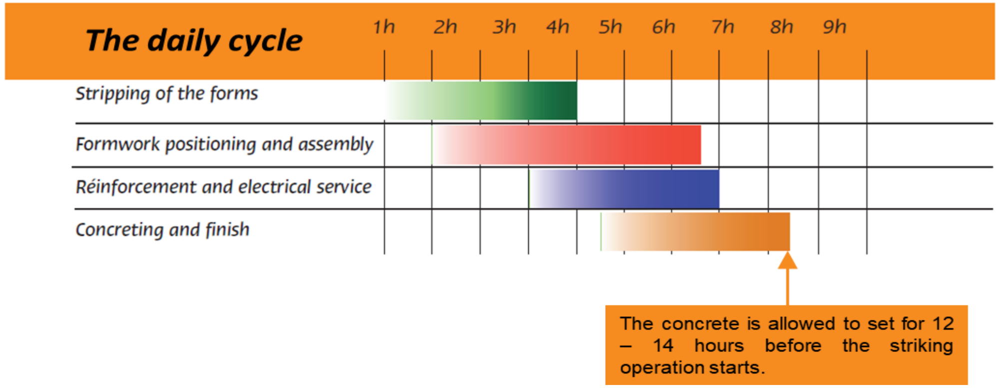
This formwork is manufactured in a completely automated facility in France and there is no manufacturing plant in India.

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 selected under the Global Housing Technology Challenge (GHTC) – India

Monolithic Concrete Construction using Tunnel Formwork

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

Prefabricated Sandwich Panel System

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

Precast Concrete Construction System – Precast Components Assembled at Site

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

Precast Concrete Construction System – 3D Volumetric

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

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

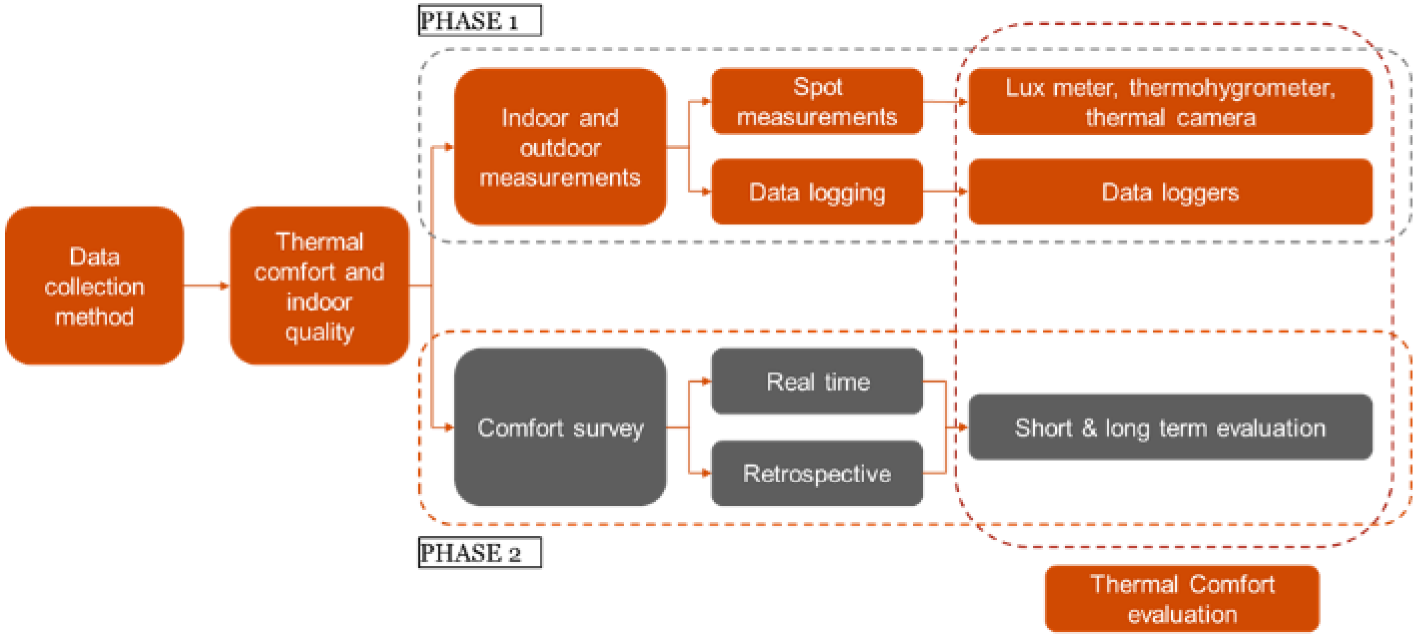
03

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.

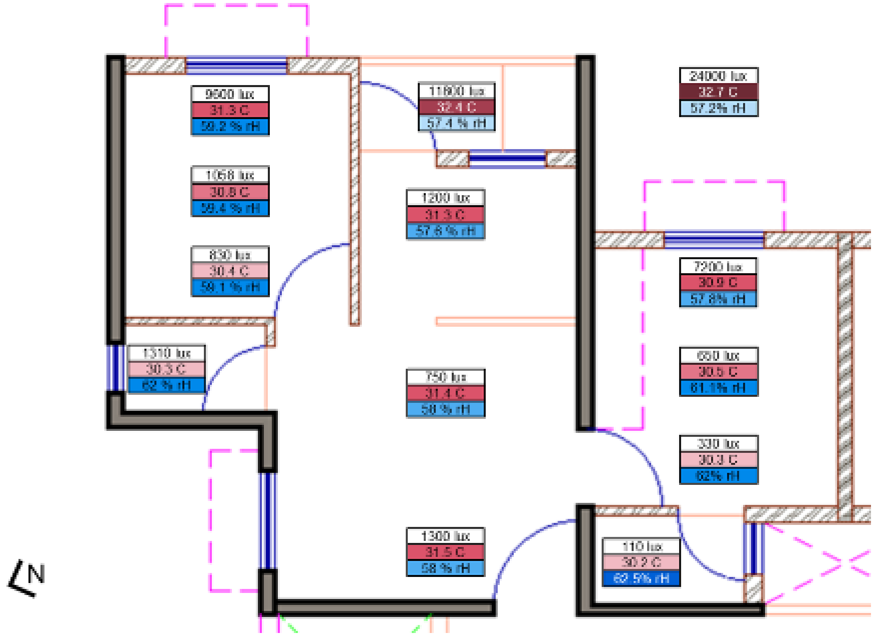


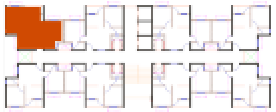
Methodology for monitoring and evaluation

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

Thermal comfort study of the Light House Project- Rajkot

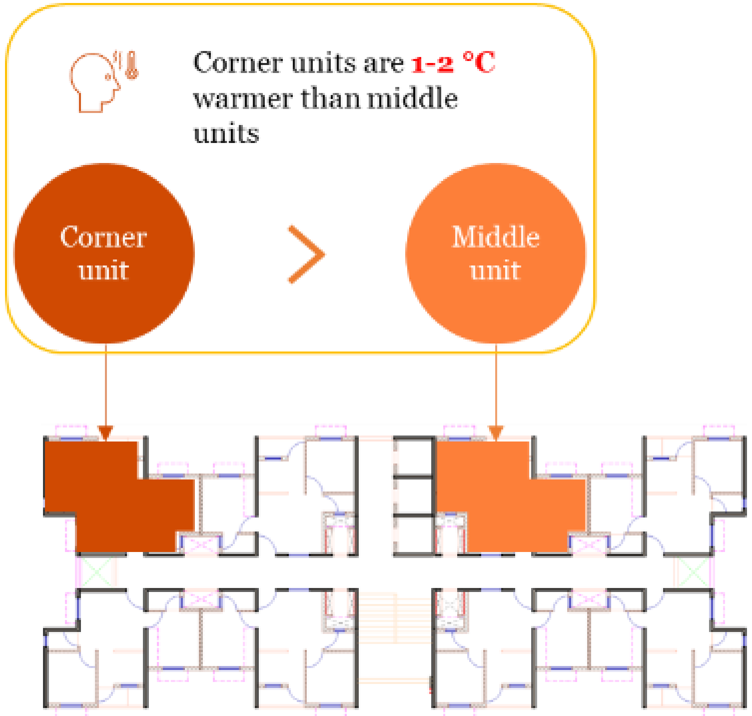
On-site spot measurements





Key Plan

Findings

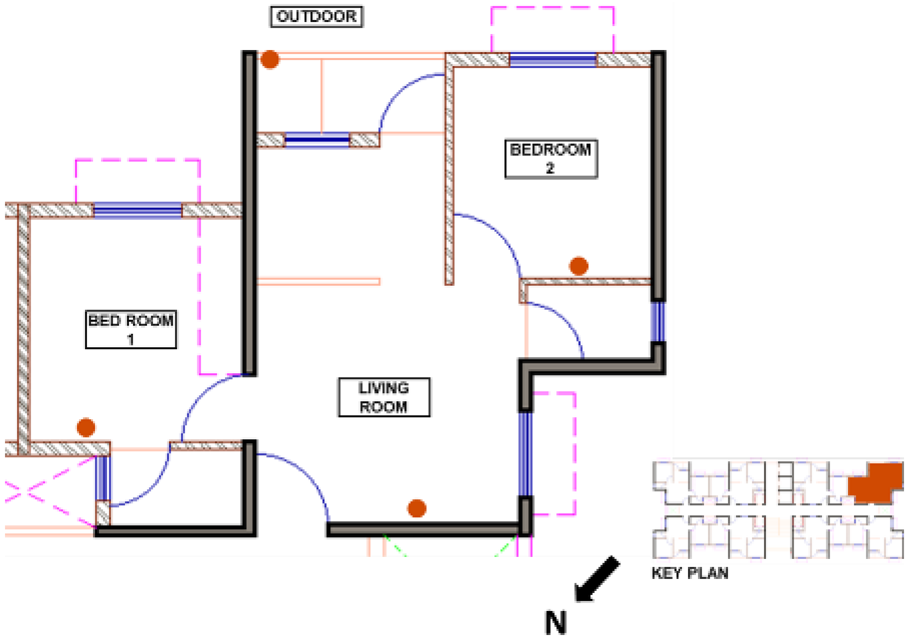


Thermal comfort study of the Light House Project- Rajkot

Findings (Cont.)

Thermal comfort study of the Light House Project- Rajkot

Datalogger placement

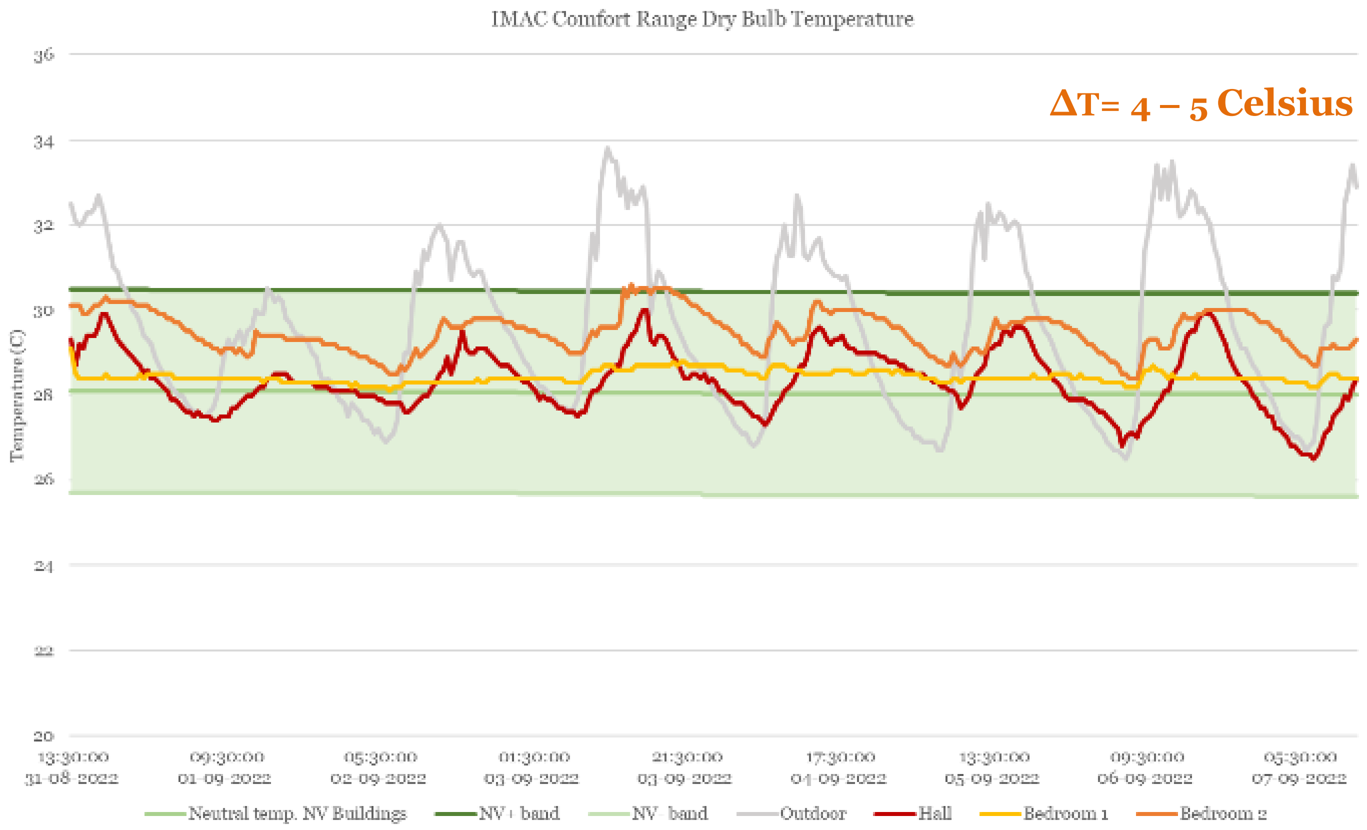


Location: Tower 8 | 1st floor | Corner unit

Occupancy: 9 am to 5 pm

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

Findings

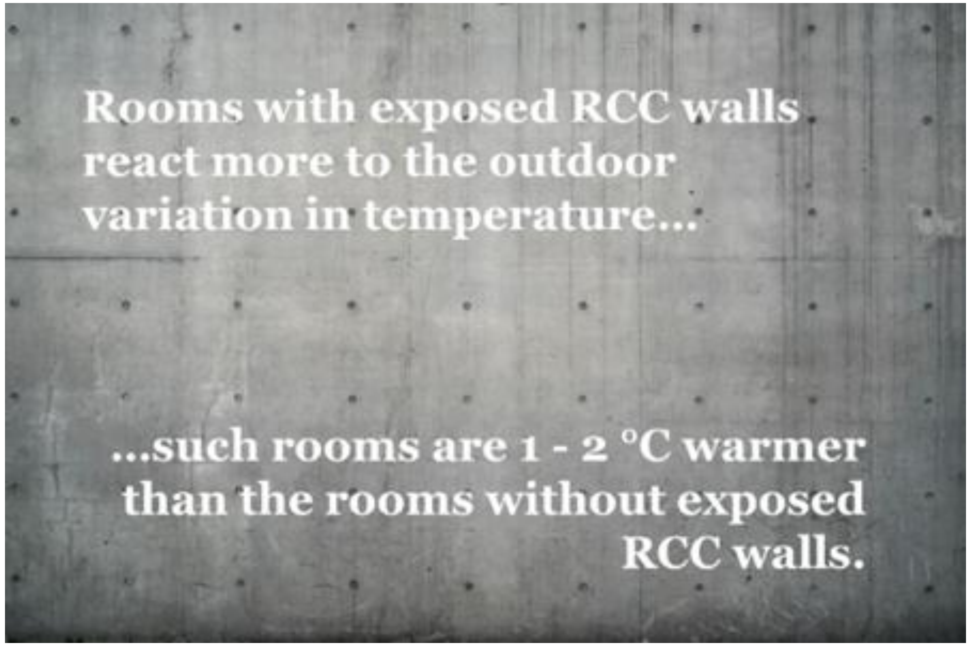


The data loggers readings from Wednesday, 31st August to 7th September 2022.

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%**

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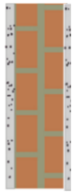
Comparation between building envelope of conventional building vs LHP, Rajkot

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

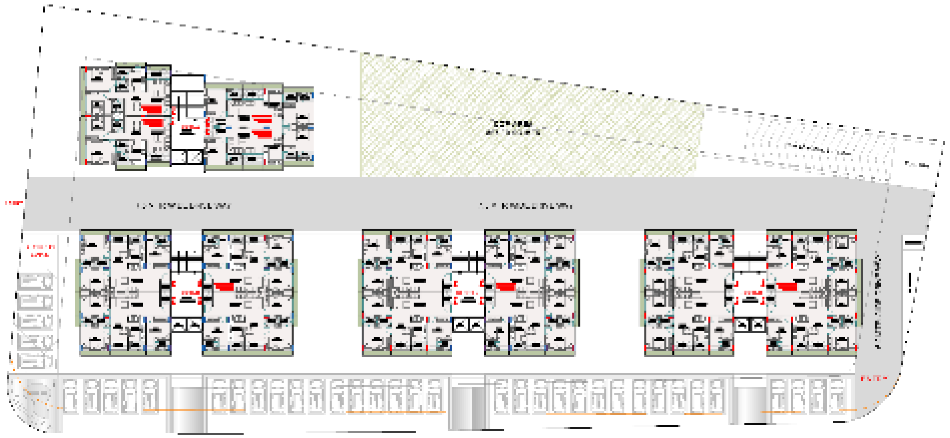
Envelope Type	LHP Case - Construction Configuration	Section	U Value*
Wall	Interior Surface Film resistance + Internal Cement Mortar (10 mm) + AAC Block (200mm) + External Cement Mortar (30 mm) + Exterior Surface film resistance		0.68 W/m2K
Roof	Interior Surface Film resistance + RCC slab (160 mm) + screeding (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, conclutions, 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/m².k	RETV W/m²	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/m².k	RETV W/m²	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	-	✓	

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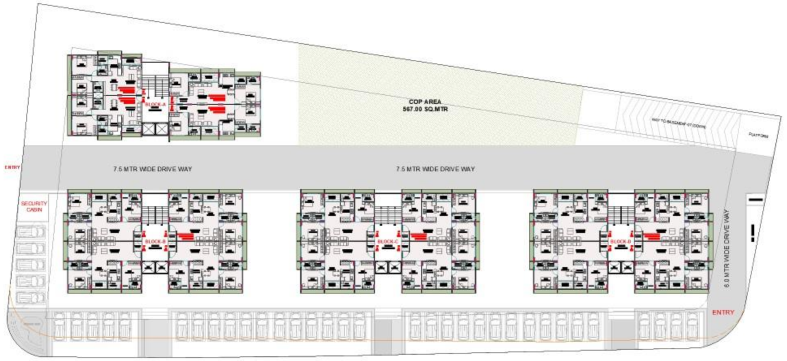
ENS compliance and recommendations for Demonstration Housing Project

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.

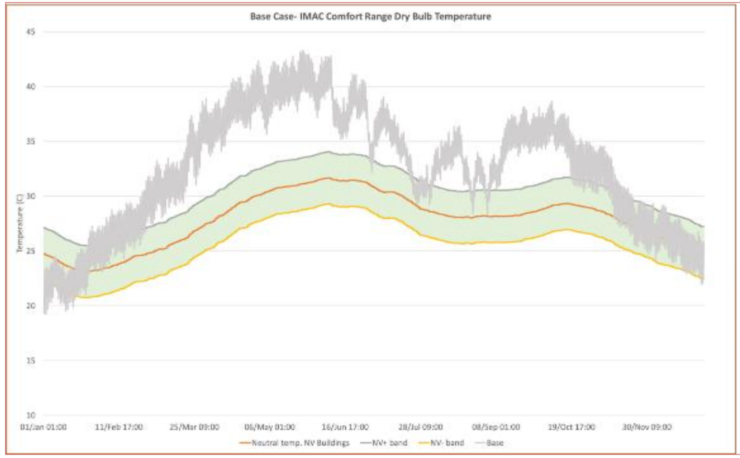
As designed

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

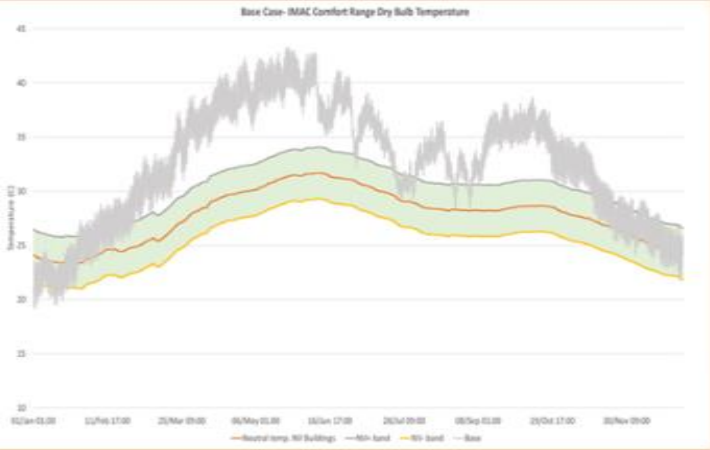
150mm concrete slab

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

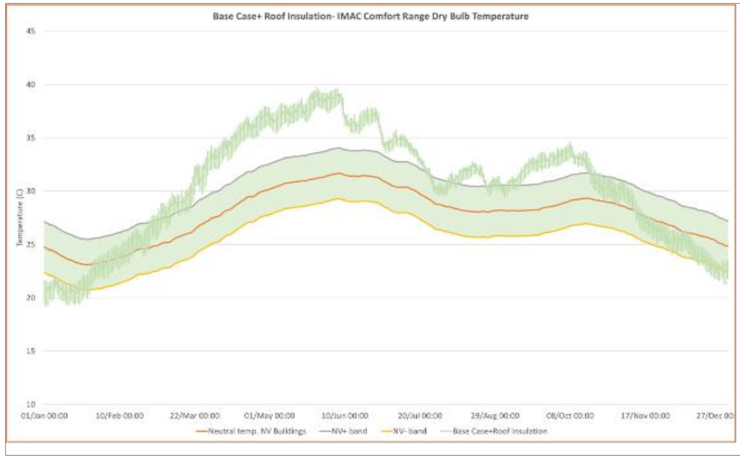
150mm concrete slab

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

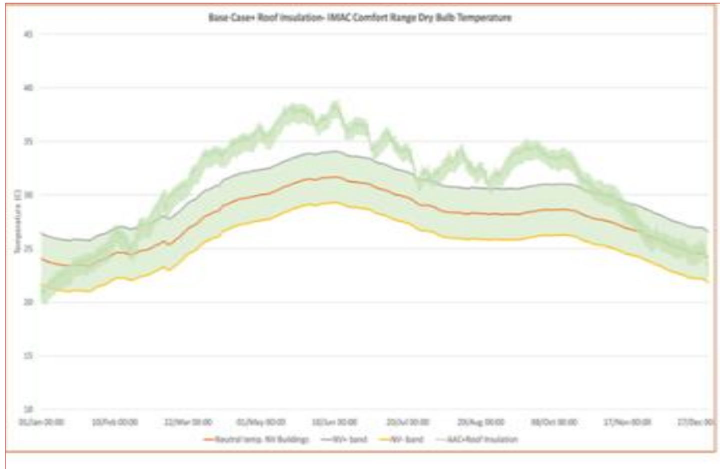
ANNUAL DISCOMFORT HOURS

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.

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.

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04

Life Cycle Cost and its impact on Carbon Emission

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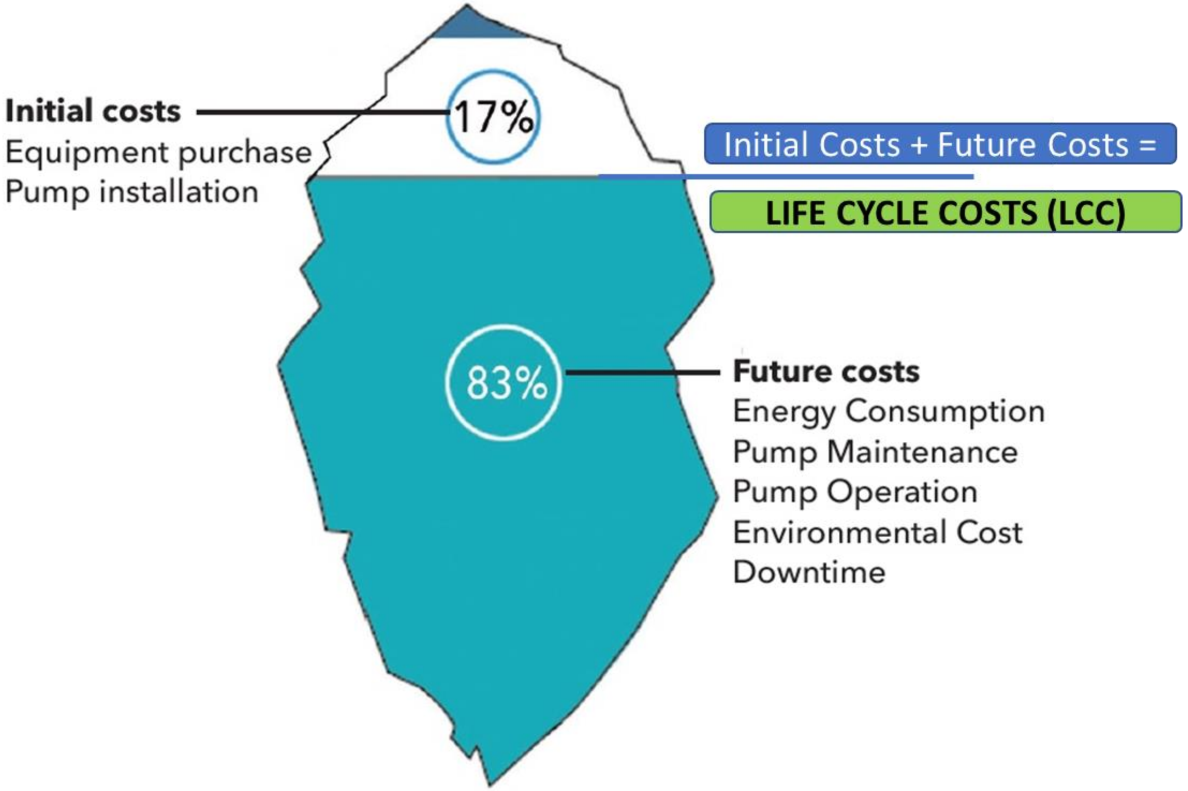
Concept of life cycle cost and its impact on carbon emission

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

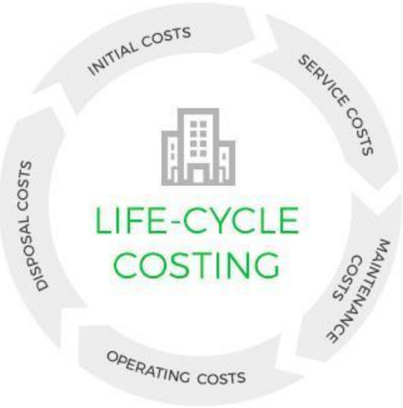
Why LCC matters in sustainable building

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

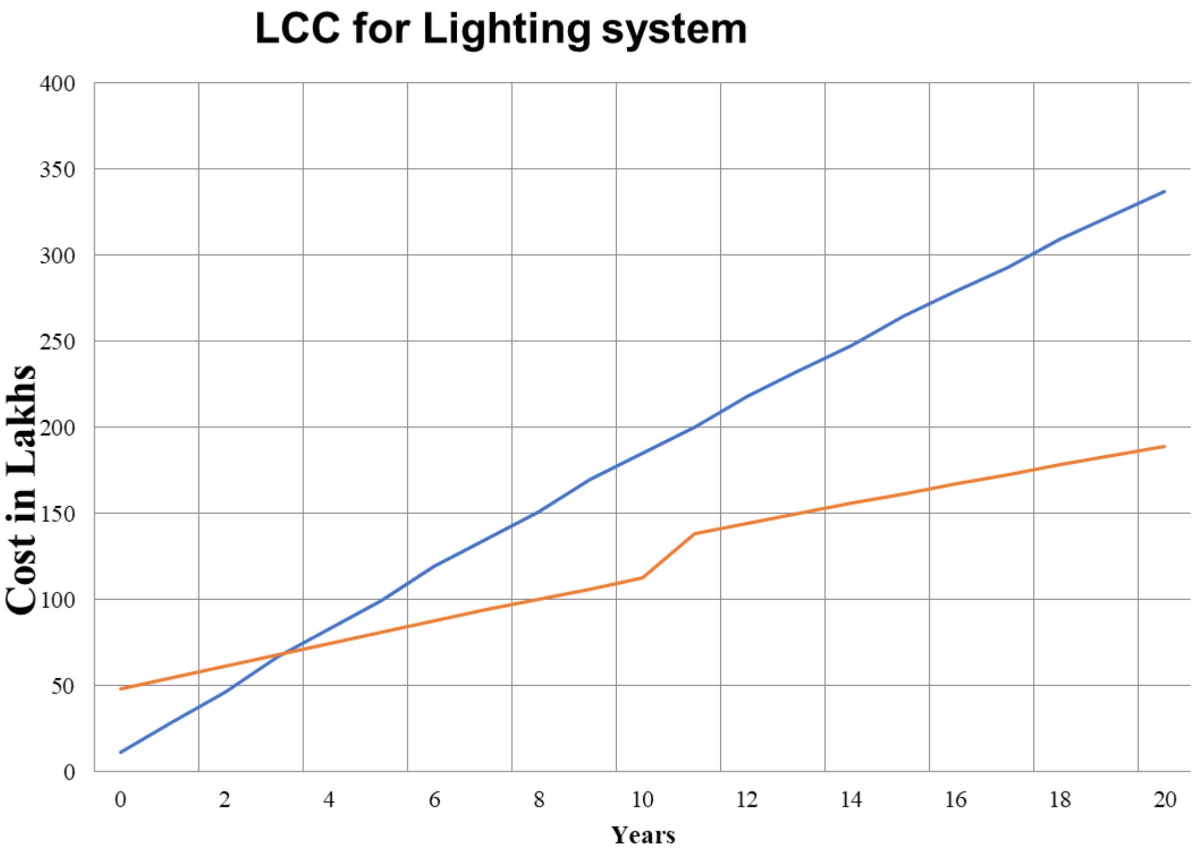
Why LCC matters in sustainable building

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



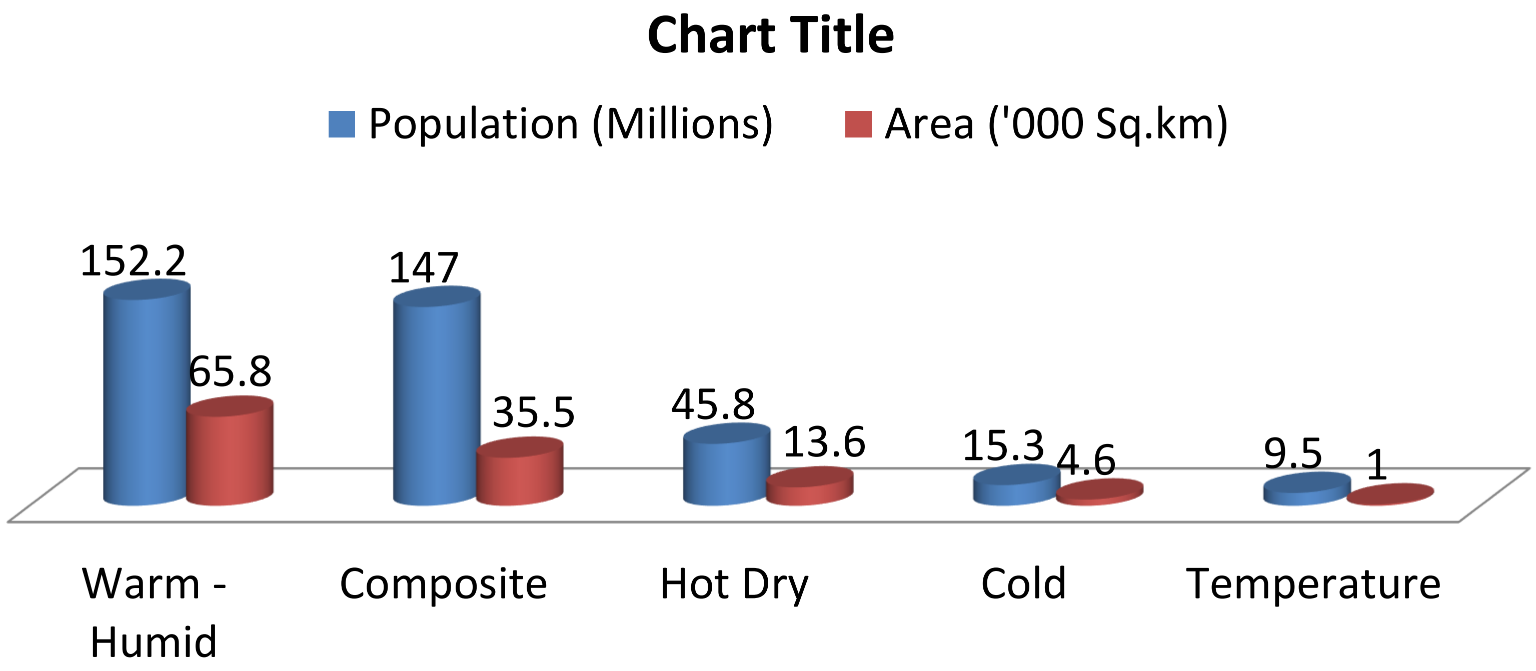
Q&A Session on New & Innovative technologies and Thermal Comfort

Session 2: Importance of Thermal Comfort

05

Thermal Comfort and Cooling Demand

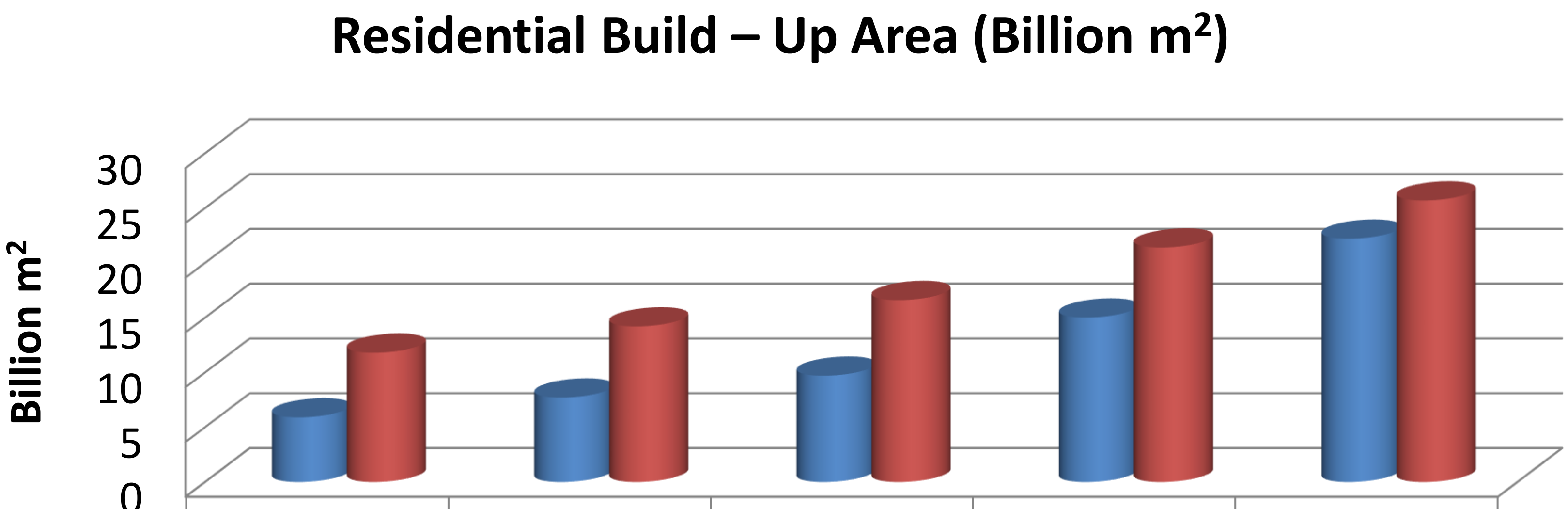
Thermal Comfort & Cooling Demand



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



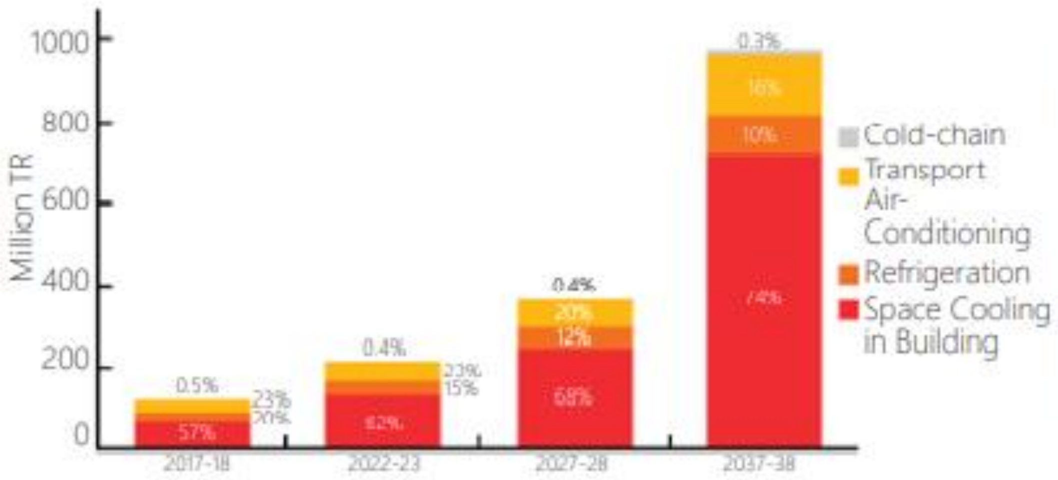
	2020	2025	2030	2040	2050
Urban	5.9	7.7	9.7	15	22.2
Rural	11.8	14.2	16.6	21.4	25.7

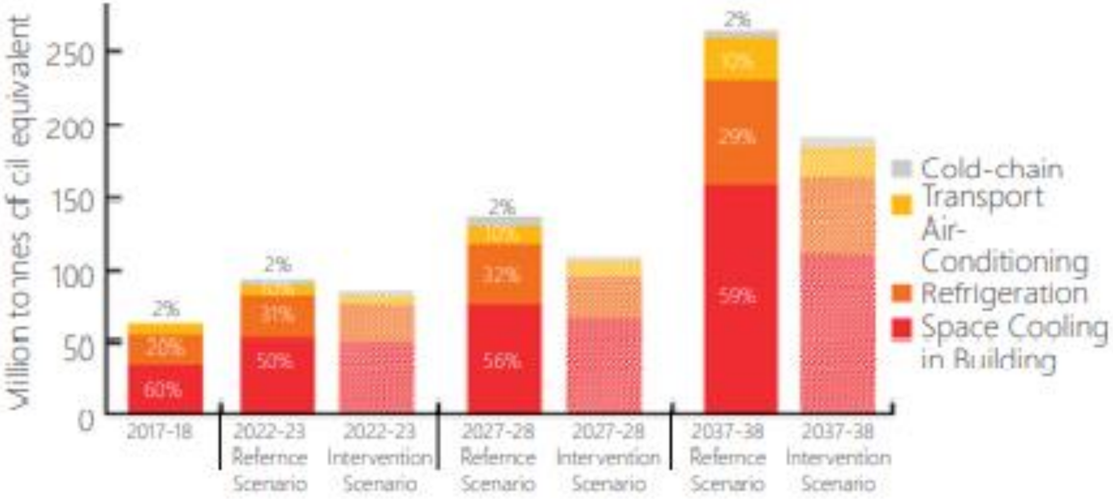
Projected increase in residential built-up area in urban and rural India. Source: ICAP

- 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.





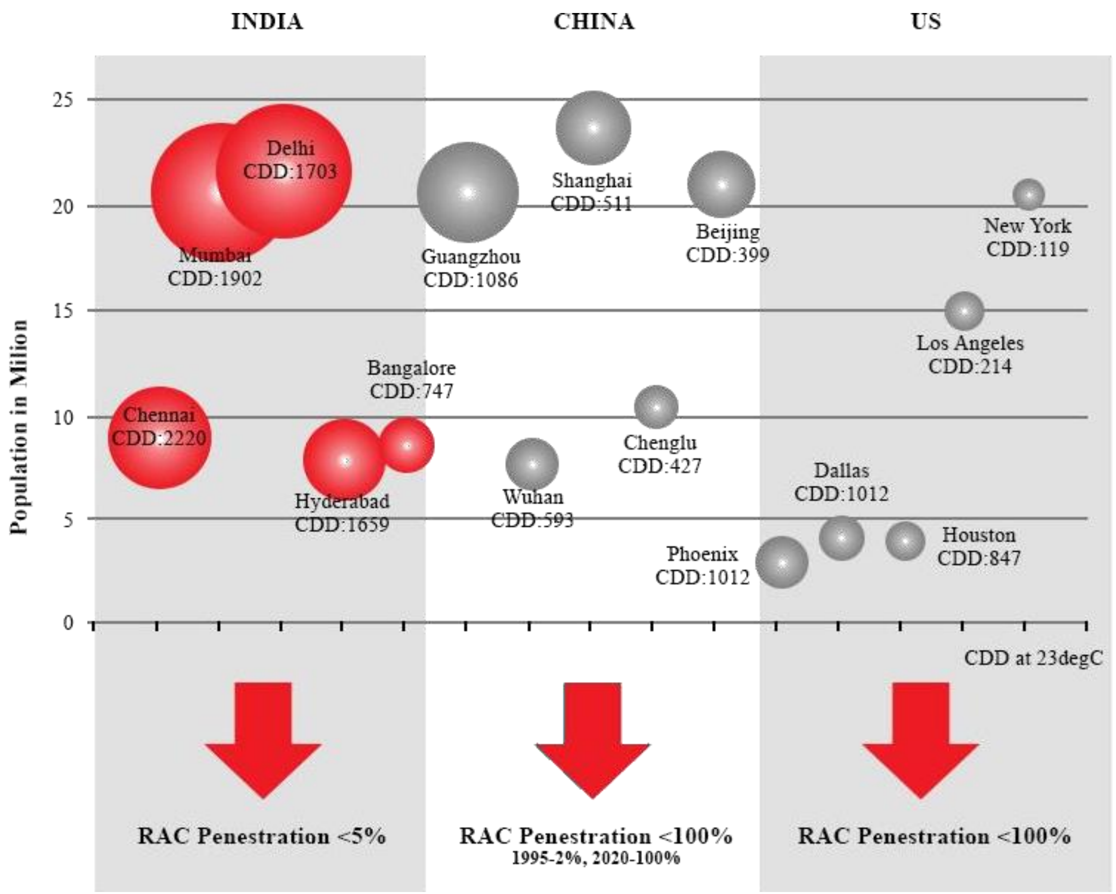
Above: Sector-wise growth in cooling demand; Below: India's Total Primary Energy Supply (TPES) for cooling. Source: India Cooling Action Plan (redrawn)

Impact of need of Thermal Comfort: 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

Impact of need of Thermal Comfort: International Perspective

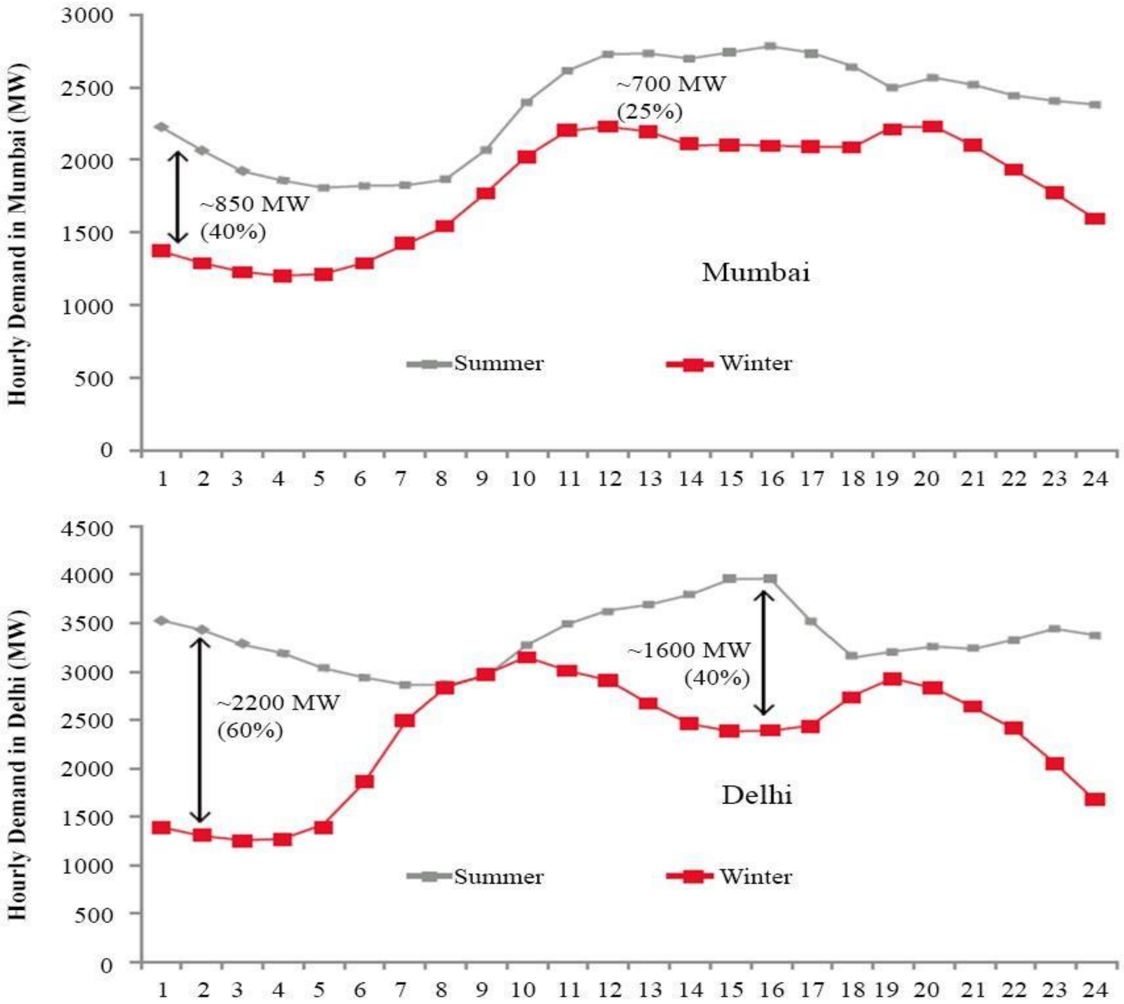


Cooling Demand in India, China, and the US

- 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

Impact of need of Thermal Comfort: Peak Demand



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

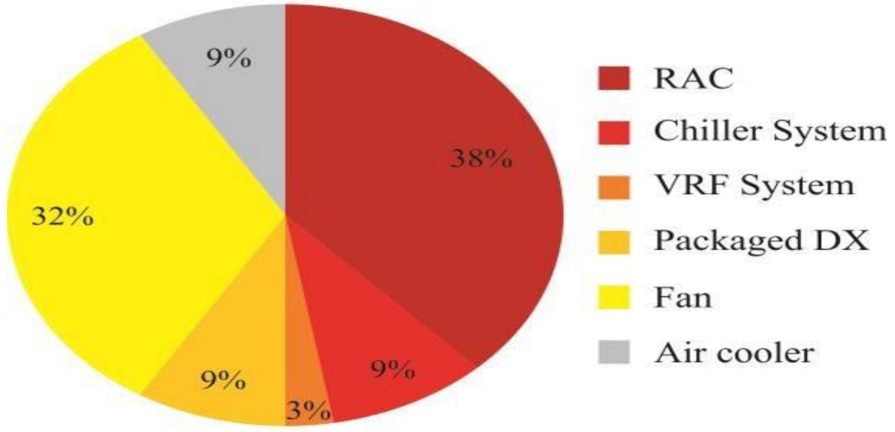
Late-night 850 MW to late afternoon 700 in Mumbai
Late-night 2200 MW to late afternoon 1600 in Delhi

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.

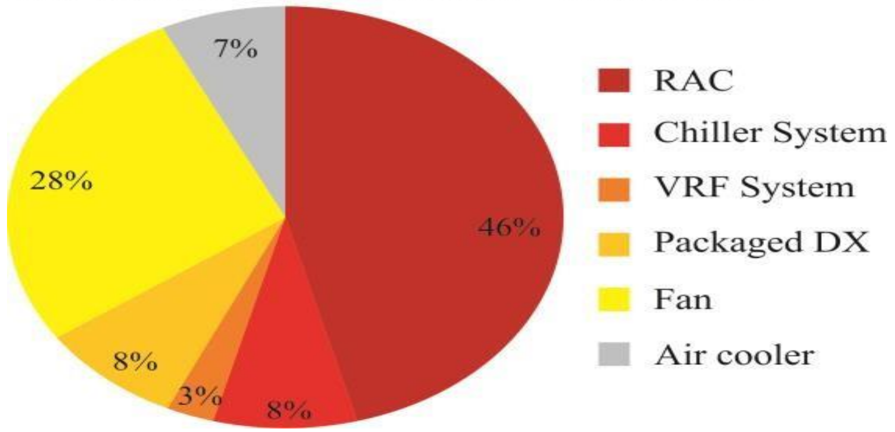
https://international.lbl.gov/publications/avoiding-100-new-power-plants

Impact of need of Thermal Comfort: 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

Impact of need of Thermal Comfort: Consumption & Emission

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

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

- 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

06

Factors affecting Thermal Comfort and Cooling Demand

Factors affecting Thermal Comfort

PHYSIOLOGICAL FACTORS

When trying to maintain maximum thermal comfort in a building, are individualized in nature and impossible to manage

PHYSICAL FACTORS

Venus has a beautiful name and is the second planet from the Sun

PHYSICAL FACTORS

•01

•Air Temperature

•02

•Mean Radiant Temperature

•03

•Radiant Temperature Asymmetry

•04

Floor Surface Temperature

•05

•Relative Humidity

•06

•Air Speed

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

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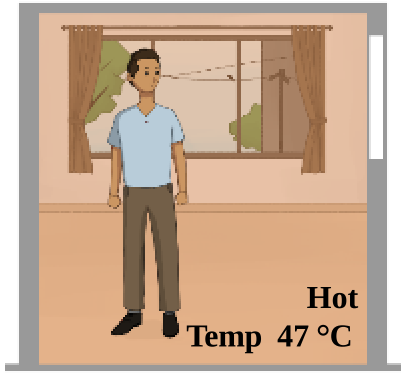
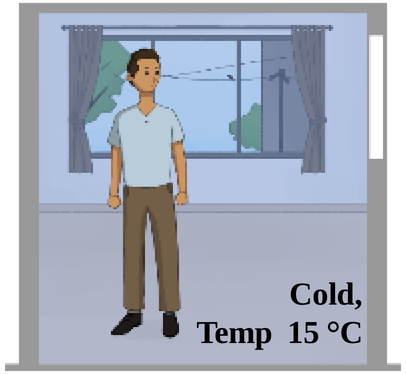
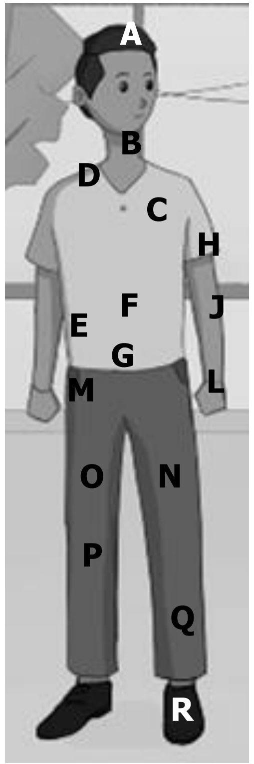
Thermal Comfort – Cold – Neutral - Warm



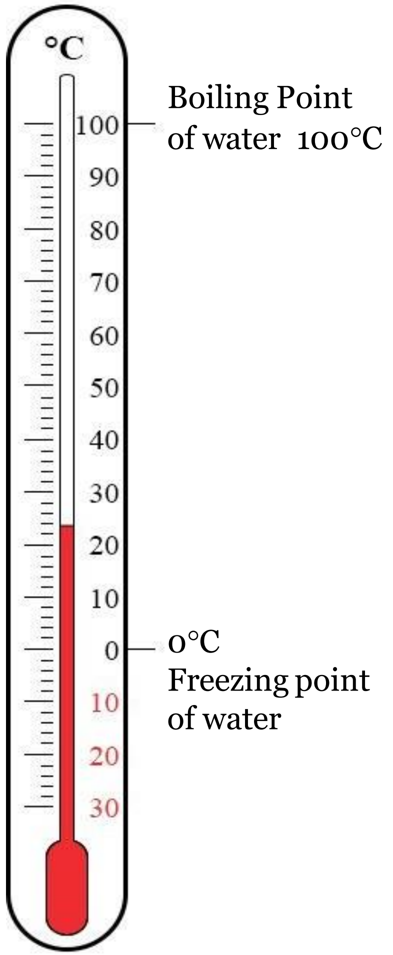


Air Temp 27 °C



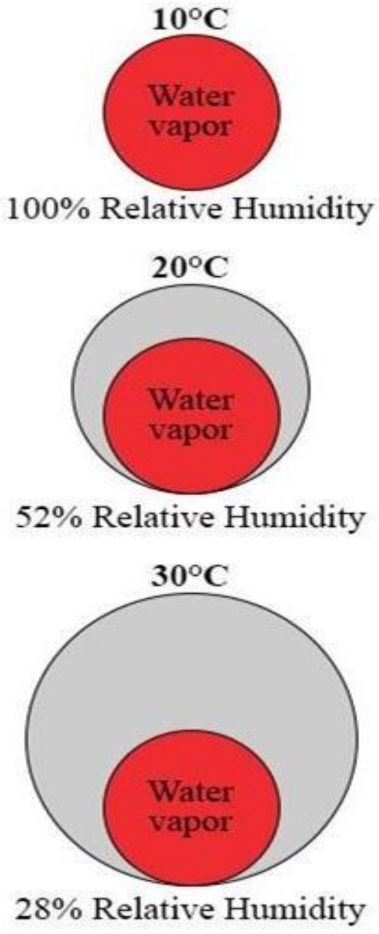
Body Part	Skin Location	Cold (15 °C)	Neutral (27°C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37
L	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



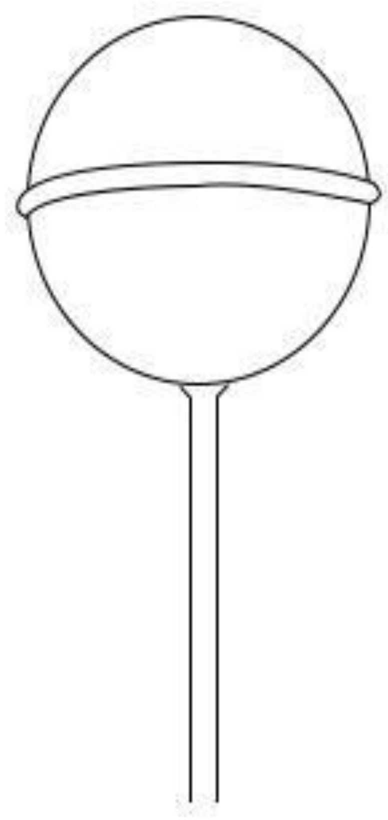
- Temperature of the air surrounding the body (Dry Bulb Temperature) – DBT)
- Temperature of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture.
- Degrees Celsius (°C)

Factors Affecting Thermal Comfort – Relative Humidity



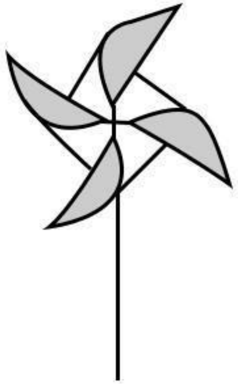
- Moisture Content of the air
- The amount of moisture in the air depends upon
- Air Pressure
- Air Temperature
- Percentage (%)

Factors Affecting Thermal Comfort – Mean Radiant Temperature



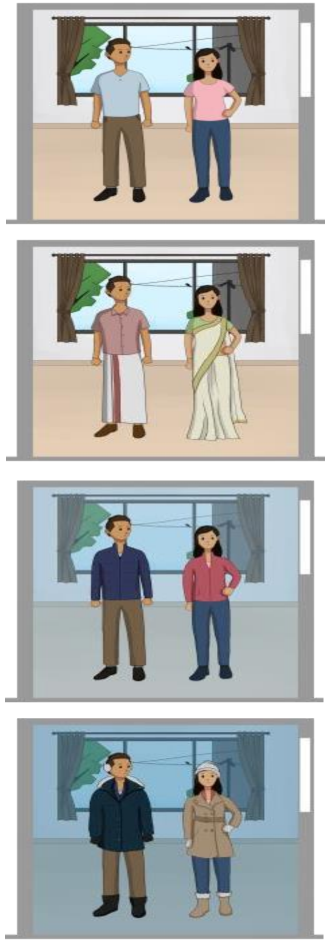
- Uniform temperature of an imaginary enclosure
- Measure of the effect of Radiant interchanges at a point in space
- Calculated using (T_g), (T_a) and air velocity

Factors Affecting Thermal Comfort – Air Speed



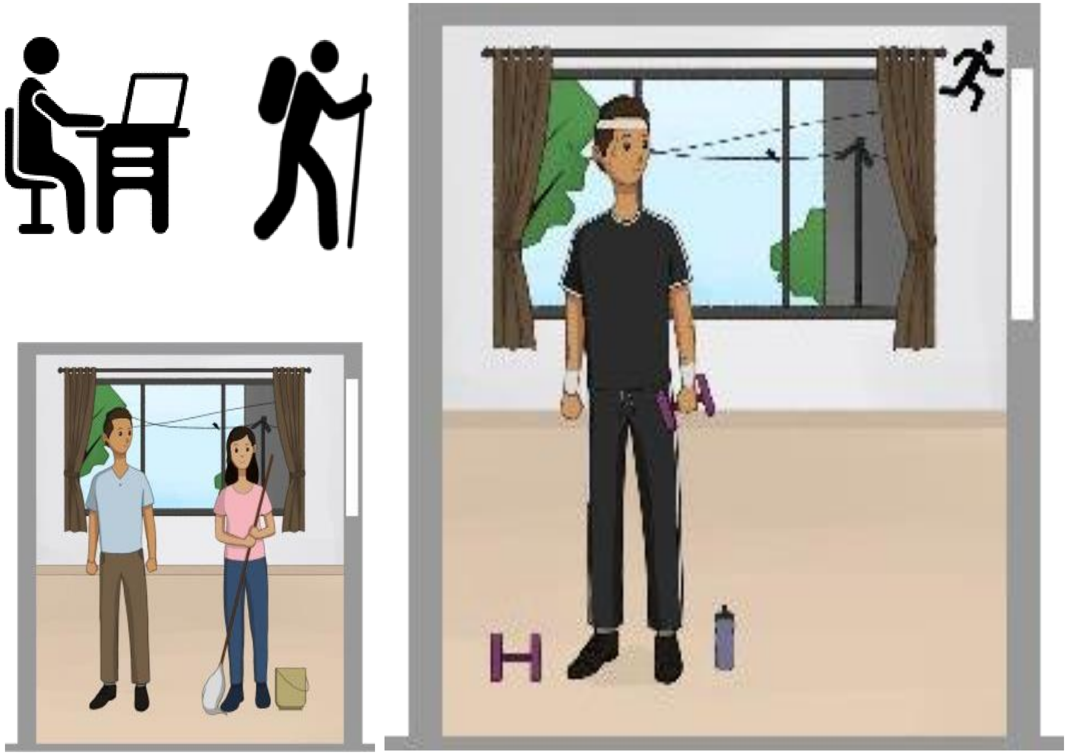
- Air Speed is the rate of air movement at a point, without regard to direction
- Average air speed, height and directions
- Calculated using (T_g), (T_a) and air velocity
- Meter per second (m/s)

Factors Affecting Thermal Comfort – Clothing Value



- The resistance to sensible heat transfer provided by clothing ensemble
- Clothing Insulation Value (clo - I_{cl})
- Impact of furniture such as chair and beddings

Factors Affecting Thermal Comfort – Metabolic Rates



- The rate at which metabolism occurs in a living organism.
- Rate of energy expenditure per unit time
- Average adult 1.8 square meter
- Energy per unit areas, watts per square meter (W/m^2)

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

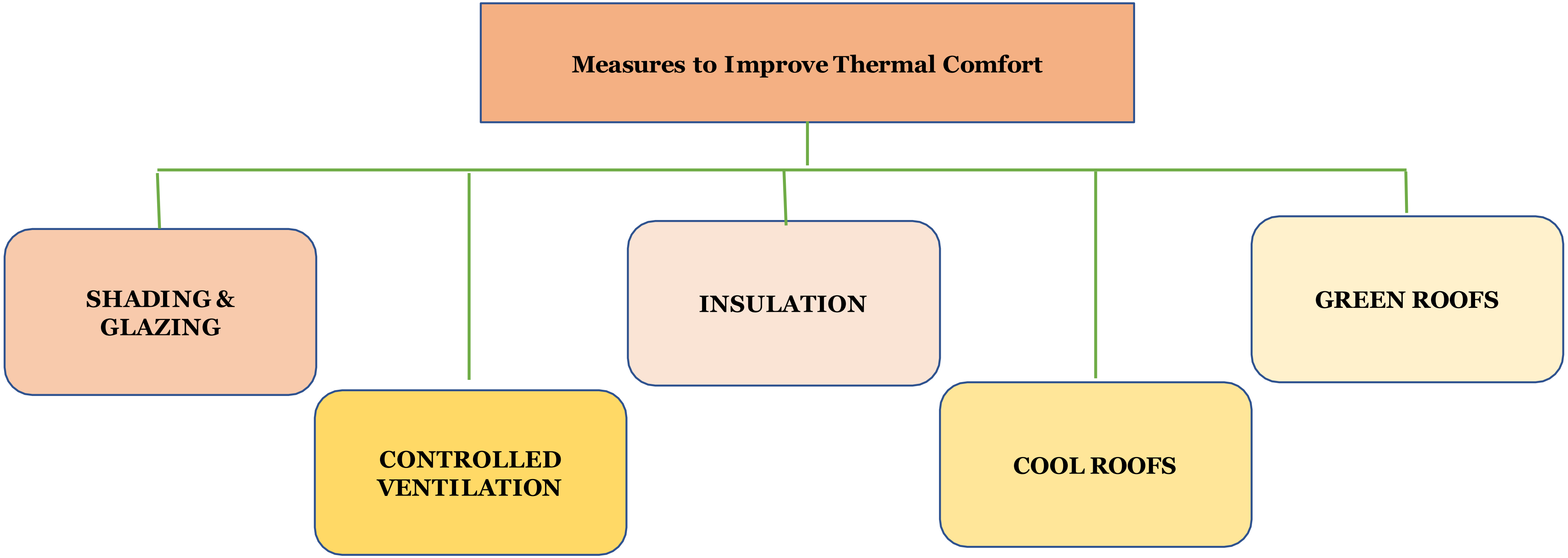
ACTIVITY	Met
Seated, Relaxed	1.0
Sedentary Activity (office, dwelling, school, laboratory)	1.2
Standing, Light Activity (shopping, laboratory, light industry)	1.6
Standing, Medium activity (shop assistant, domestic work, machine work)	2.0

METABOLIC RATE

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**

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

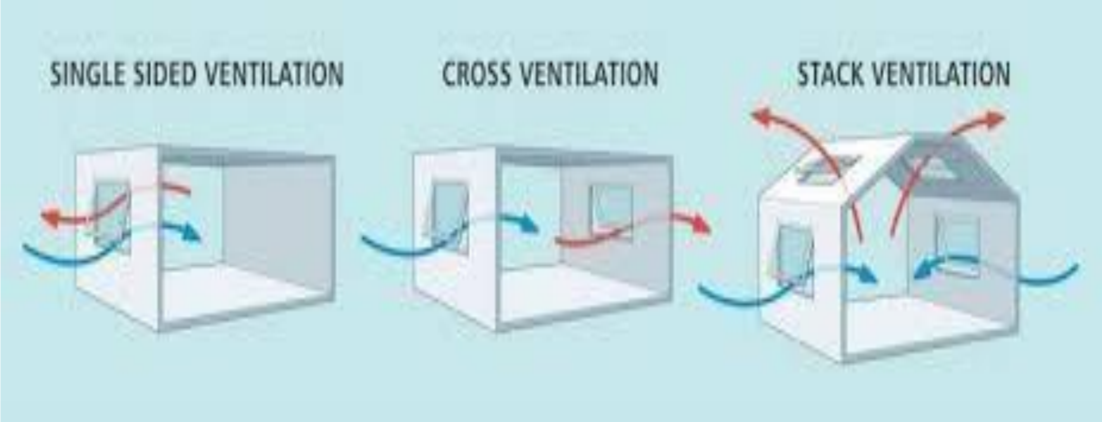
GLAZING

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.)

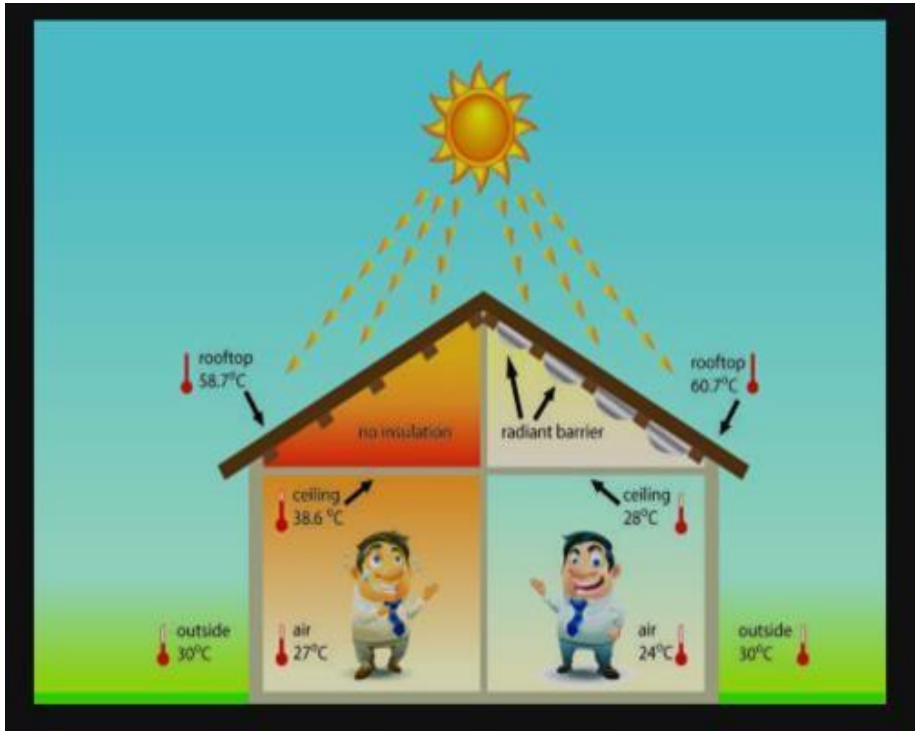
Controlled Ventilation

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	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
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		

Insulation



Heat Conduction takes place through

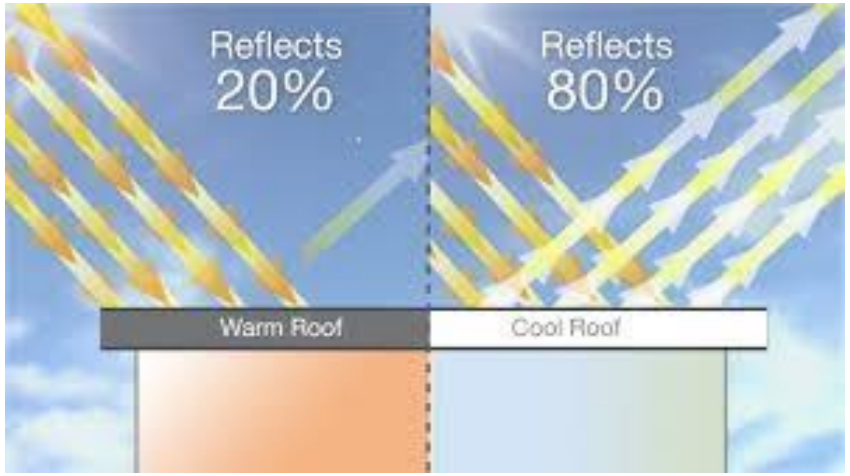
- Roof
- Walls
- Windows

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 is the 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

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Thermal Comfort Metrices – Preference, Comfort and Acceptability

Metabolic Rate

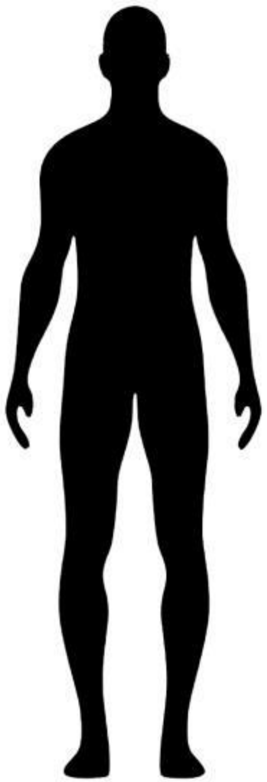
Clothing Insulation

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

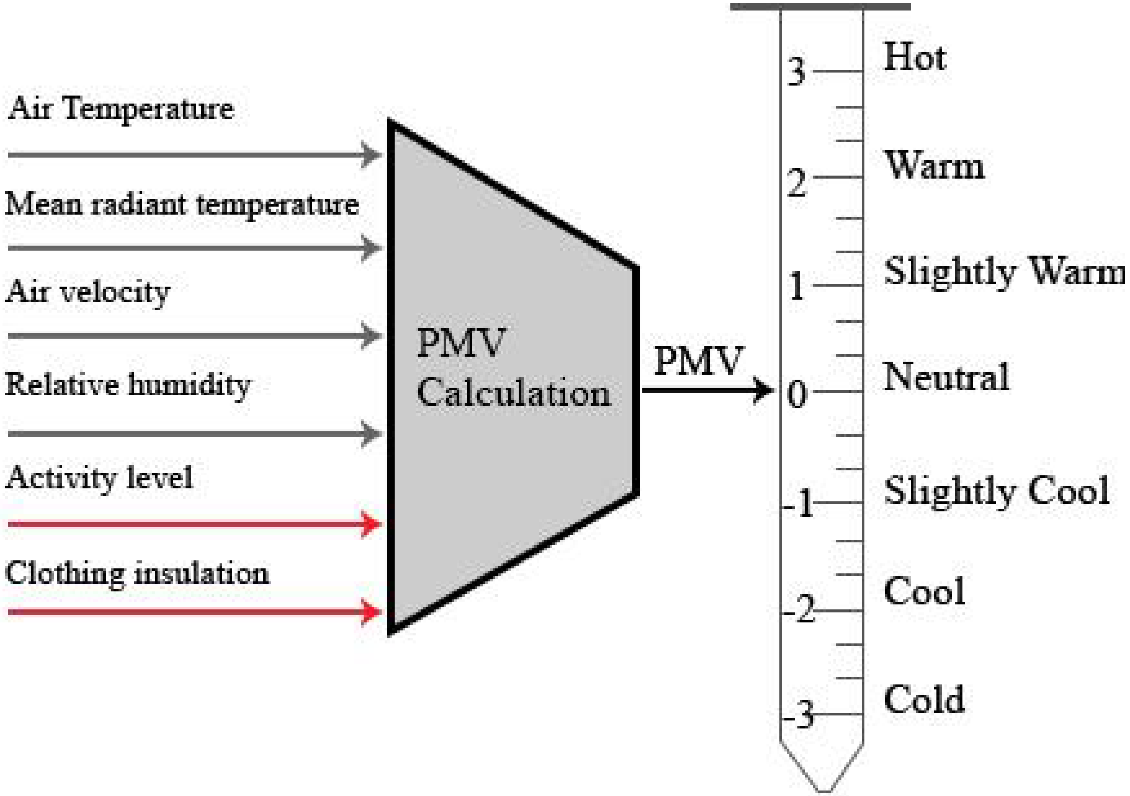
Thermal Comfort Metrices

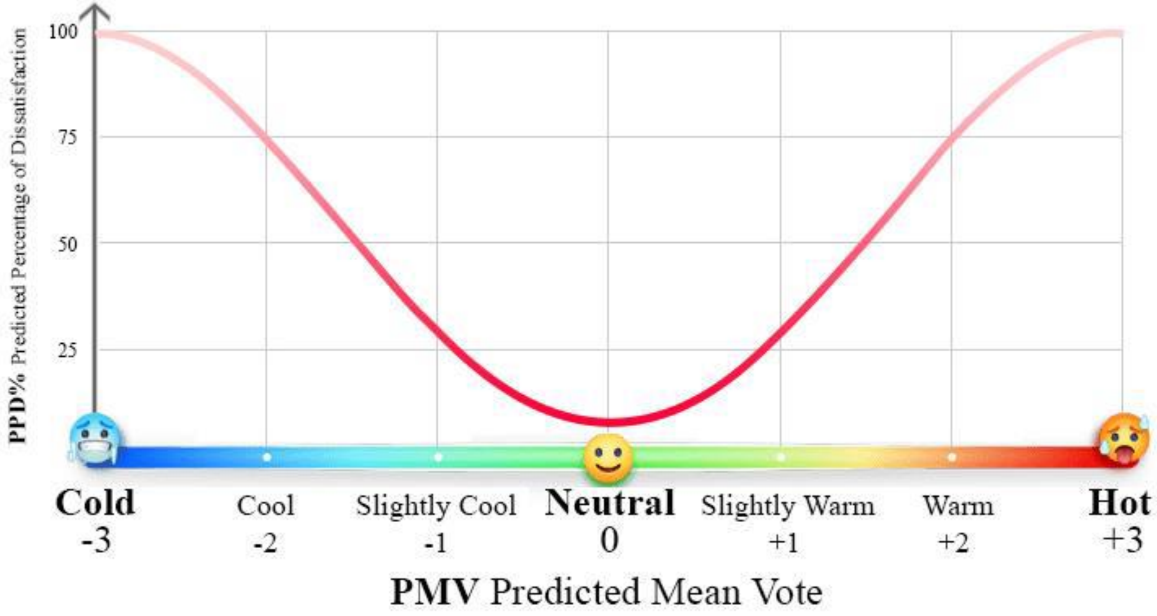
- Thermal Sensation
- Thermal Acceptance (Thermal Comfort)
- Thermal Preference
- Thermal Satisfaction

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	-	-

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

Lunch Break

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Session 3: Building Physics and Fundamentals of Thermal Comfort

09

Building Physics Affecting Thermal Comfort

Building Physics Affecting Thermal Comfort

Energy & Heat

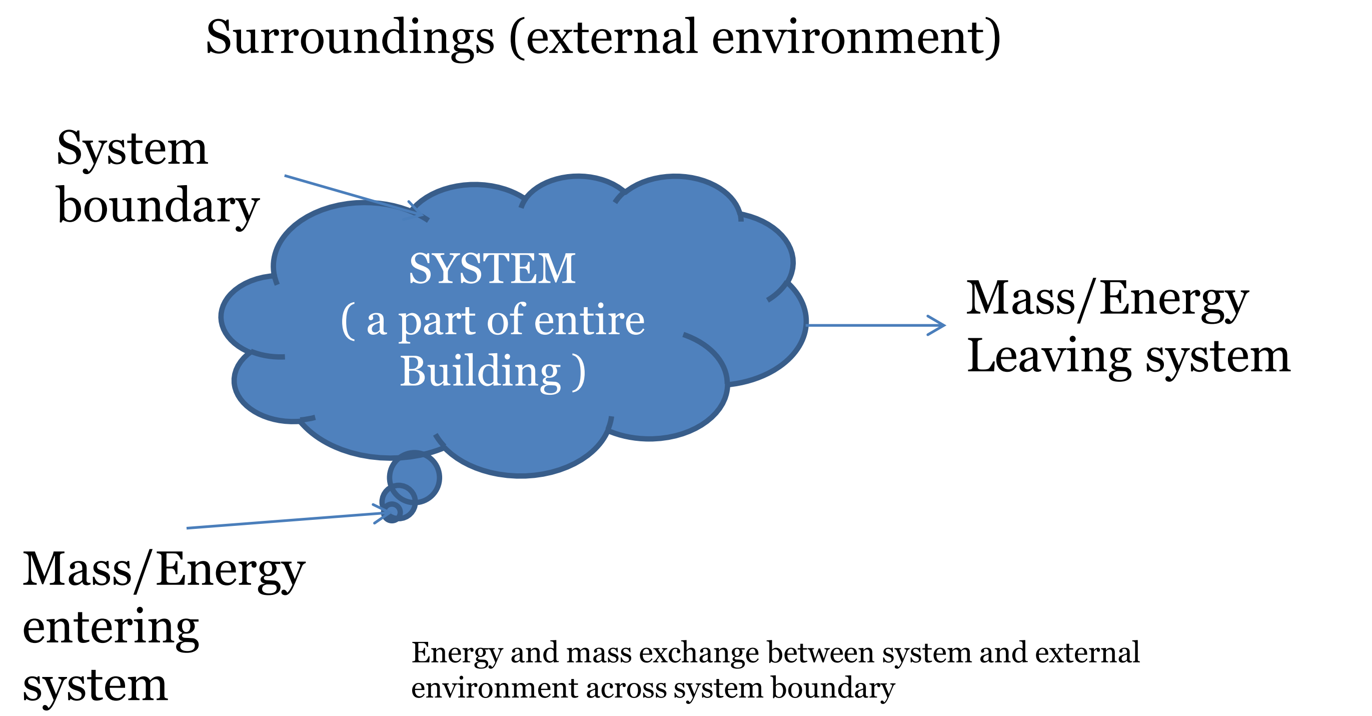
As chemical and atomic energy are not relevant in the context of buildings, the phrase "internal energy" is limited to perceptible and latent energy.

- **Macroscopic Energy** ⟷ **Microscopic Energy**
  - Macroscopic Energy:
    - Kinetic Energy
    - Potential Energy
  - Microscopic Energy:
    - Sensible Energy – resulting from the movement of molecules or atoms in translation, rotation, and vibration
    - Latent Energy – energy released or gained to switch phases
    - Chemical Energy – as a result of atomic bonds
    - Atomic Energy – due to connections that exist within the nucleus.

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

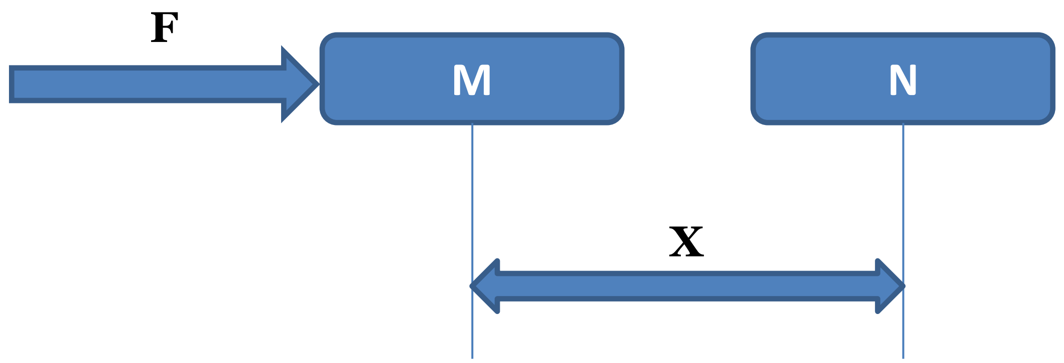
The envelope is regarded as the boundary when a building is viewed as a system in order to comprehend its thermal interactions with the surrounding environment.

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

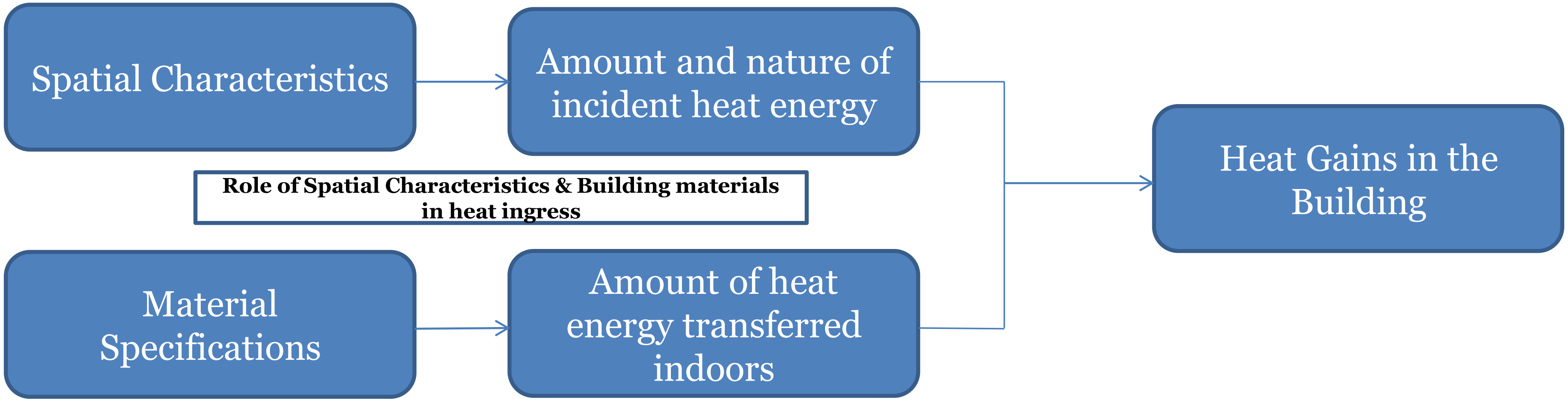
the amount of heat transferred inside a building is a function of the following

- 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

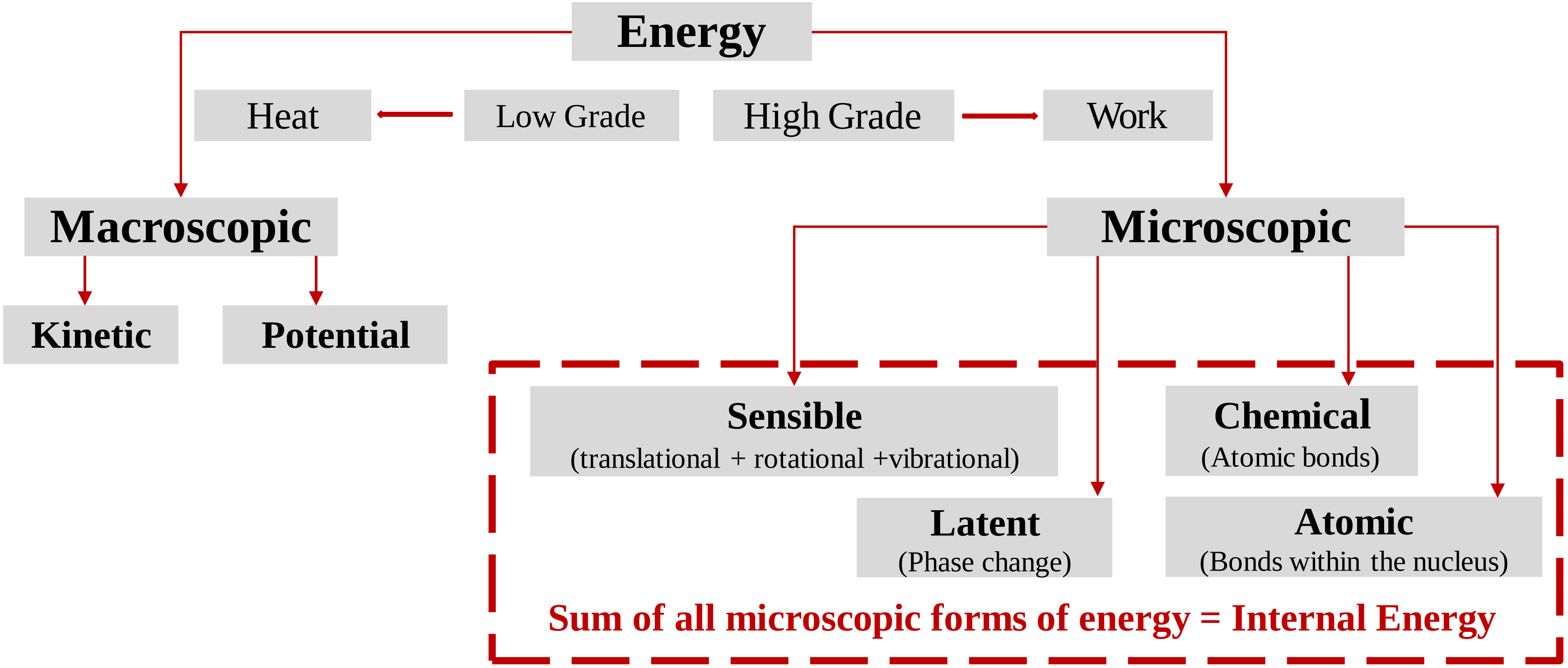
Factors Influencing Heat Transfer

- 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

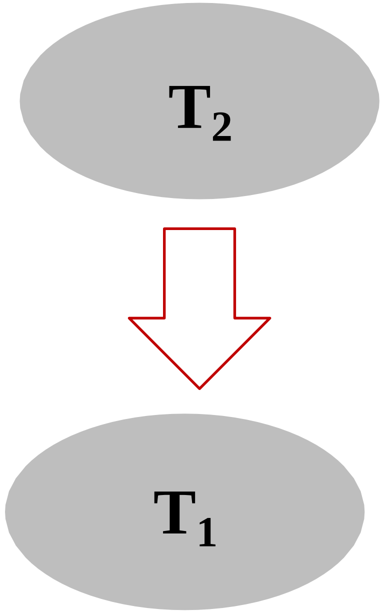
Establishes a relationship between a system's

- 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

2^{nd} Law of Thermodynamics

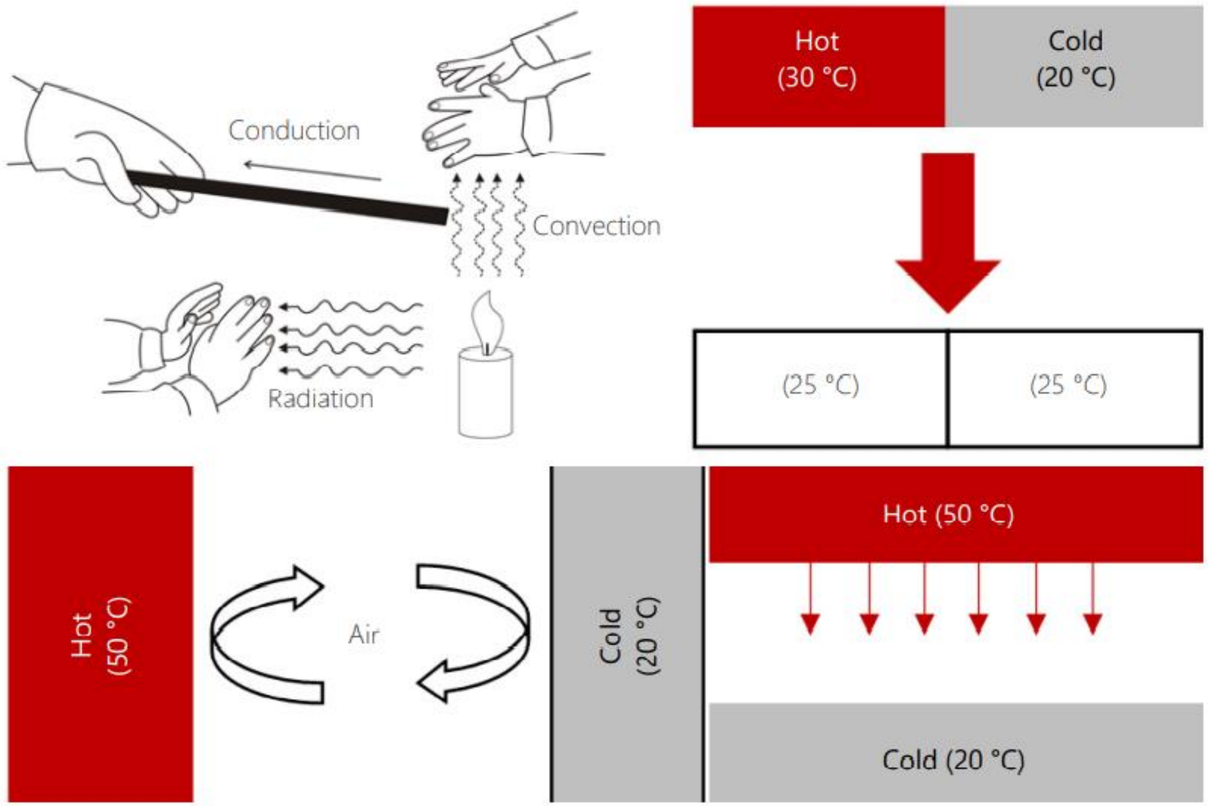


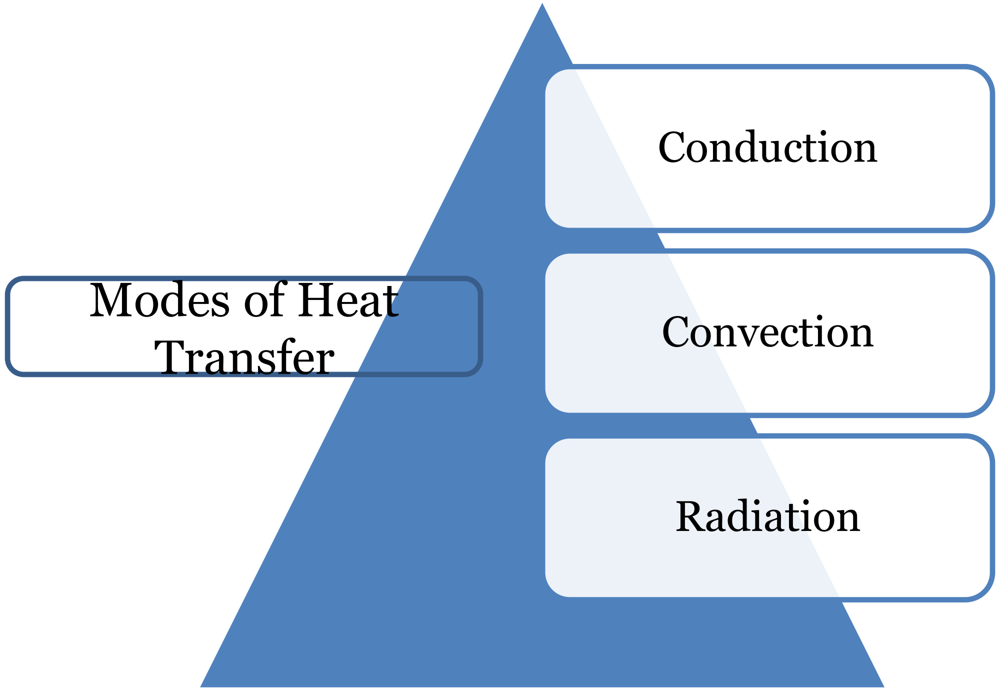
$(T_2 > T_1)$

- The natural (spontaneous) direction of heat flow between bodies is from hot to cold.
- Heat moves from higher temperature to lower temperature

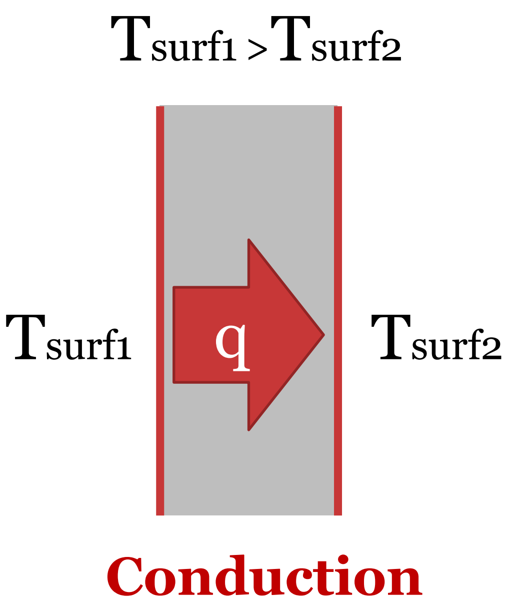
Building Physics Affecting Thermal Comfort

Modes of Heat Transfer





Heat Transfer in Buildings – Conduction Principles



Occurs in a stationary medium

Hot objects with higher energy

(due to intense random molecular motions)

transfer heat to

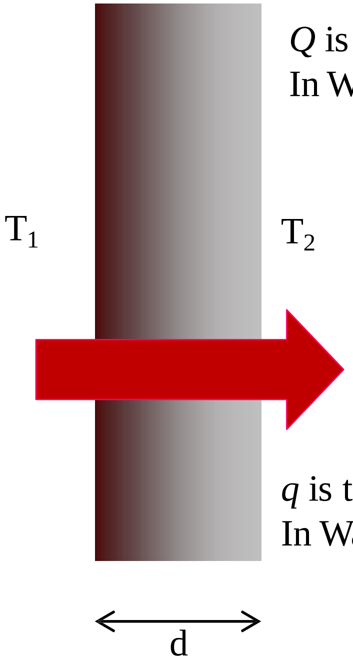
Cool objects with lesser

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



Q is the heat rate
In Watts

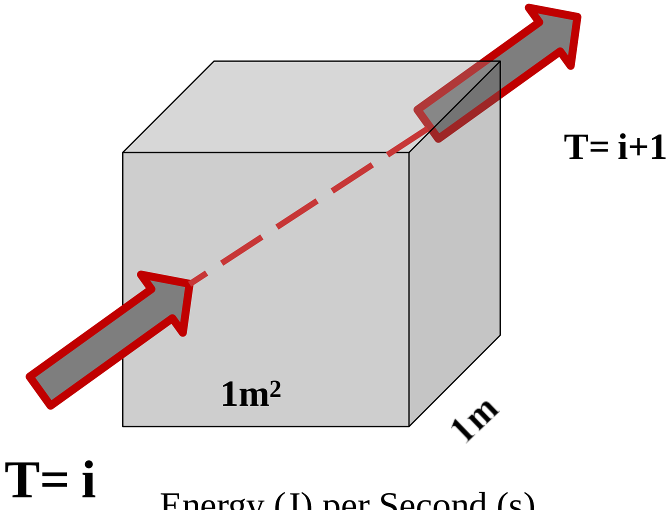
q is the heat flux
In Watts/m²

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



Energy (J) per Second (s)
J/s = W

_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

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/m^3)	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

Heat Transfer in Buildings – Conduction Principles

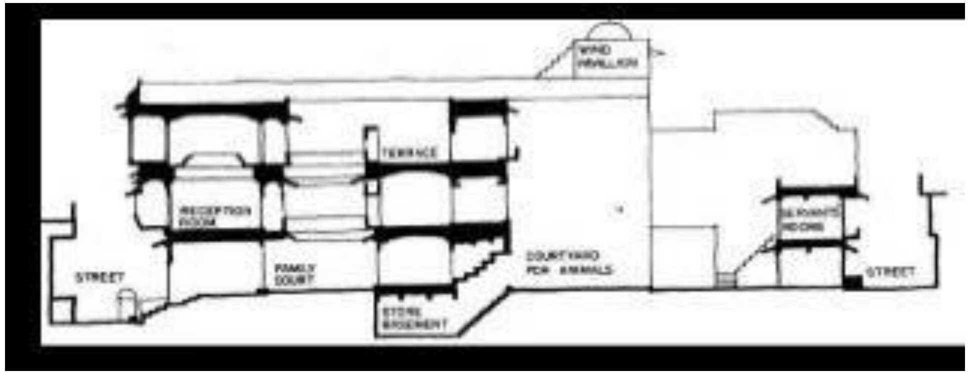
Energy & Heat

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

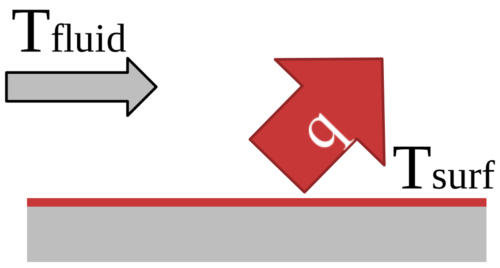
Heat Transfer in Buildings – Conduction Principles



Conduction through walls

Heat Transfer in Buildings – Convection Principles

$T_{surf} > T_{fluid}$

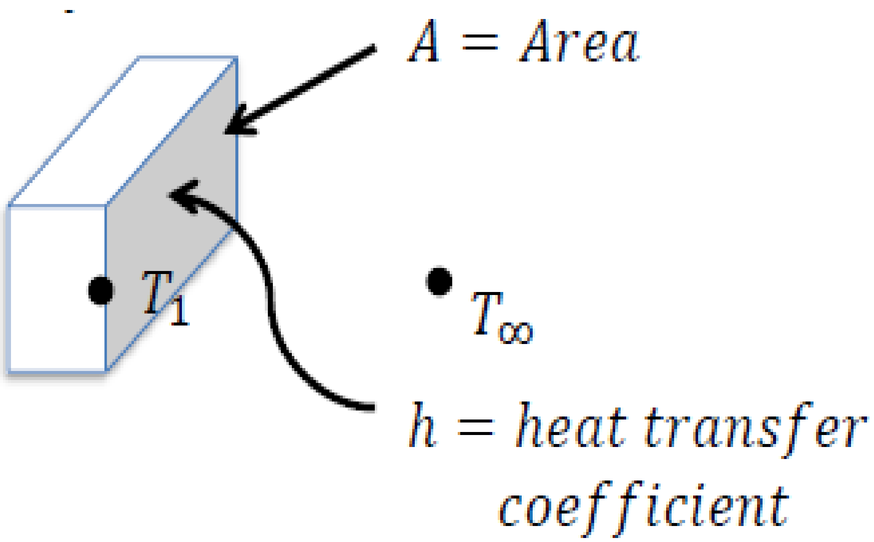


Convection

- 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

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Heat Transfer in Buildings – Convection Principles

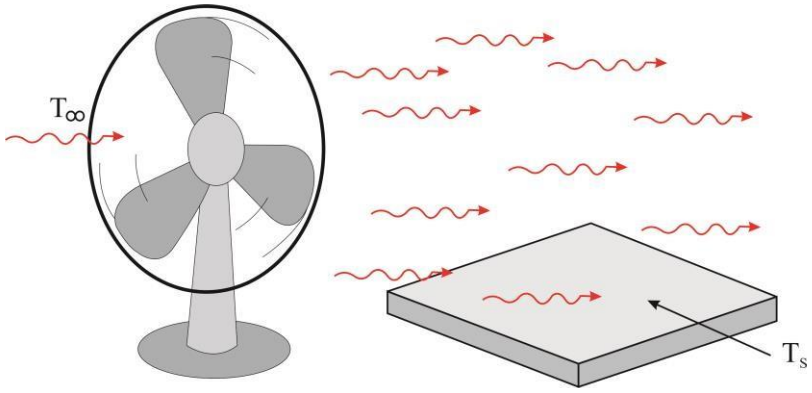
Surface resistance (ISO 6946)		
Heat flow direction	R_{si} [$m^2 \cdot K \cdot W^{-1}$]	R_{so} [$m^2 \cdot K \cdot W^{-1}$]
Horizontal (±30°)	0.13	0.04
Up	0.10	0.04
Down	0.17	0.04

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

$h = h_c + h_r$

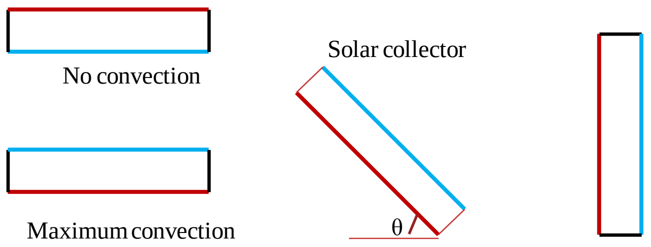
h_c = convective heat transfer coefficient

h_r = radiative heat transfer coefficient

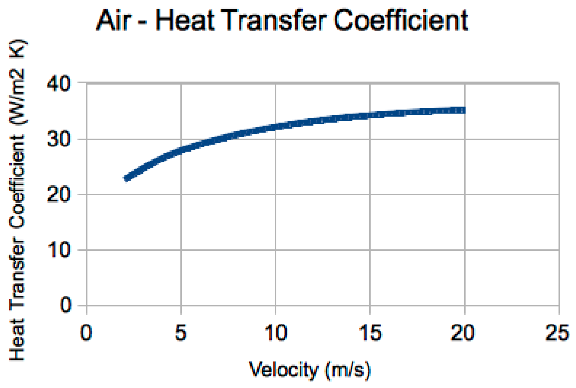
Natural Convection – Forced Convection

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

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Heat Transfer in Buildings – Convection Principles

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

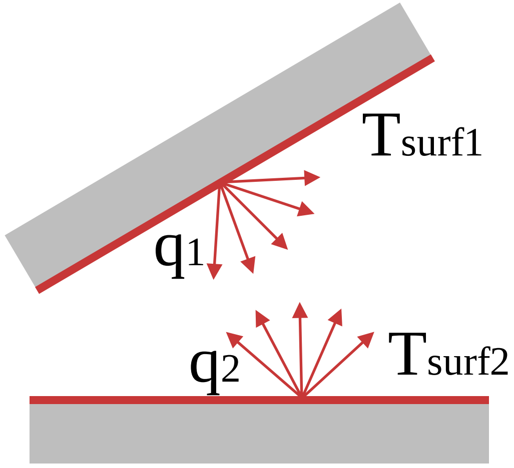
Wind-induced airflow

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

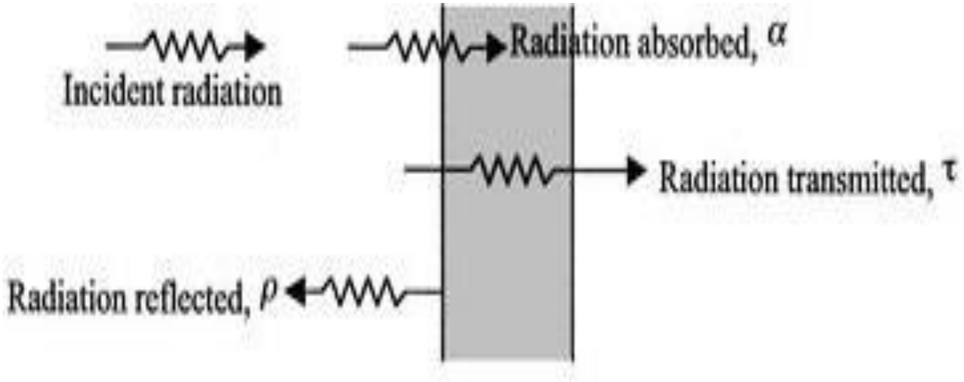
- Radiation heat transfer is a process where heatwaves are emitted that may be absorbed, reflected, or transmitted through a colder body.
- Energy has an electric field and a magnetic field associated with it,
- Wave-like properties. “electromagnetic waves”
- Wide range of electromagnetic radiation in 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	Neutral	V. High	Neutral	Neutral	Neutral	Low
Fenestrations (Windows)	High	V. High	High	Neutral	V. High	V. High
Roofs	Low	High	V. Low	V. Low	High	V. High

- 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/

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/

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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:

$$M-W= q_{sk}+q_{res}+S=(C+R+ E_{sk})+(C_{res}+ E_{res})+(S_{sk}+ S_{cr})$$

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

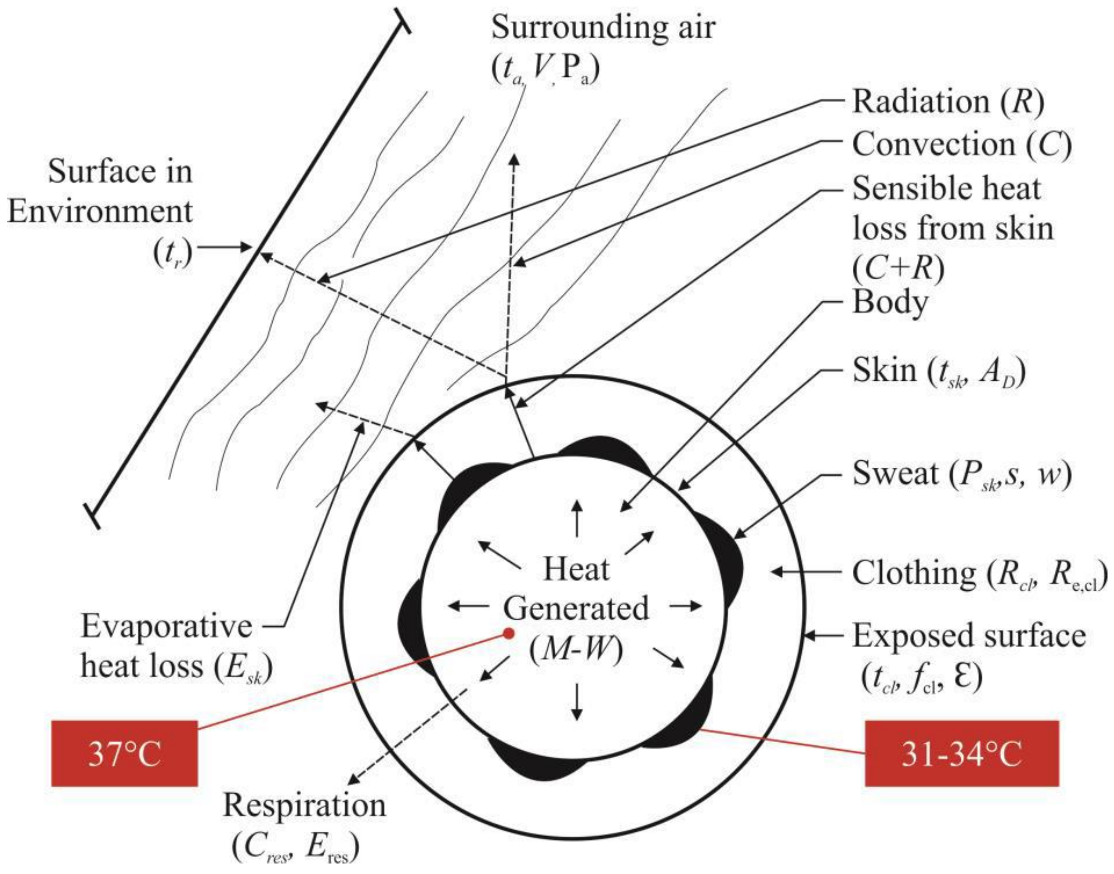
E_{res} = Rate of evaporative heat loss from respiration, W/m 2

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

Physiological Thermoregulation

Thermo reception & Integration

Body Heat- Balance

Indoor Climate

Thermal Dis/ Comfort

Behavioural Thermoregulation

Human Thermal Comfort Depends upon

- Physiology
- Psychology
- Behaviour

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

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

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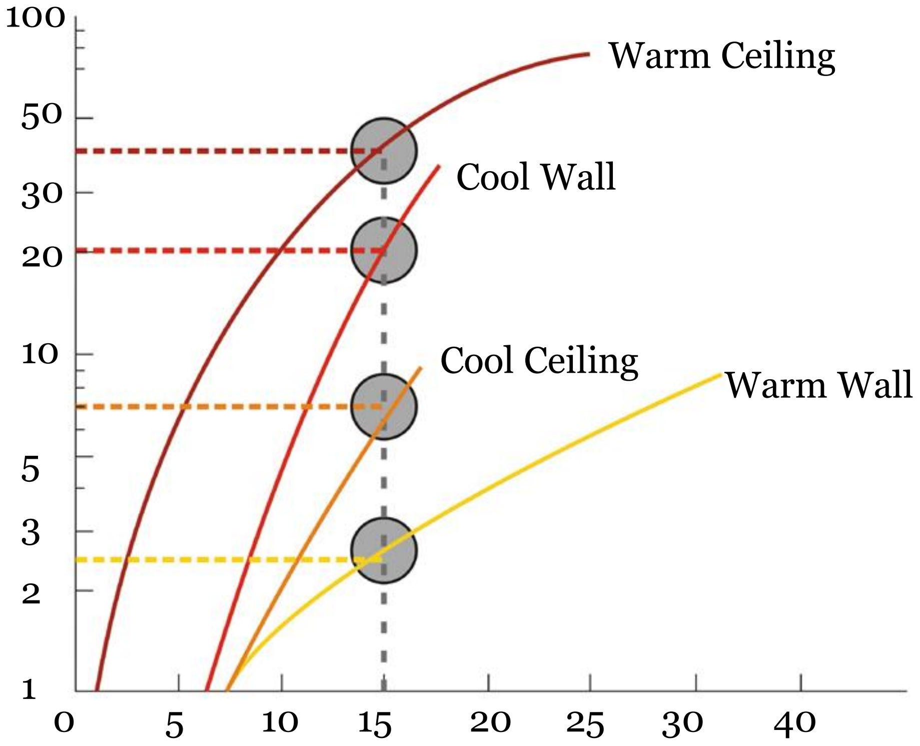
Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



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.

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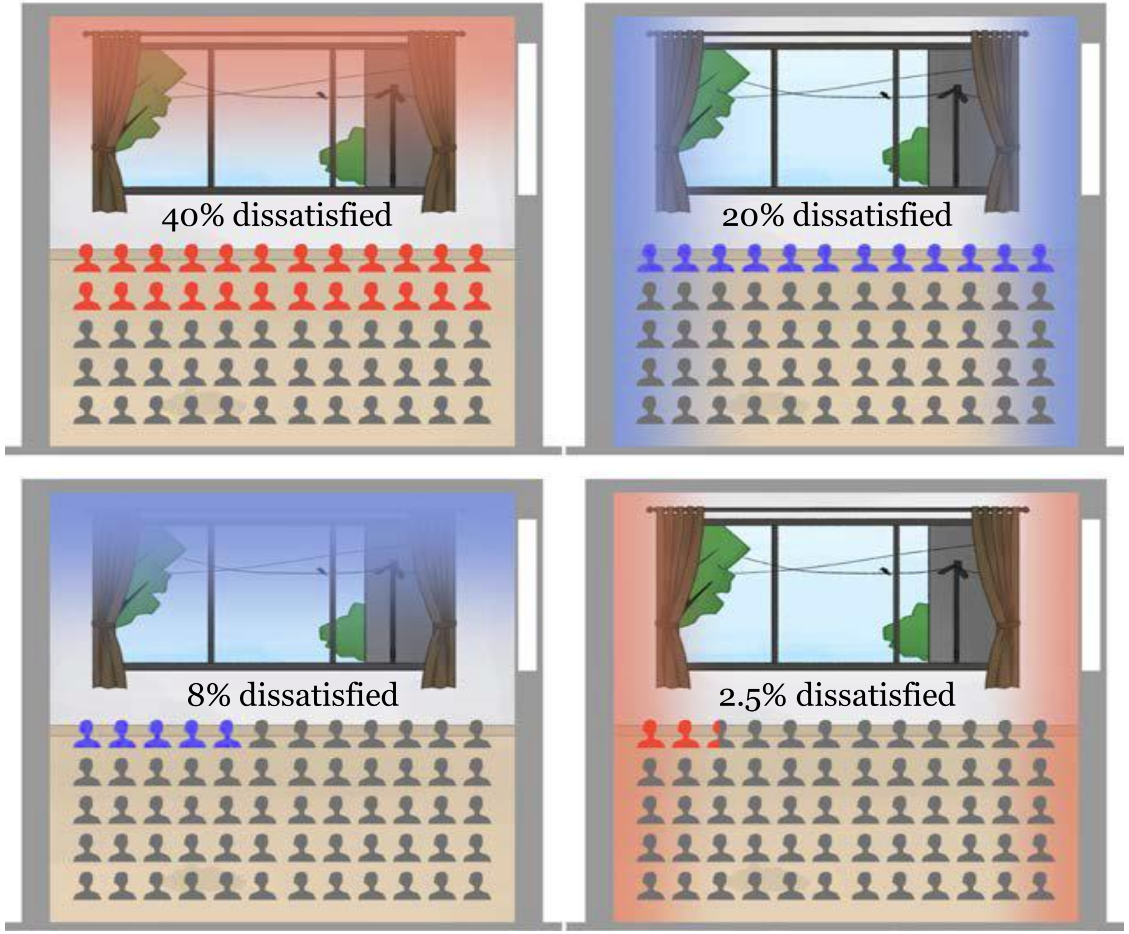
Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



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

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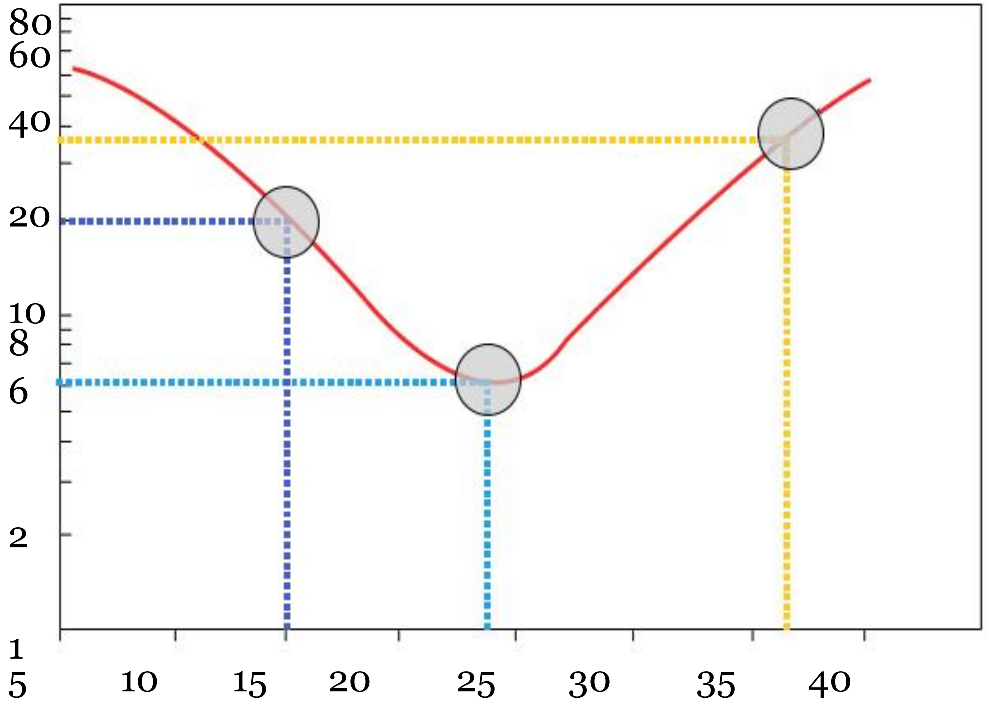
Local Thermal Discomfort due to Radiant Temperature Asymmetry – Floors



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..

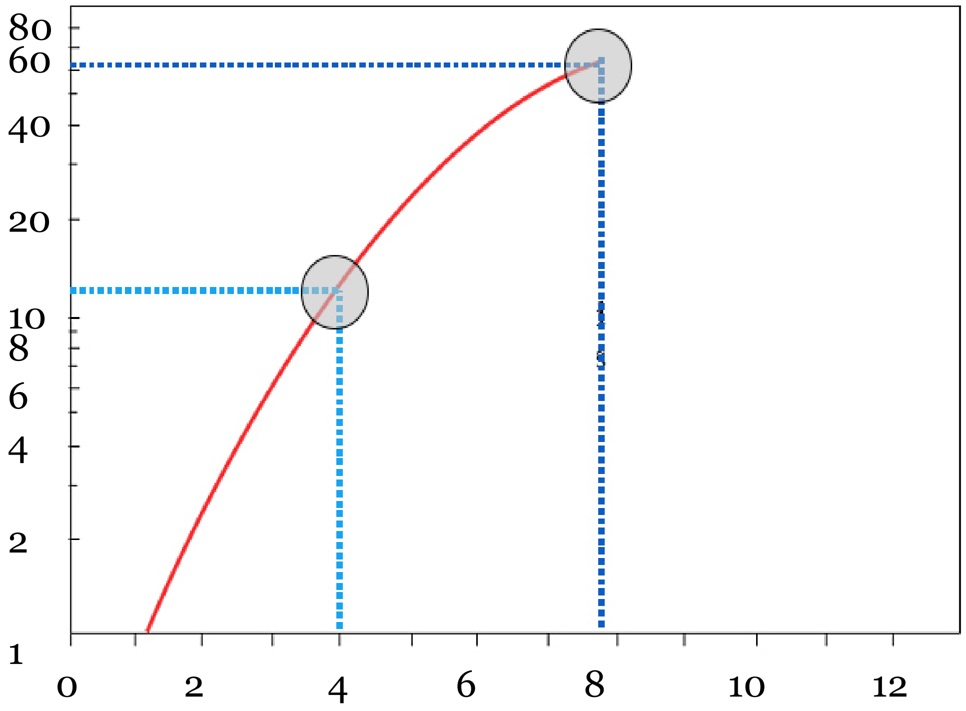
Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

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

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- ❑ The sensitivity level of these receptors towards heat or coolth.

Session 4: Passive Strategies & Building Materials

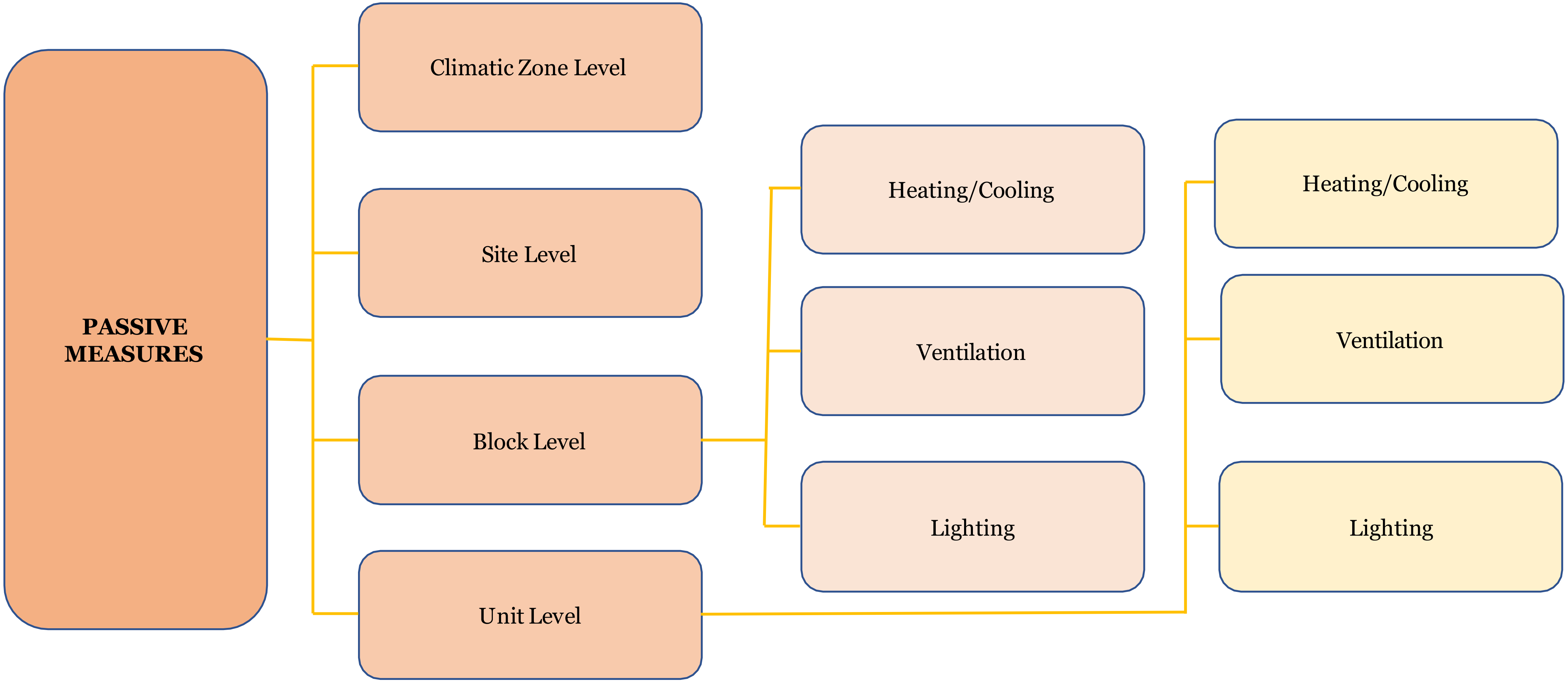
12

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



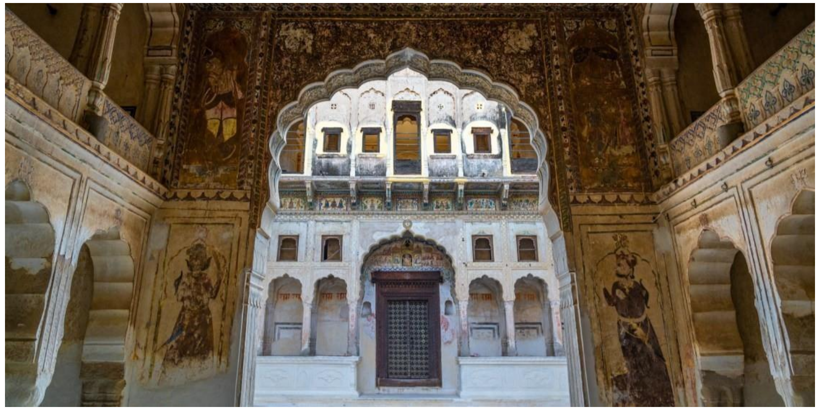
Passive Strategies & Building Physics

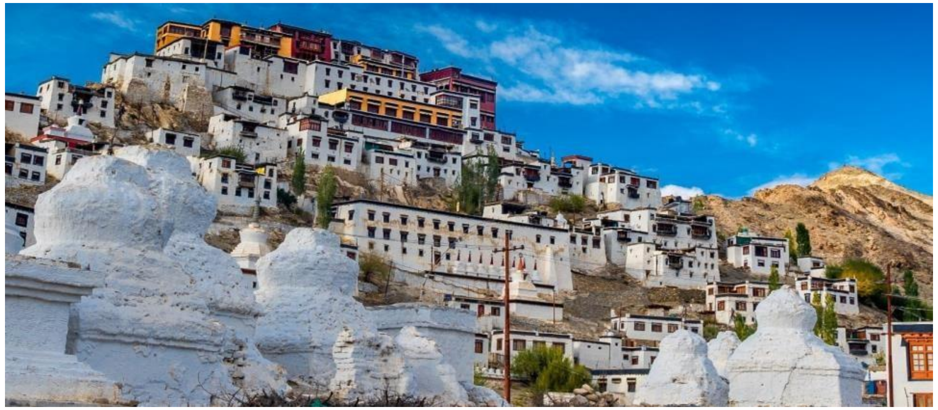
Passive Measures – Climatic Zone Level

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.





Passive Strategies & Building Physics

Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

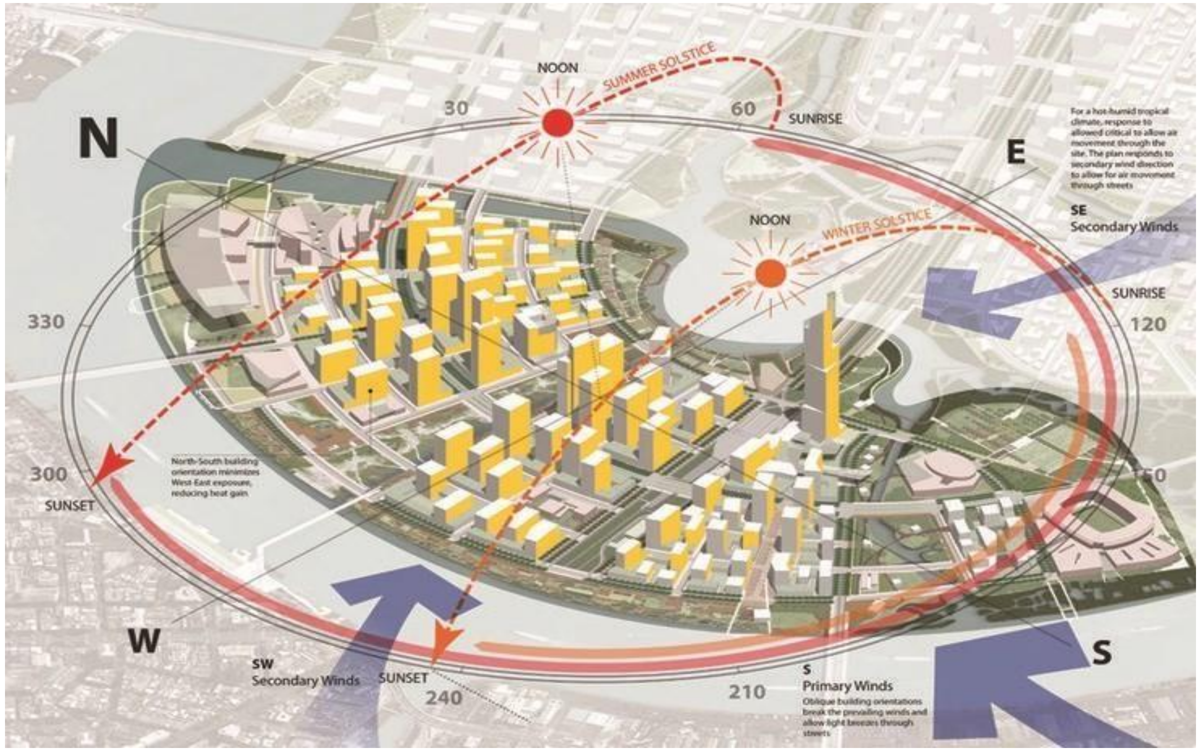
Courtyards / open courts are often surrounded by construction.

Taking advantage of block mutual shading

Using site massing to create wind passageways

lowering the amount of hard paving to allow for water absorption

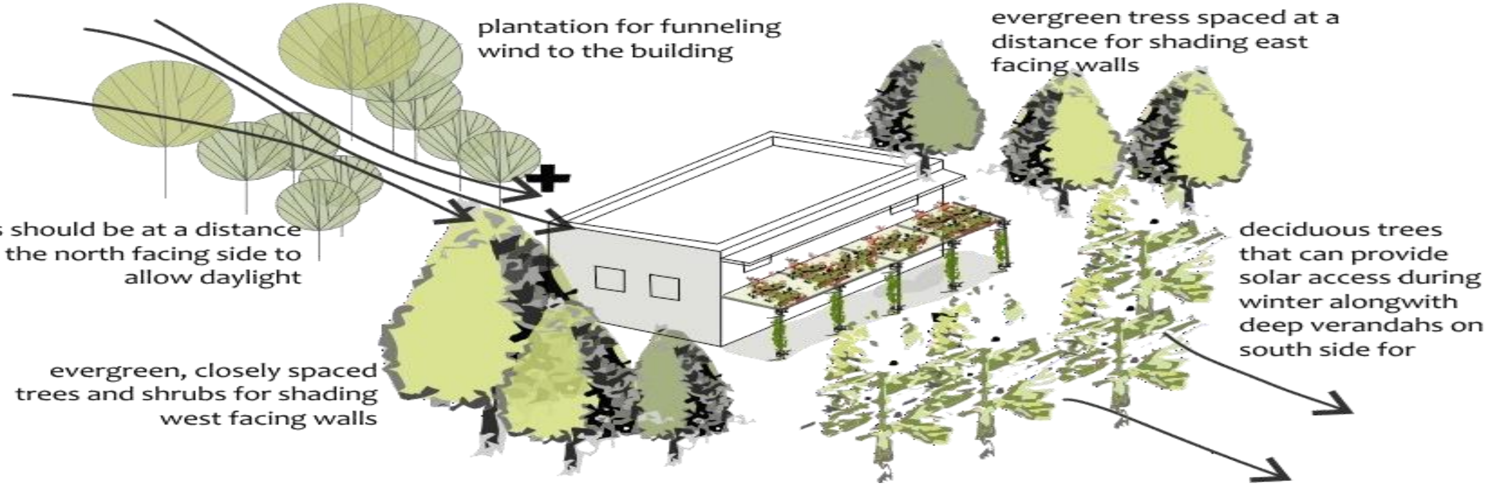
Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change

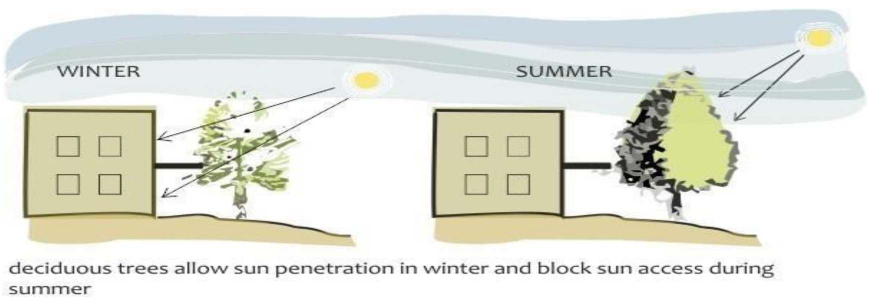


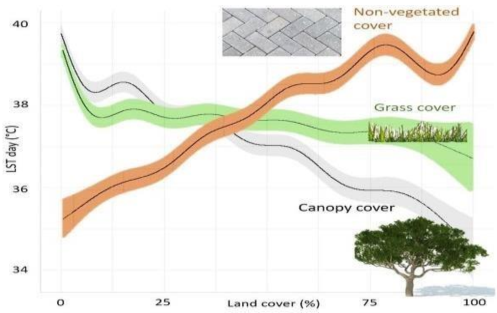
Passive Strategies & Building Physics

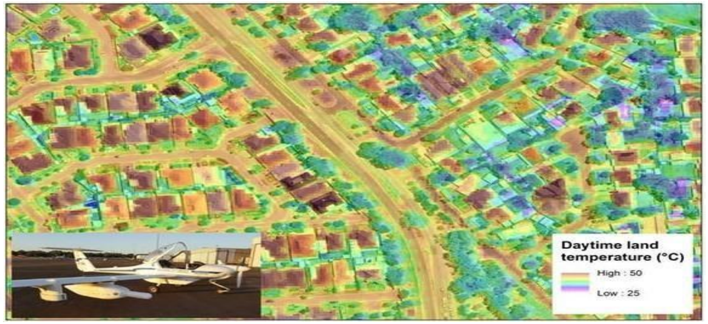
Passive Measures – Leveraging Plantation

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.





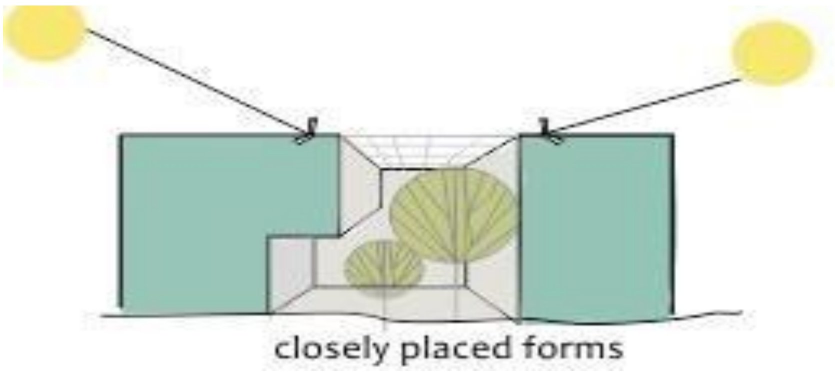


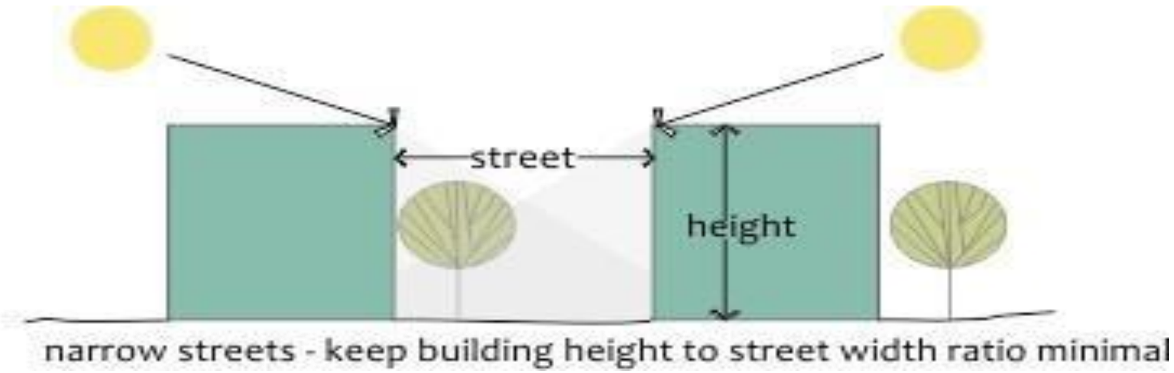


Passive Strategies & Building Physics

Block Level

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



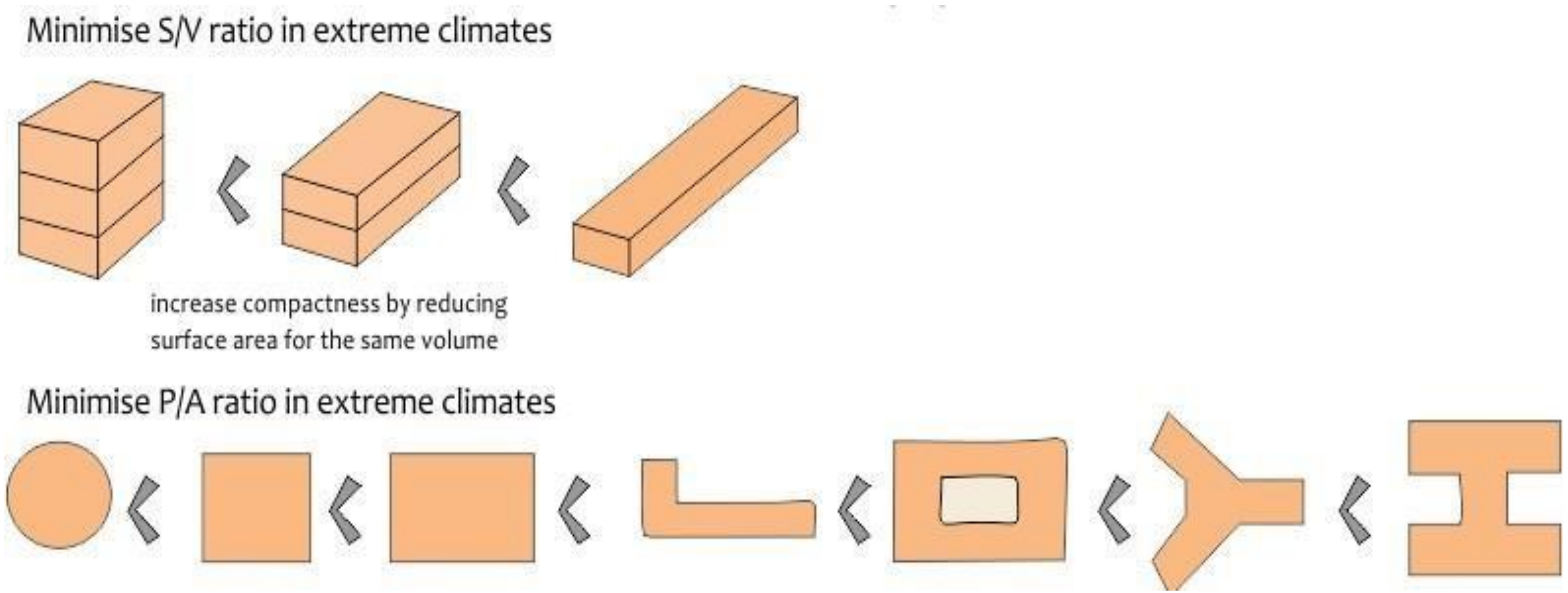


HEATING/ COOLING

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.

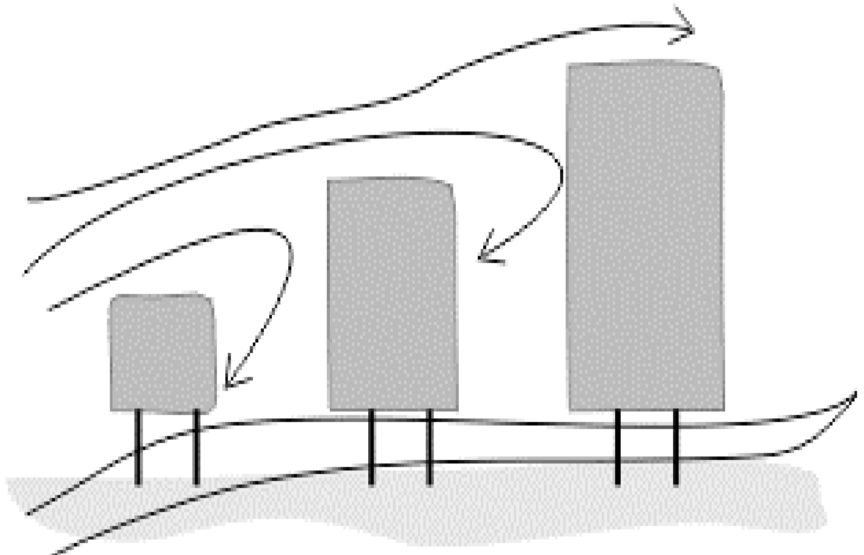


HEATING/ COOLING

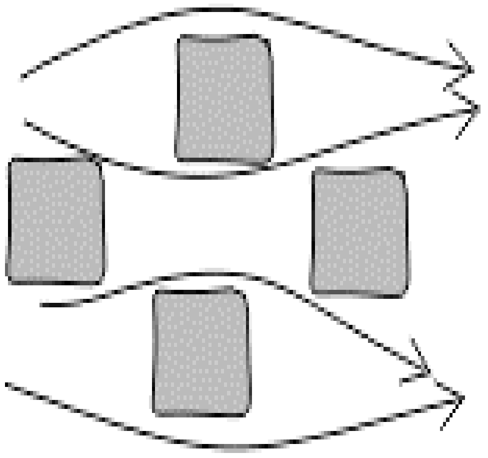
Passive Strategies & Building Physics

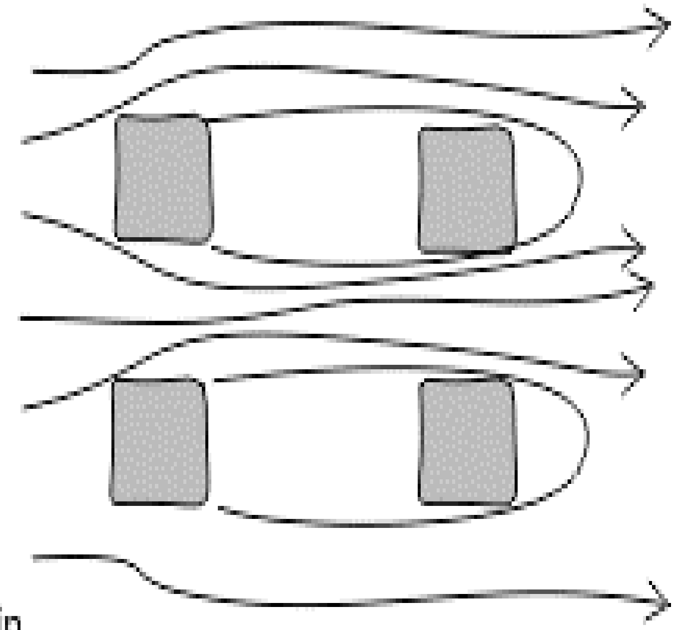
Block Level

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

VENTILATION

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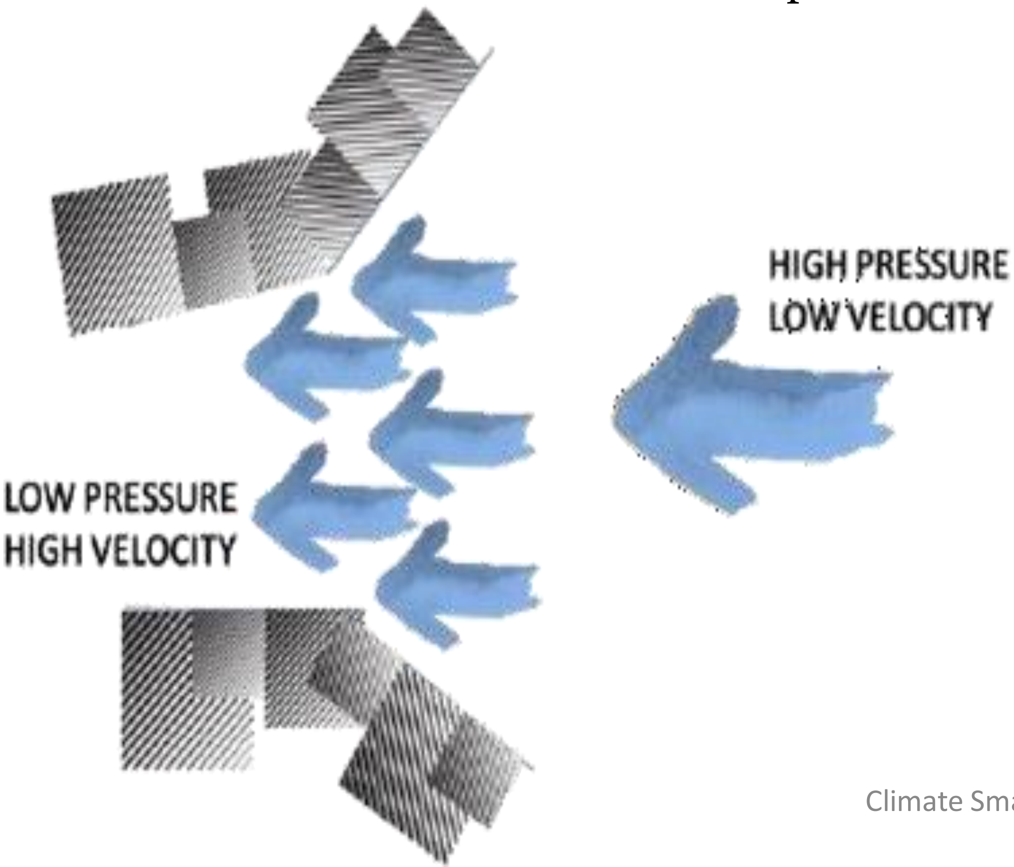
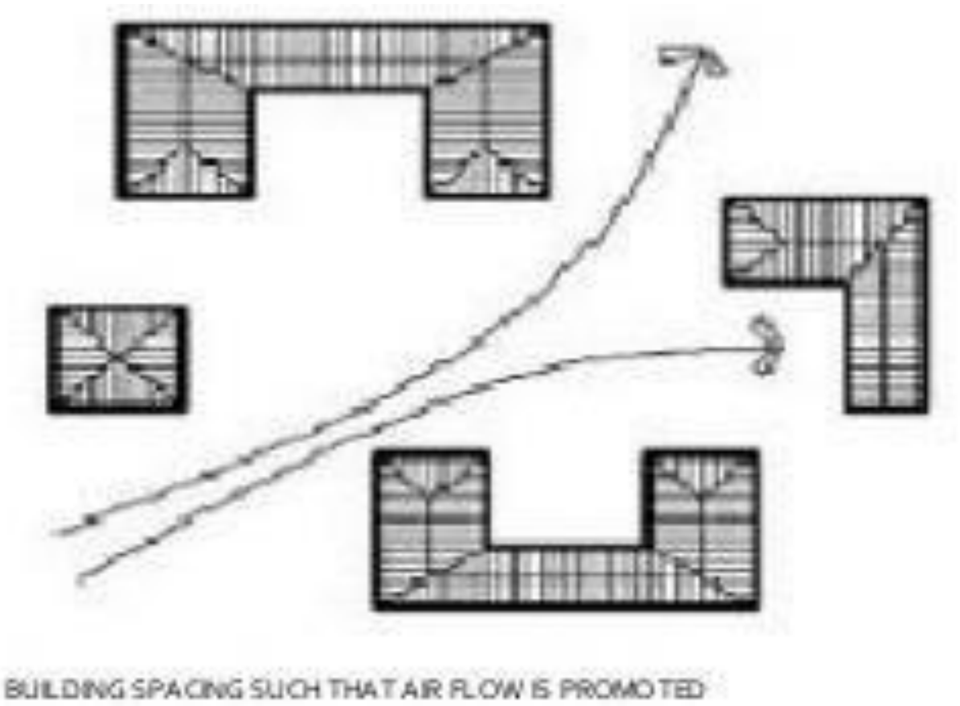
Passive Strategies & Building Physics

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.





VENTILATION

Passive Strategies & Building Physics

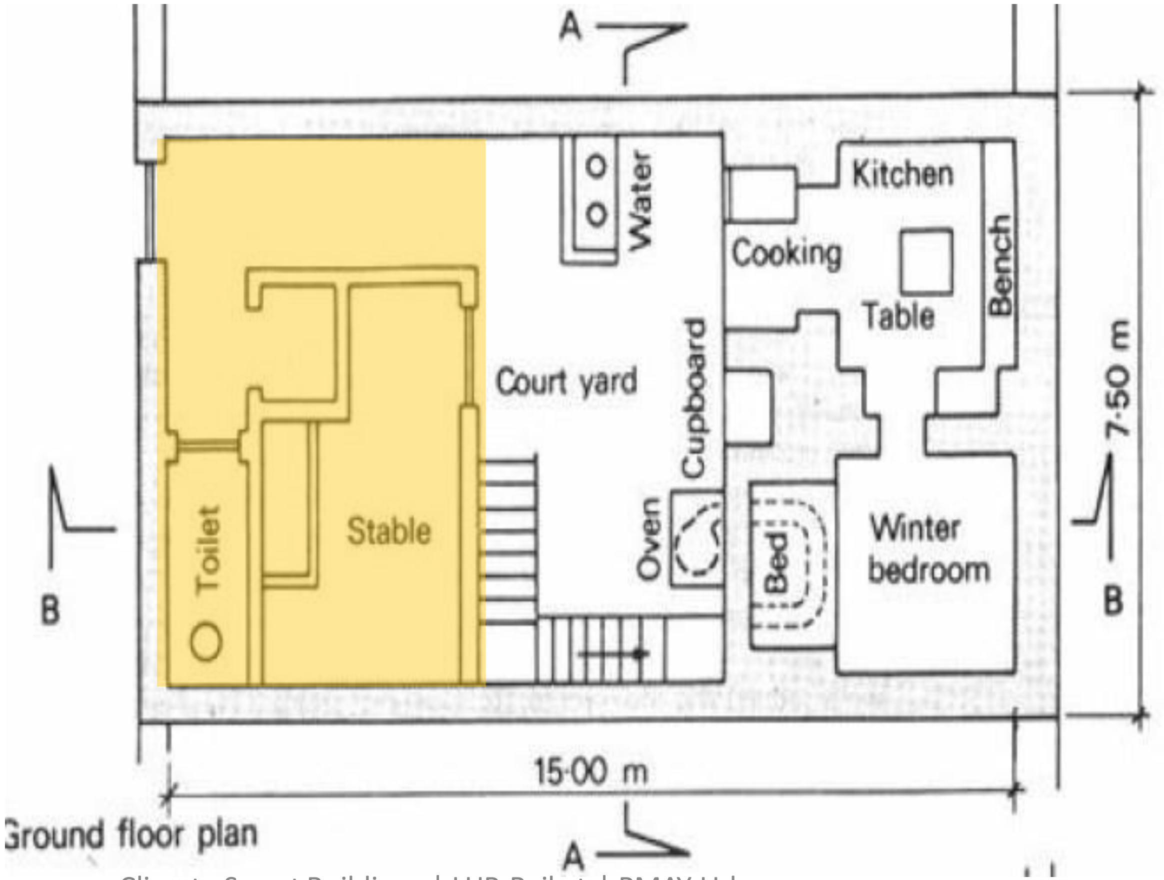
Unit Level

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

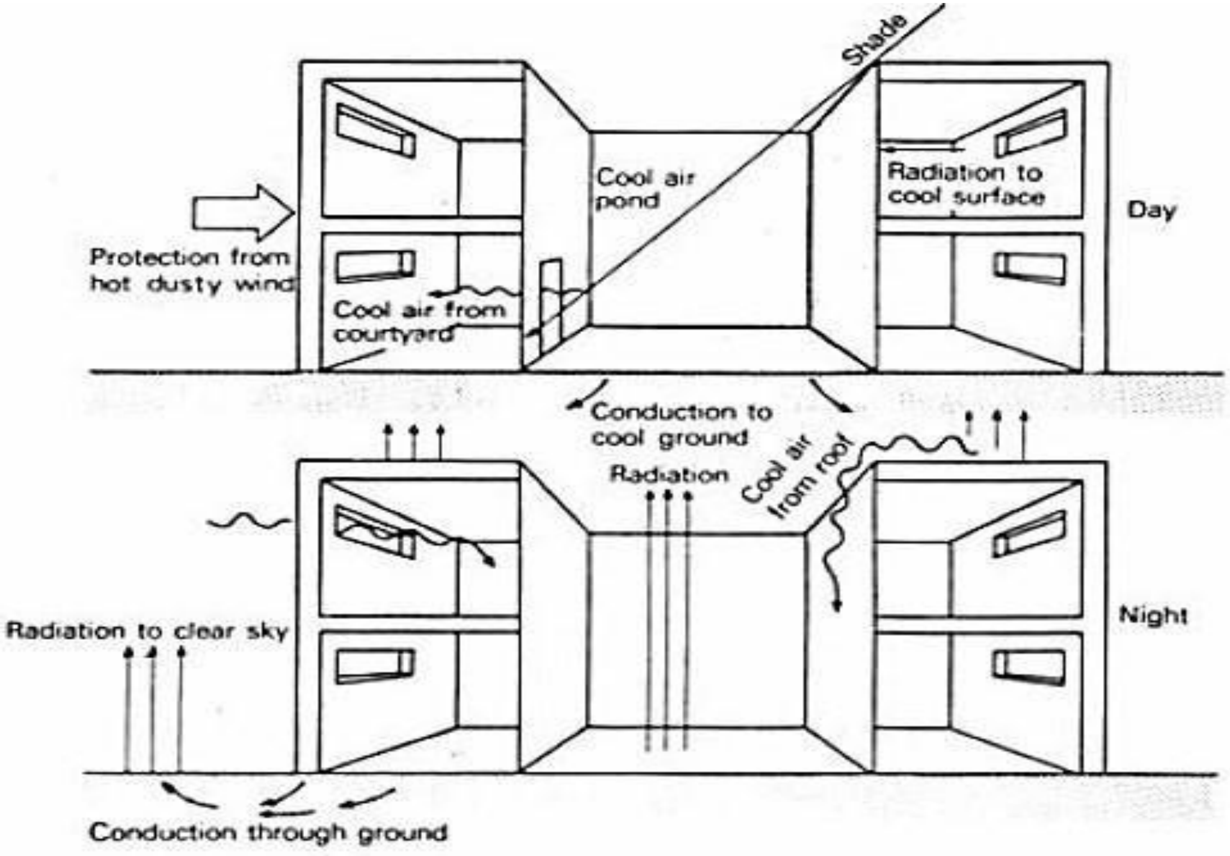
Passive Strategies & Building Physics

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

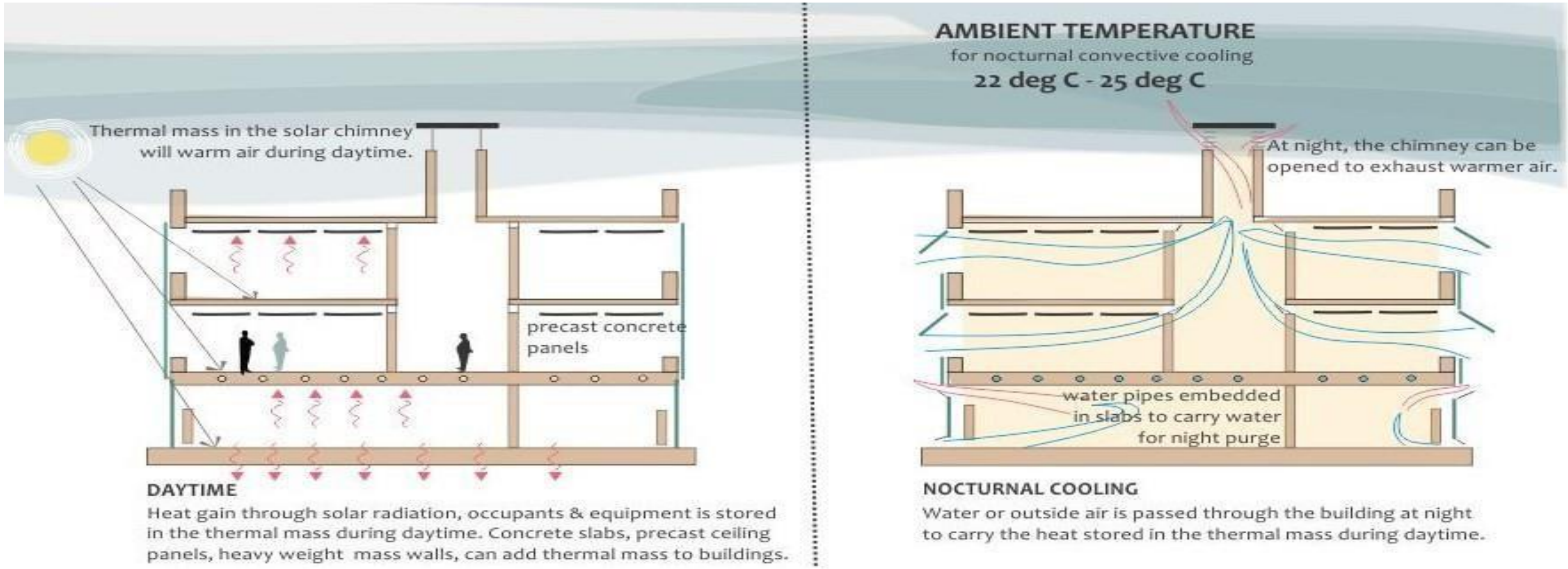
Passive Strategies & Building Physics

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

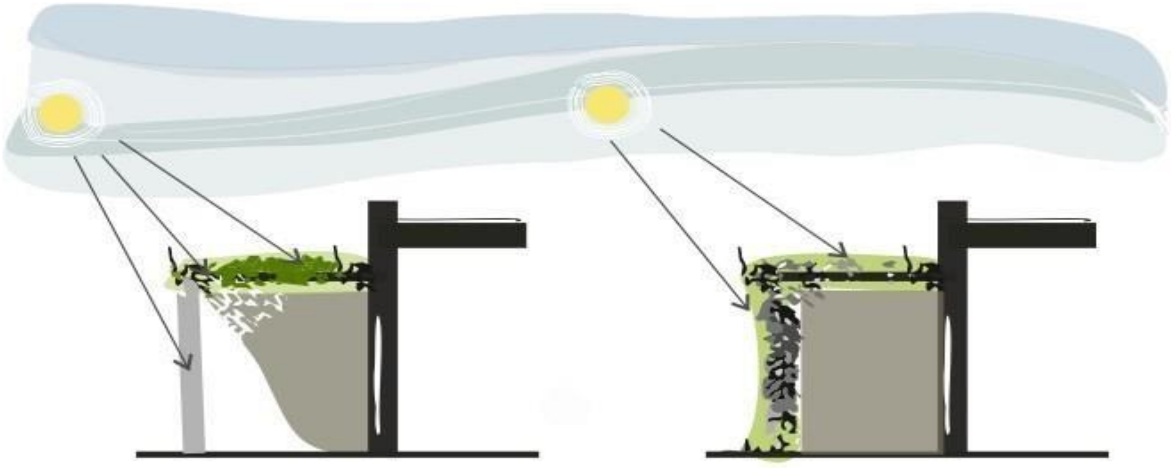
Passive Strategies & Building Physics

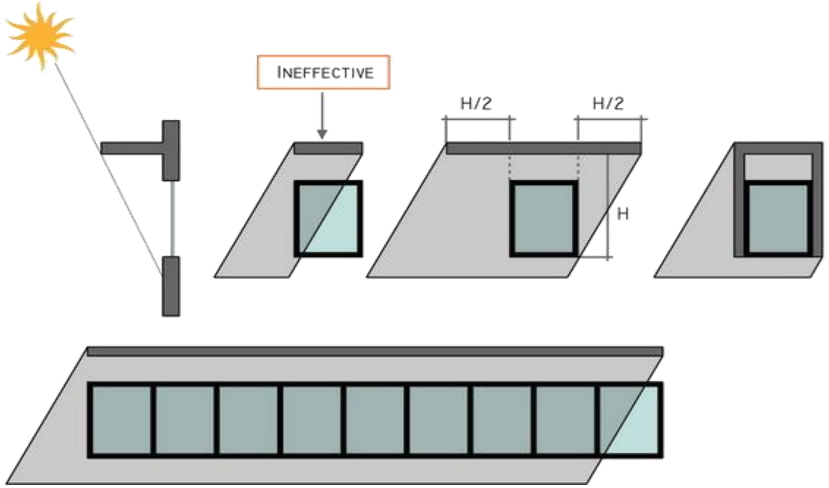
Unit Level

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

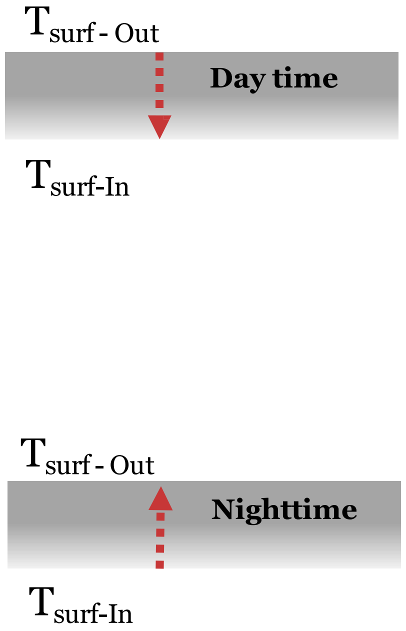
13

Innovative Building Materials

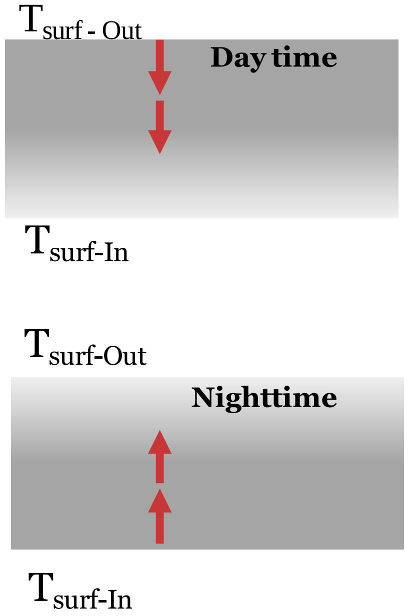
Walling Material and Walling Assemblies

Heat Transfer in Buildings: Insulation and Thermal Mass

Thermal Insulation, Thermal Conductivity



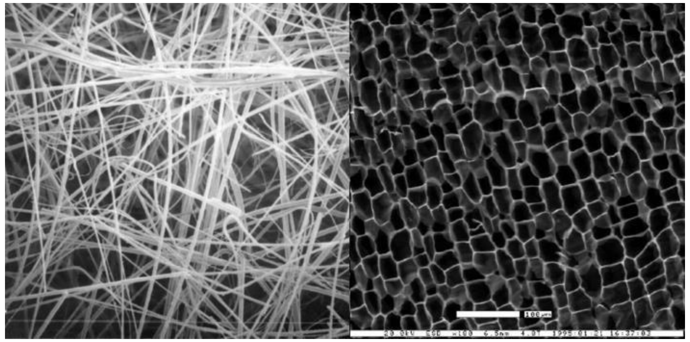
Thermal Insulation, Specific Heat Capacity



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

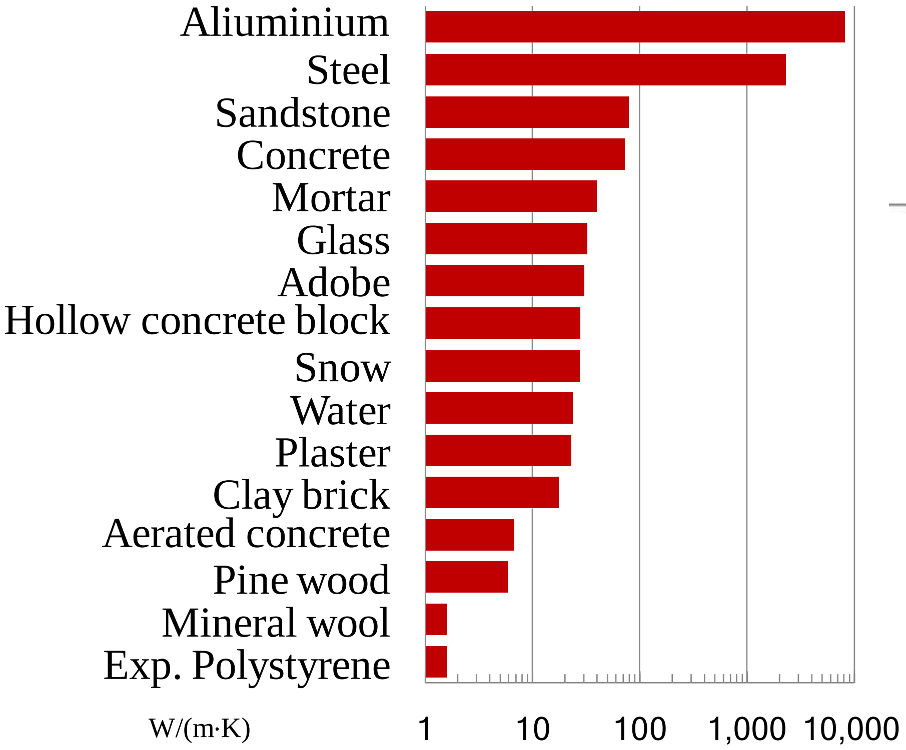
Air is locked in foam bubbles or between fibers

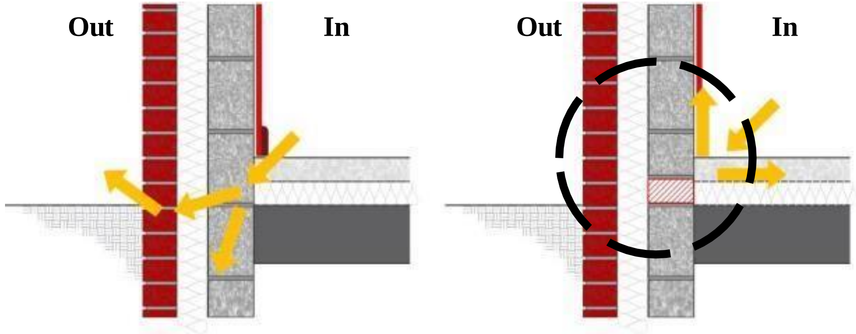
Bubble walls and fibers are themselves opaque to thermal radiation.

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

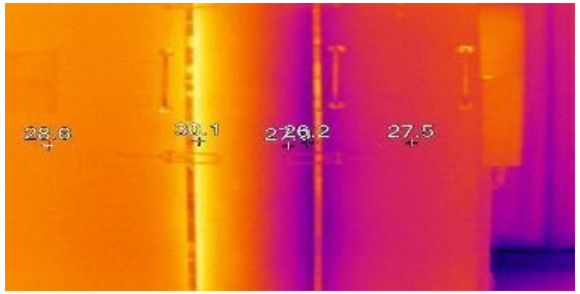
Walling Material and Walling Assemblies

Walling Materials and Methods : Conductivity & Thermal Bridge





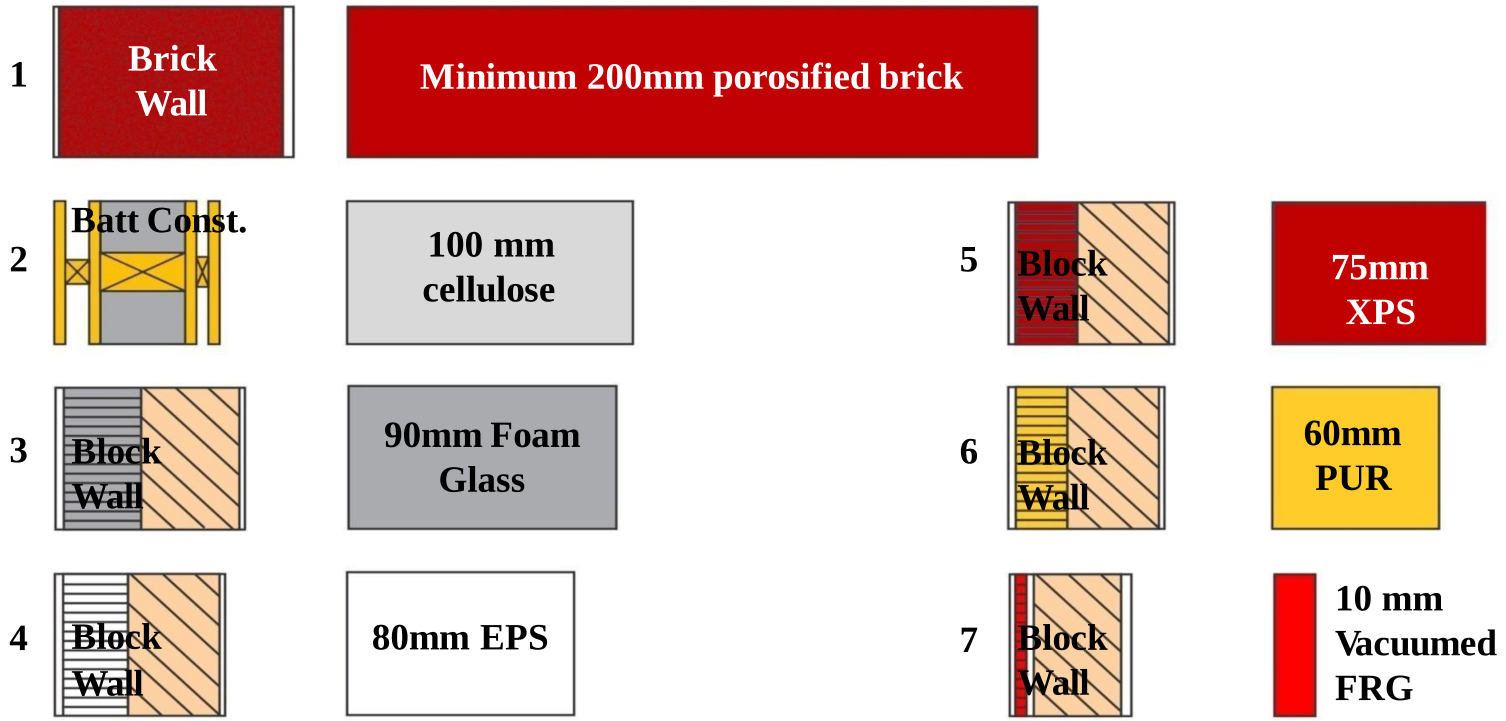
Air = 1
0.0002 Sq mts of aluminium (2 Sq Cms) = 1 Sq mts of insulation



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



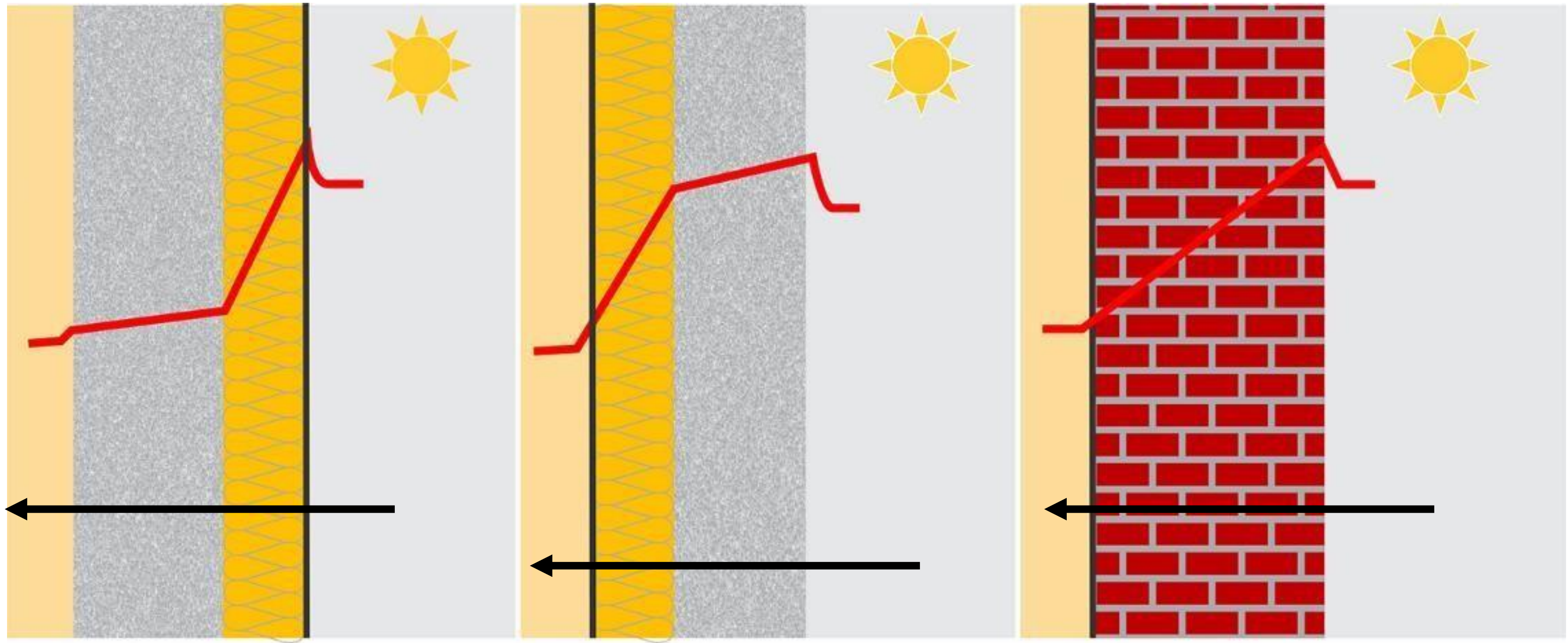
Minimum Thickness Needed to Achieve U value of < 0.40W/m²K

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



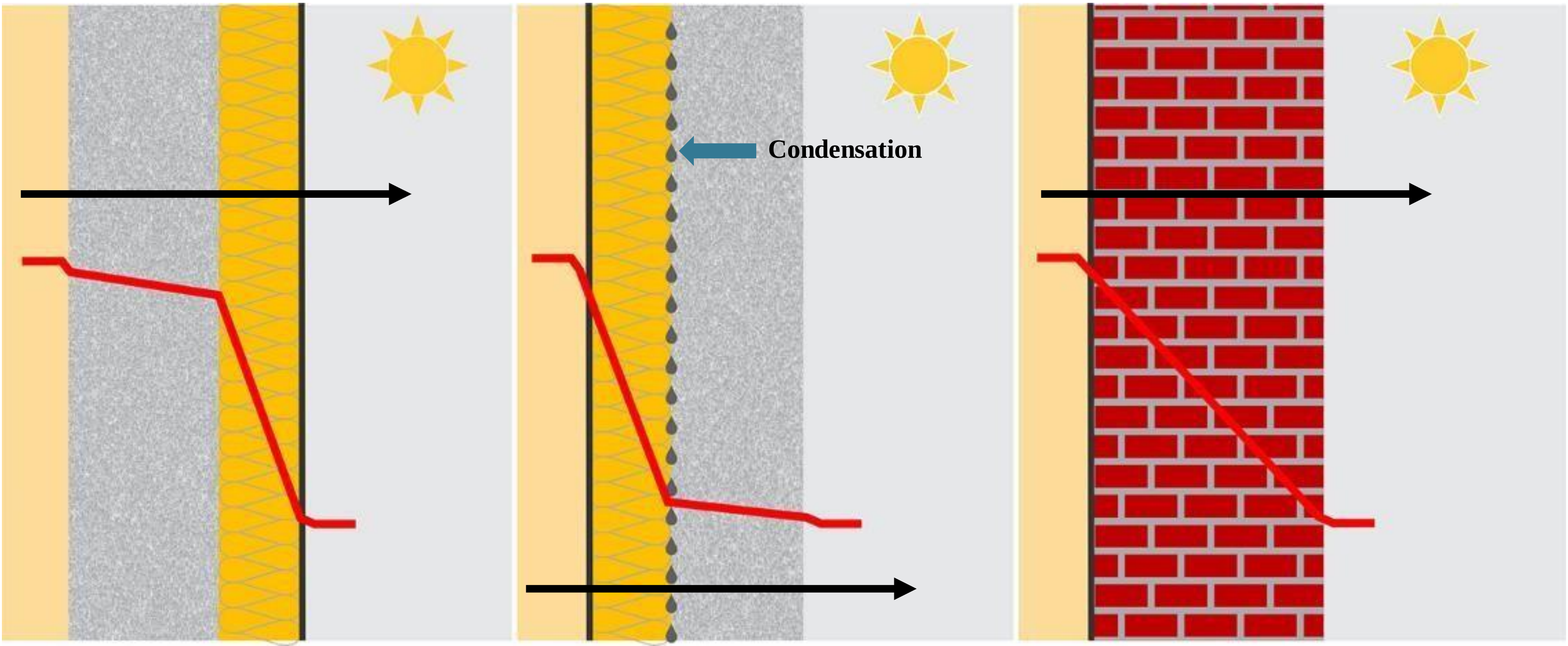
Insulation Outside **Insulation Inside** **High Thermal Mass**

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



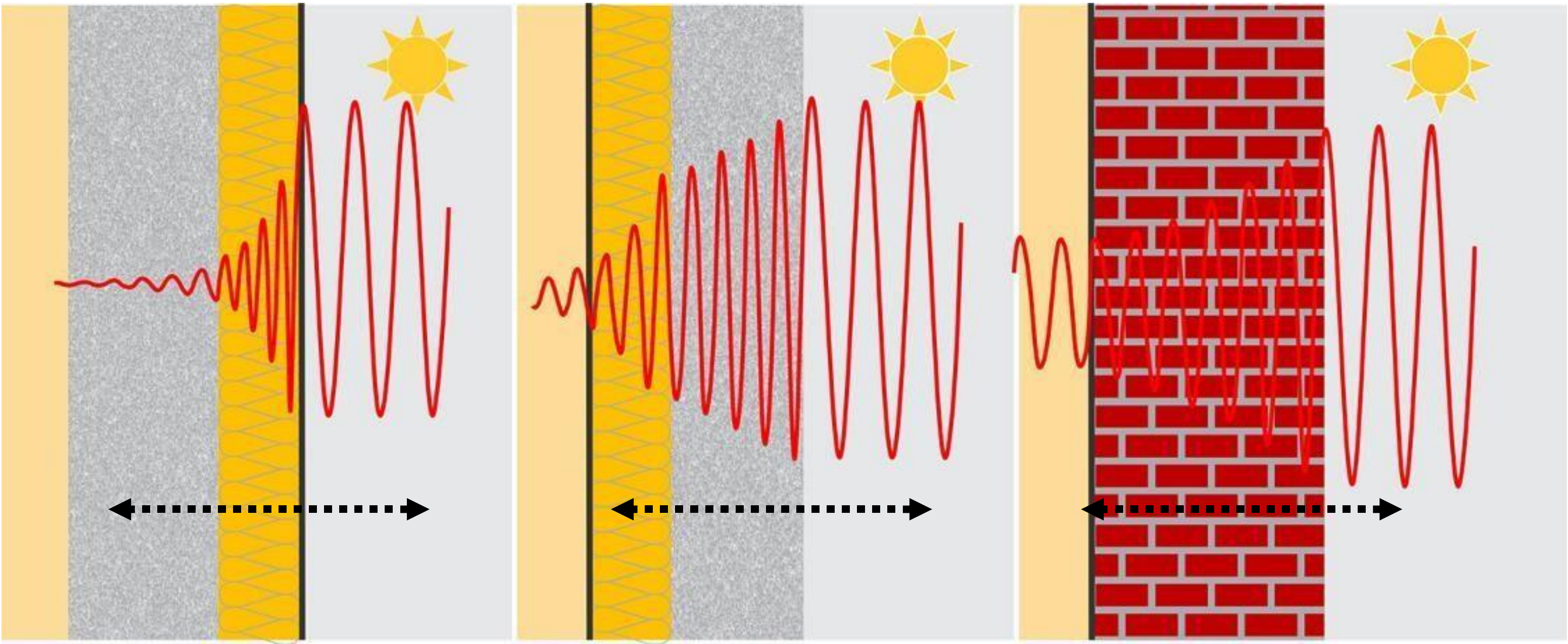
Insulation Outside | **Insulation Inside** | **High Thermal Mass**

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

Variable Indoors and Variable Outdoors

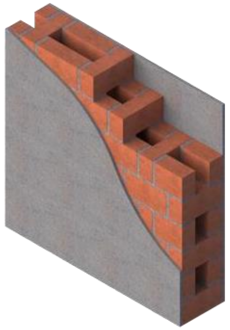


Insulation Outside | **Insulation Inside** | **High Thermal Mass**

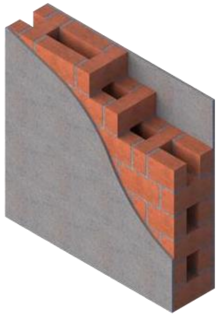
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

Walling Material and Walling Assemblies

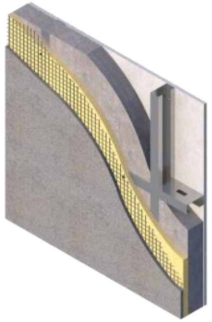
Nonhomogeneous Walling Technologies, Industrial



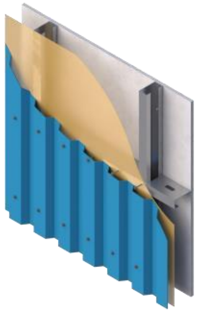
230 MM Clay Brick Wall Base Line



Rat Trap Bond



LGFSS- EPS



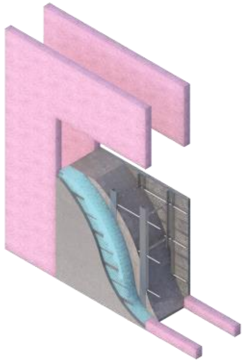
PPGL

GFRG Unfilled

GFRG Partially Filled

GFRG Fully Filled

Reinforced EPS Core

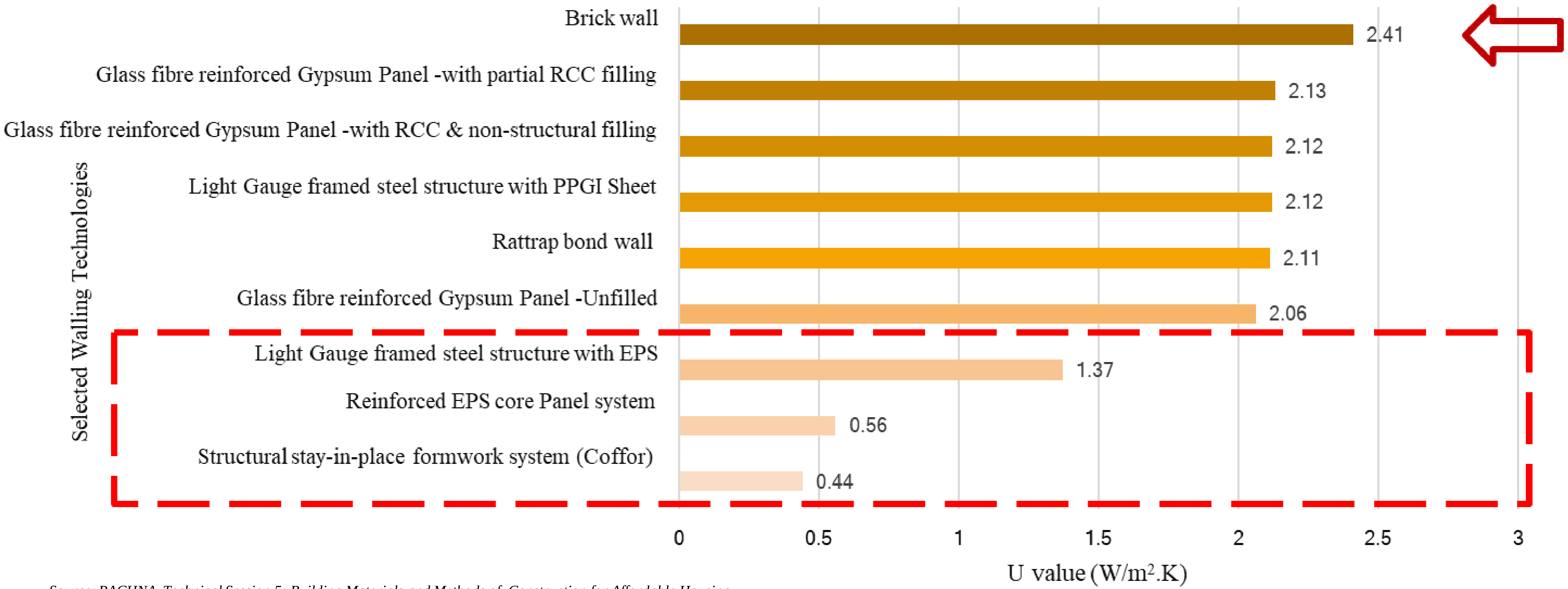


Stay-in-Place Coffer

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

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

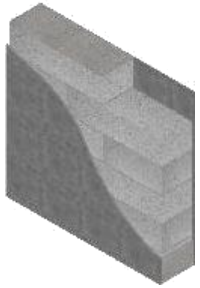
Laterite block wall
U - VALUE (W/m²K)= 1.61

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



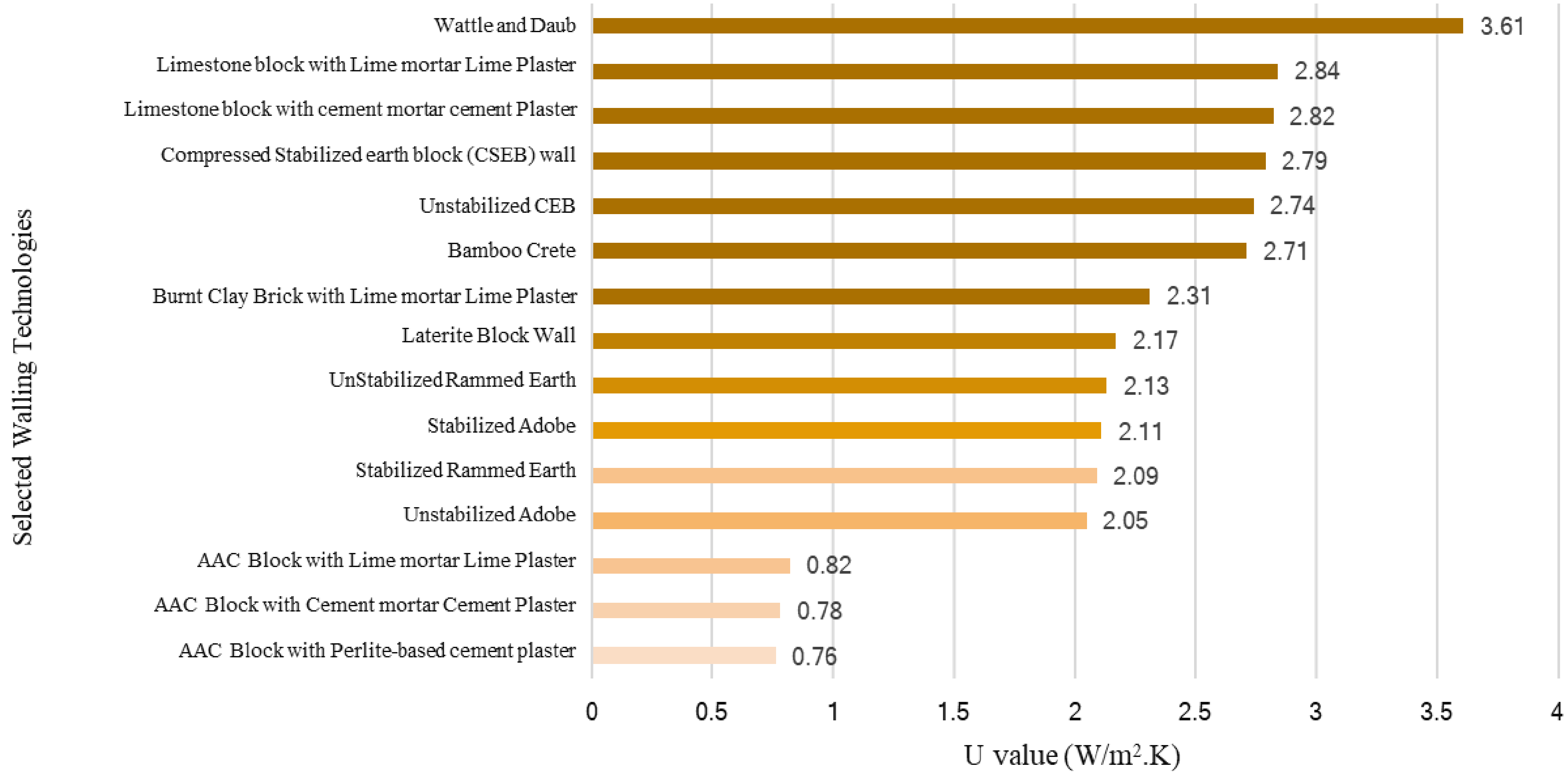
Unstabilized Rammed Earth Wall assembly
U - VALUE (W/m²K)= 1.68

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

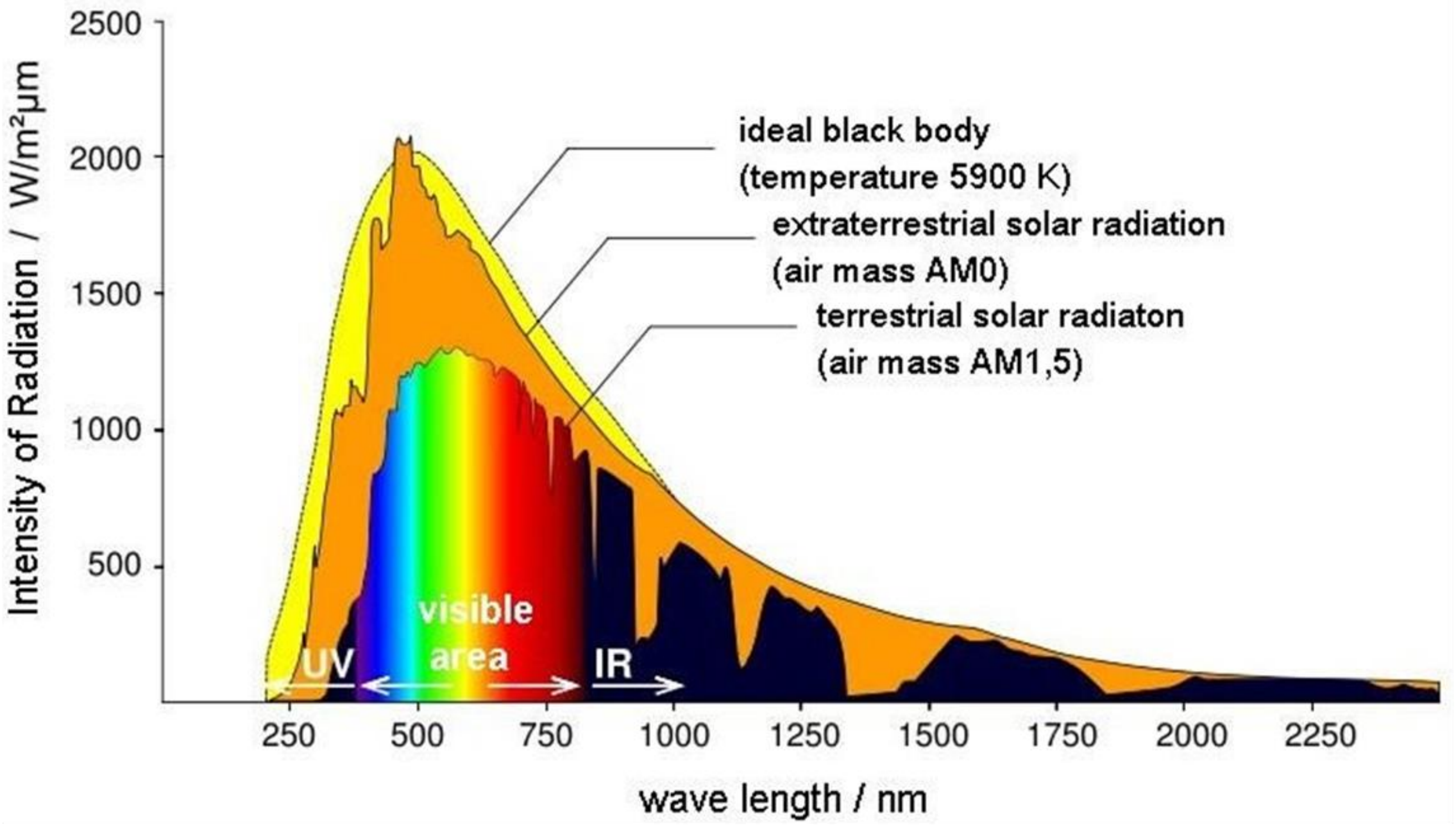
Walling Technologies: U Values, Traditional



GLAZING MATERIAL and GLAZING ASSEMBLIES

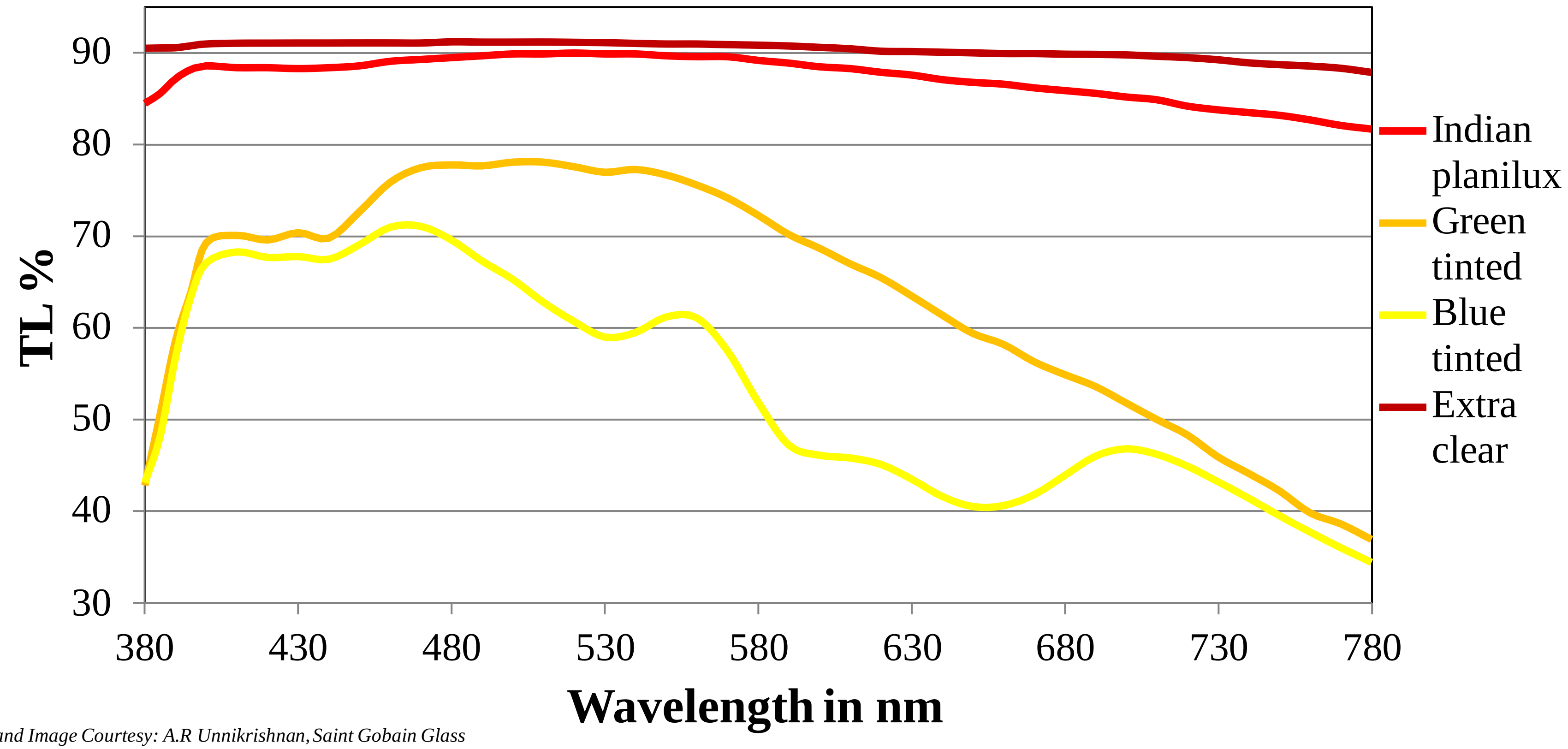
Glazing Material and Glazing Assemblies

Glazing Material and Methods: Solar Spectrum



Glazing Material and Glazing Assemblies

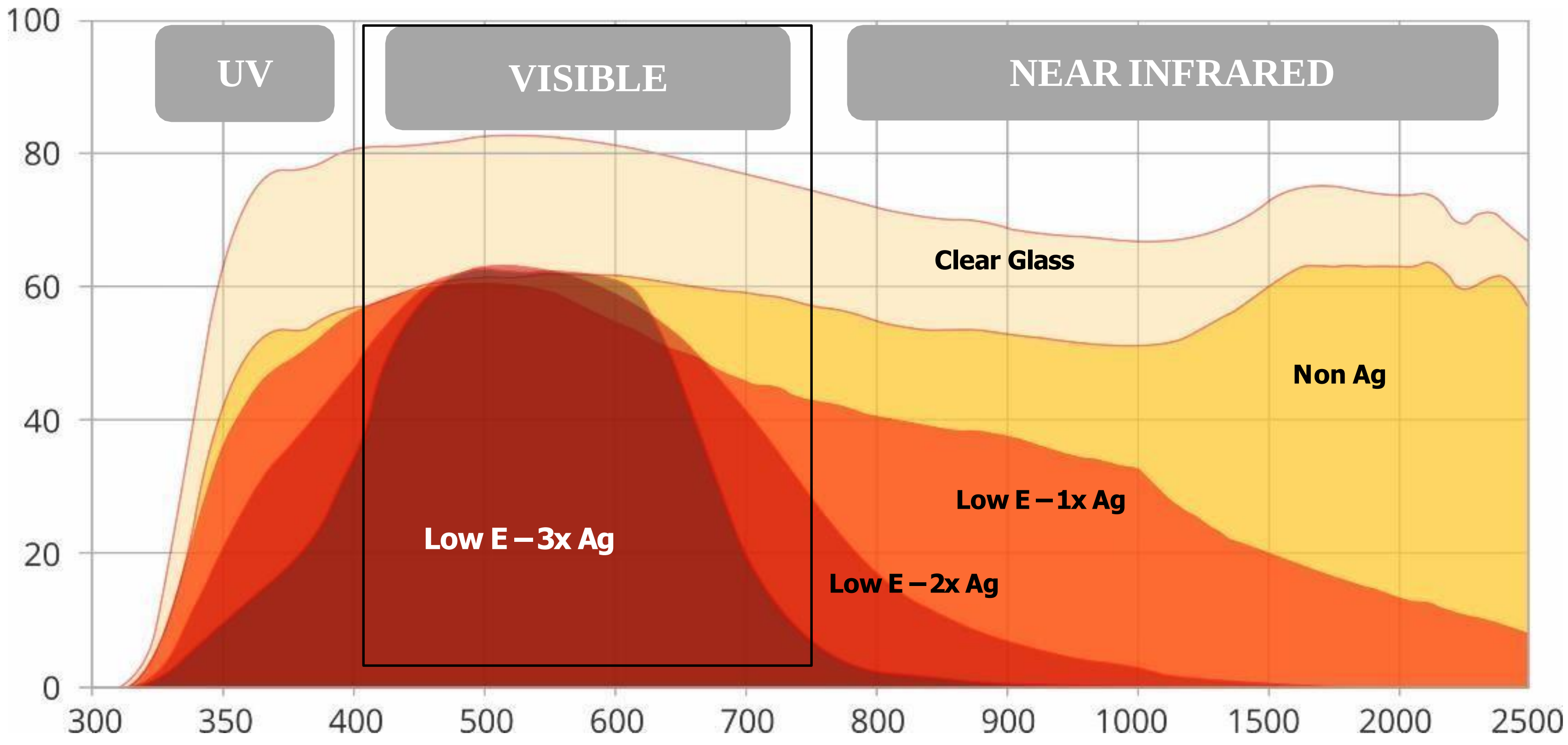
Glazing Material and Methods : Solar Radiation through Glass



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

Glazing Material and Glazing Assemblies

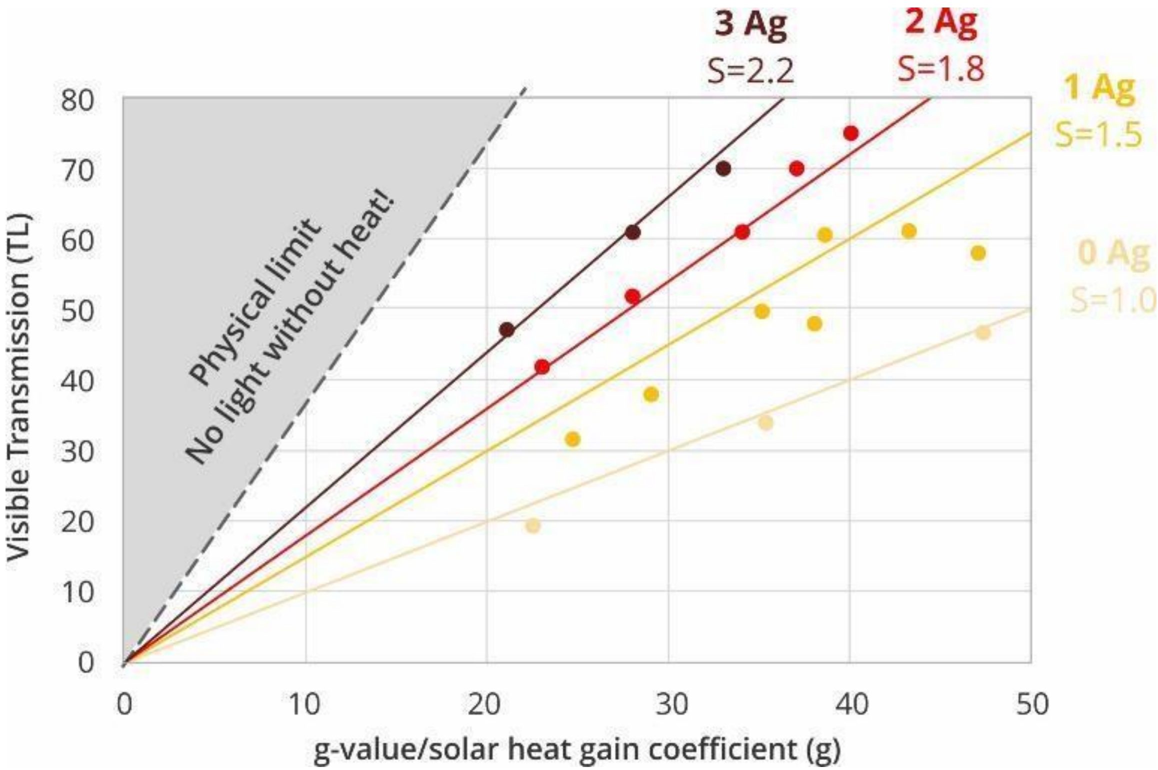
Glazing Material and Methods : Solar Control



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

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Solar Control



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

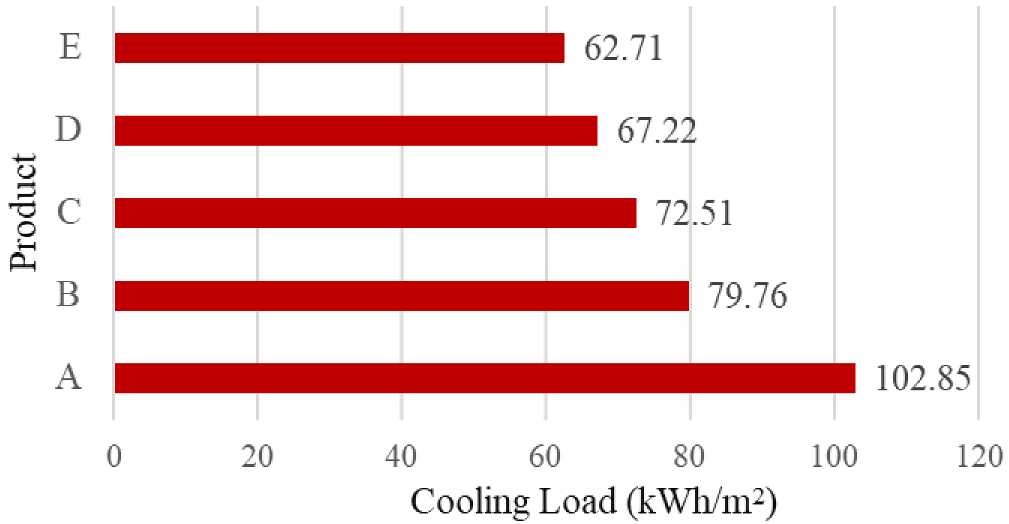
$$\text{Selectivity} = \frac{TL}{g} = \frac{\text{Light}}{\text{Heat}}$$

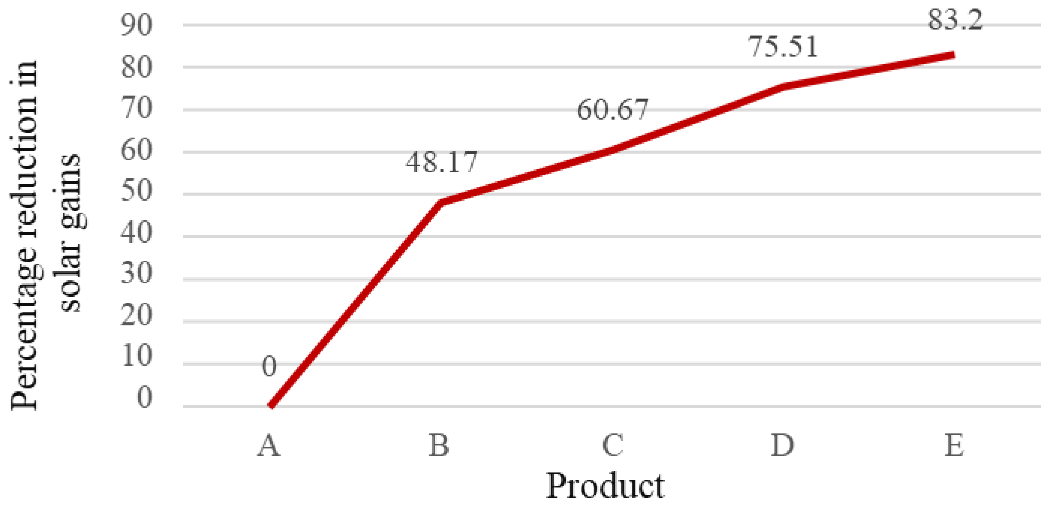
Silver (Ag) based coater products have the maximum selectivity

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

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Cooling Load Reduction



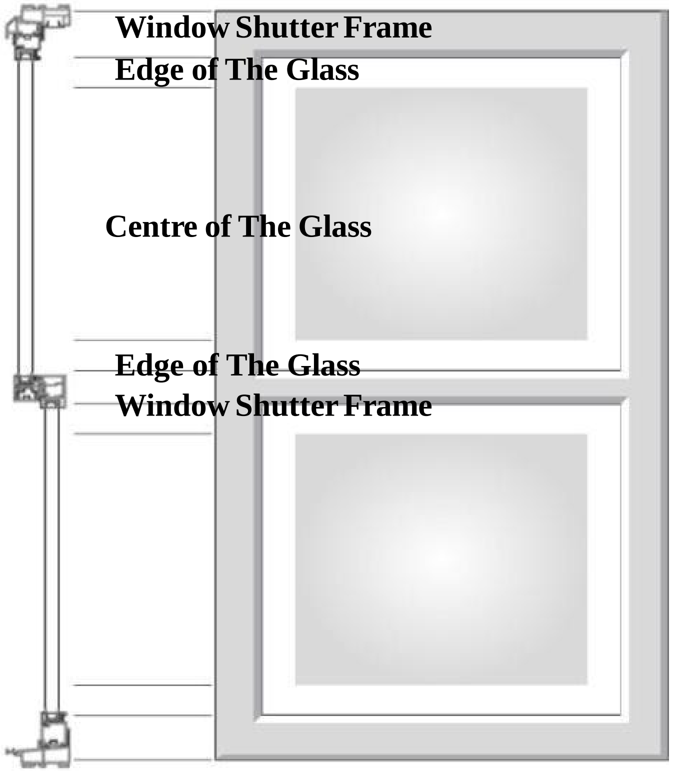


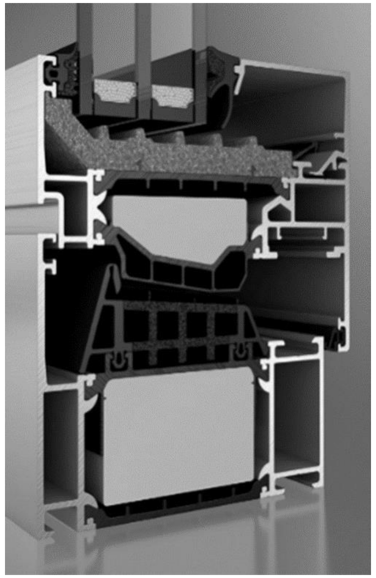
Product	VLT (%)	External Reflection (%)	Internal Reflection (%)	Solar Factor	Shading coefficient	U-value
A	80	15	15	0.76	0.87	2.6
B	46	16	18	0.22	0.25	1.5
C	46	20	22	0.47	0.54	2.8
D	51	18	22	0.28	0.33	1.5
E	47	17	11	0.38	0.43	1.9

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

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Window Frame



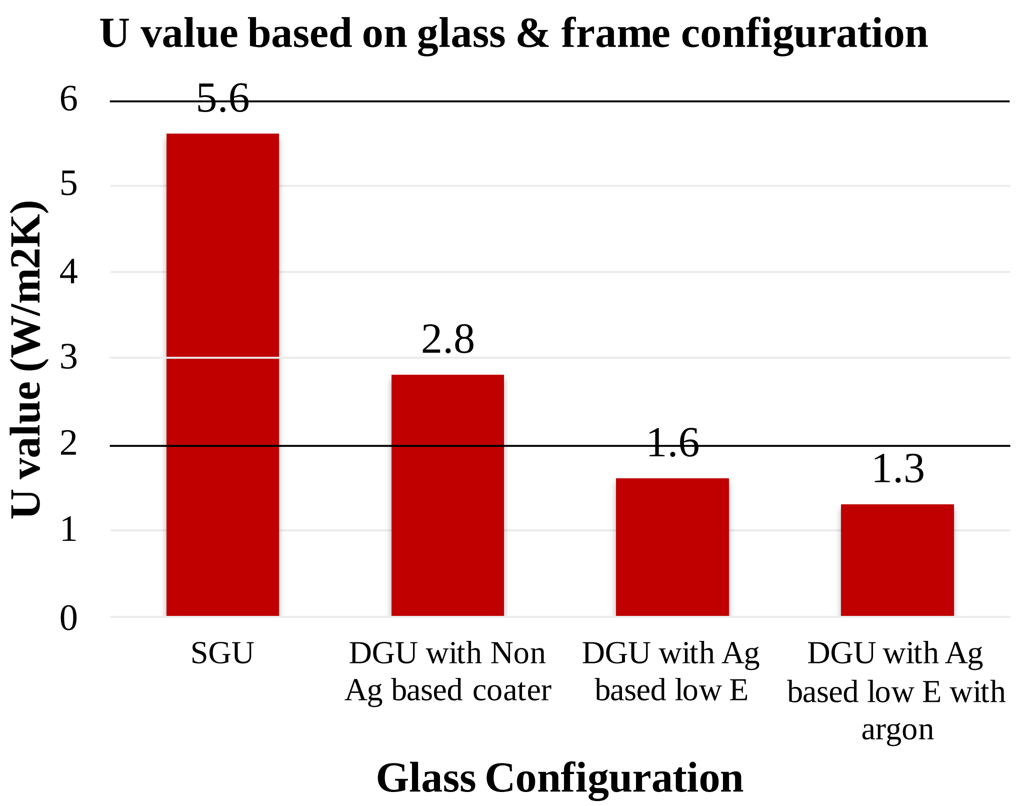


Source: Neuffer. (n.d.). Schüco Aws 90. Neuffer. Retrieved from http://192.169.1.1:8090/httpclient.html Grabex. (n.d.). Sliding-Folding Doors For Your Space. Grabex. Retrieved from https://grabex.co.uk/doors/bi-fold-

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

Glazing Material and Glazing Assemblies

Glazing Material and Methods : Window Frame



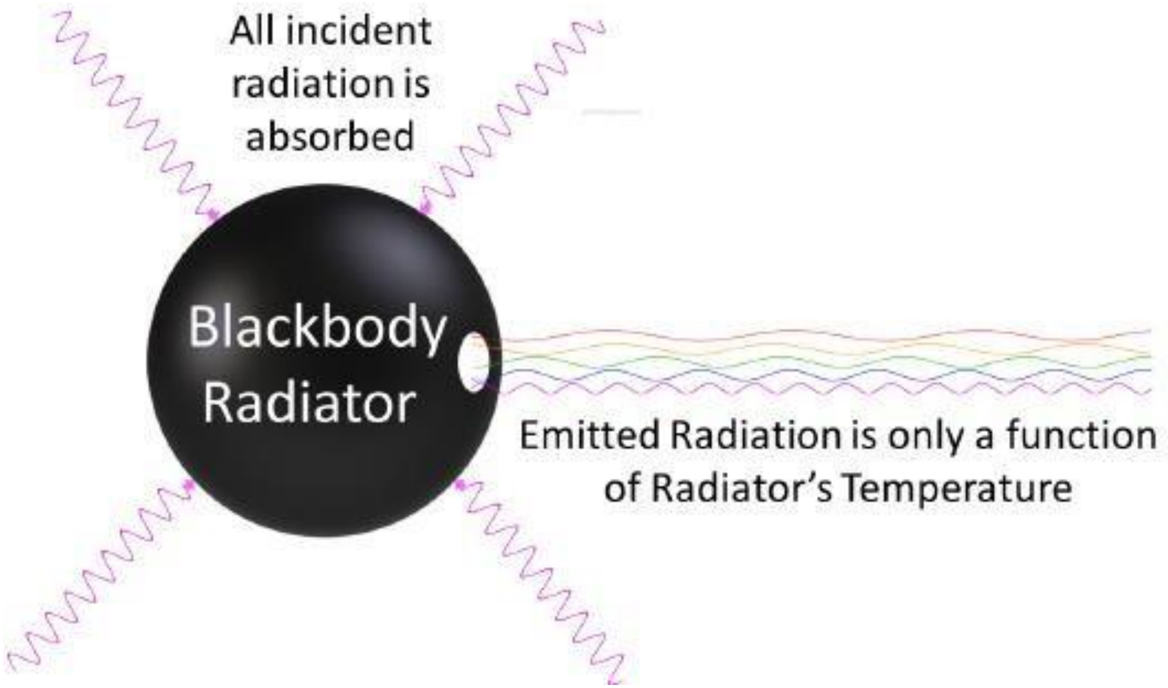
SGU **DGU with air** **DGU with Argon gas**

1.1 W/m².K 1.5 W/m².K 1.7 W/m².K

ROOFING COATING MATERIAL

Glazing Material and Glazing Assemblies

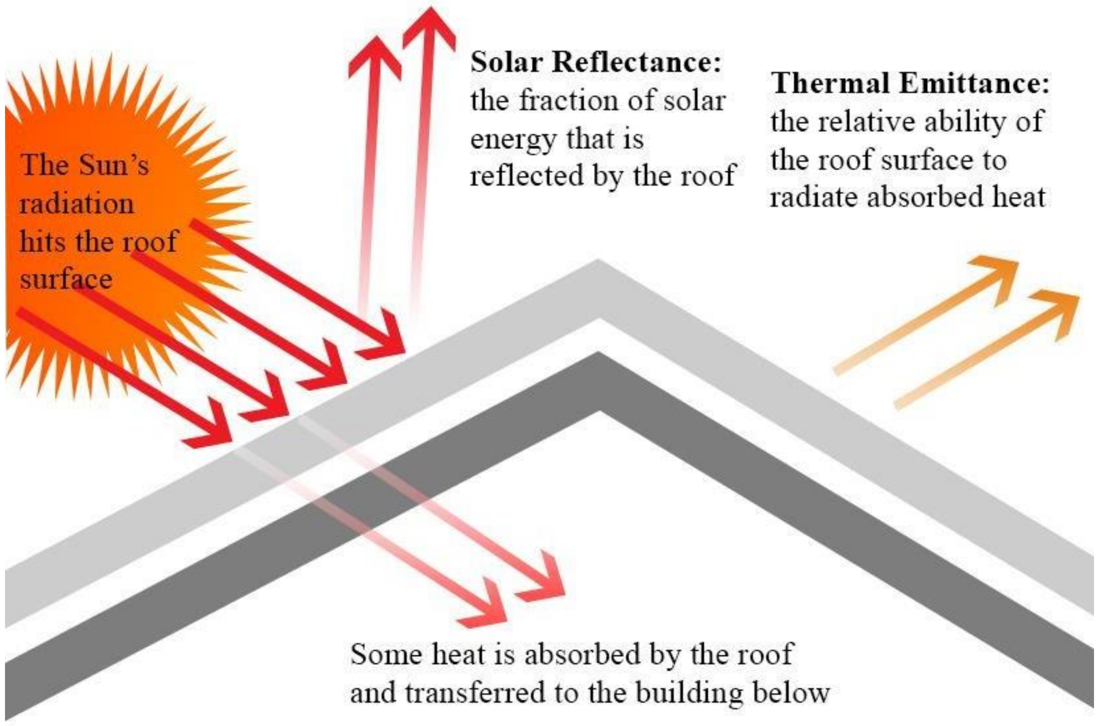
Roofing Coating Material : Black Body



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

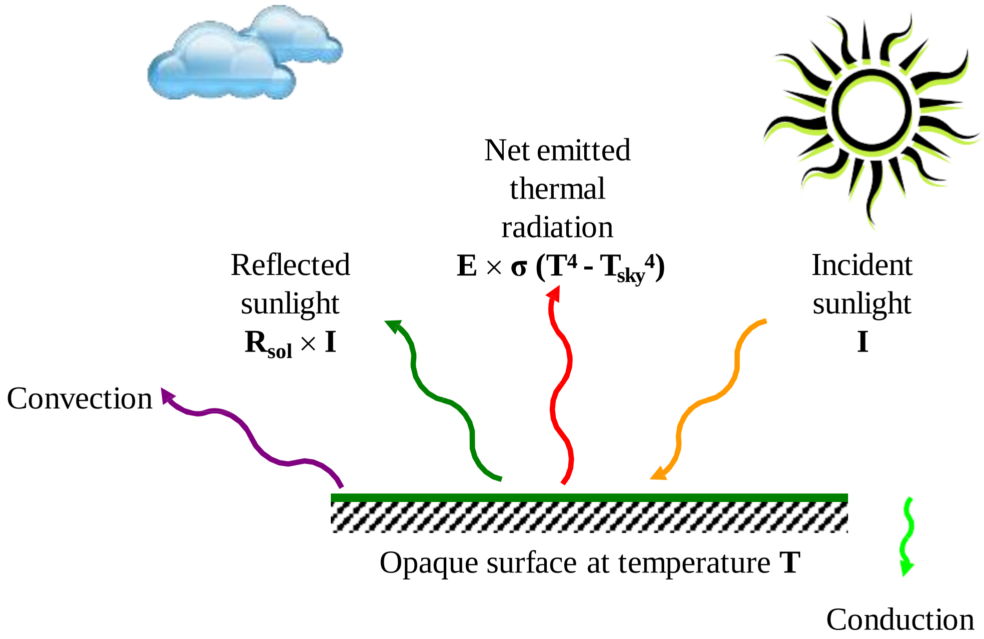


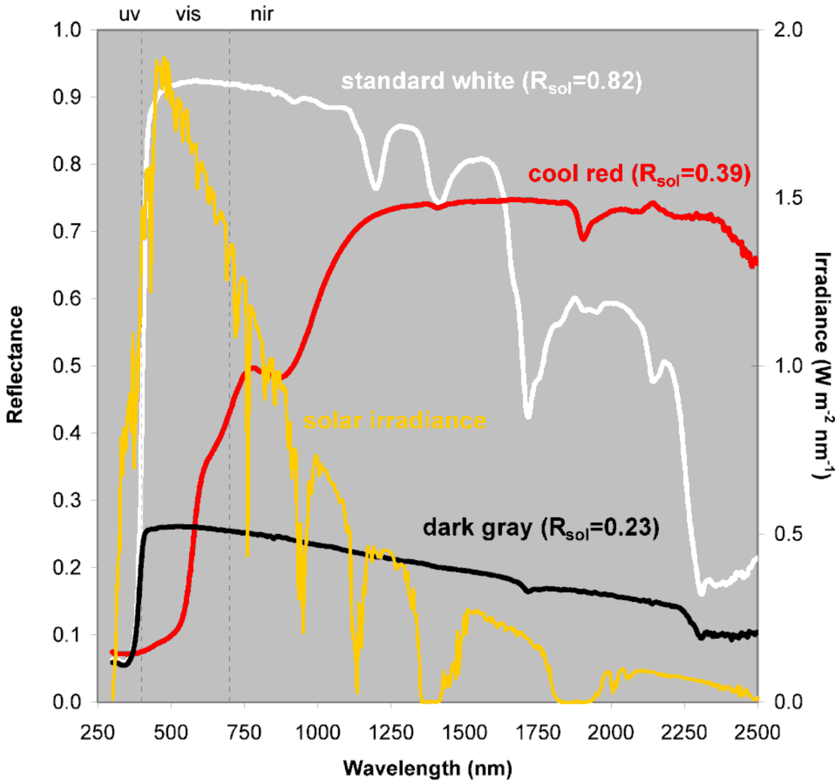
- Reflectance
- Thermal Emittance.
- Emissivity
- Solar Reflectance Index (SRI)

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





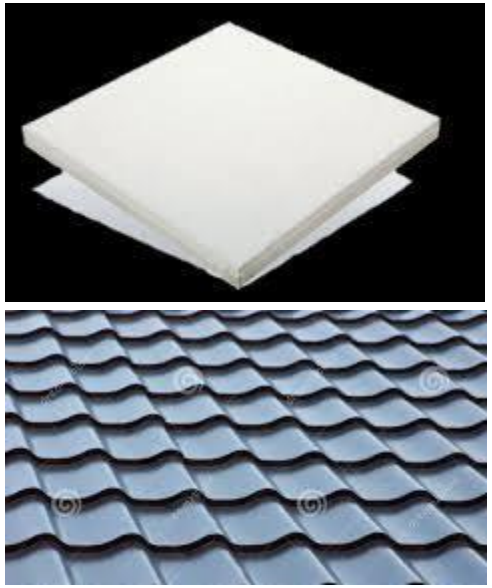
- High solar reflectance (R_{sol}) lowers solar heat gain (0.3 - 2.5 μm)
- High thermal emittance (E) enhances thermal radiative cooling (4 - 80 μm)

Glazing Material and Glazing Assemblies

Roof Coating Materials

Paints

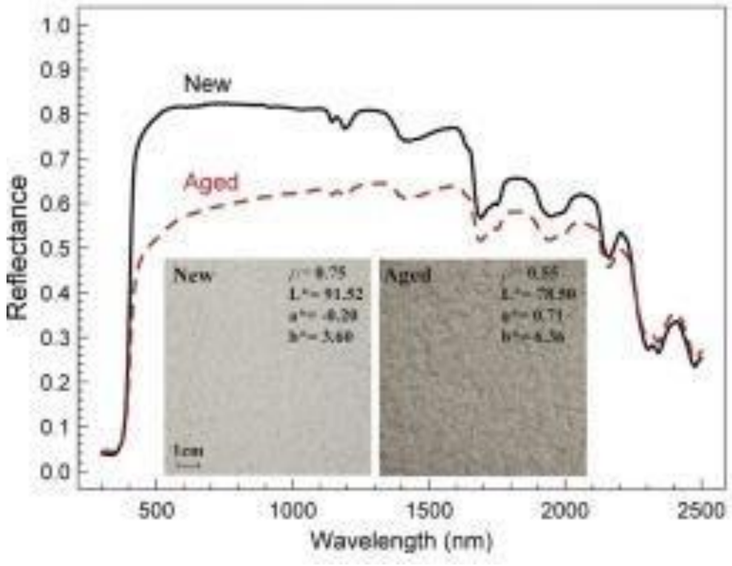
Coated Sheets

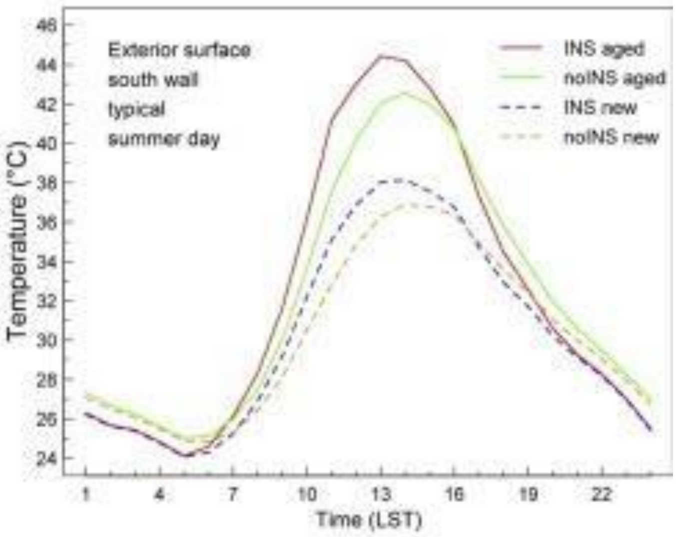


Tiles

Glazing Material and Glazing Assemblies

Roof Coating Materials





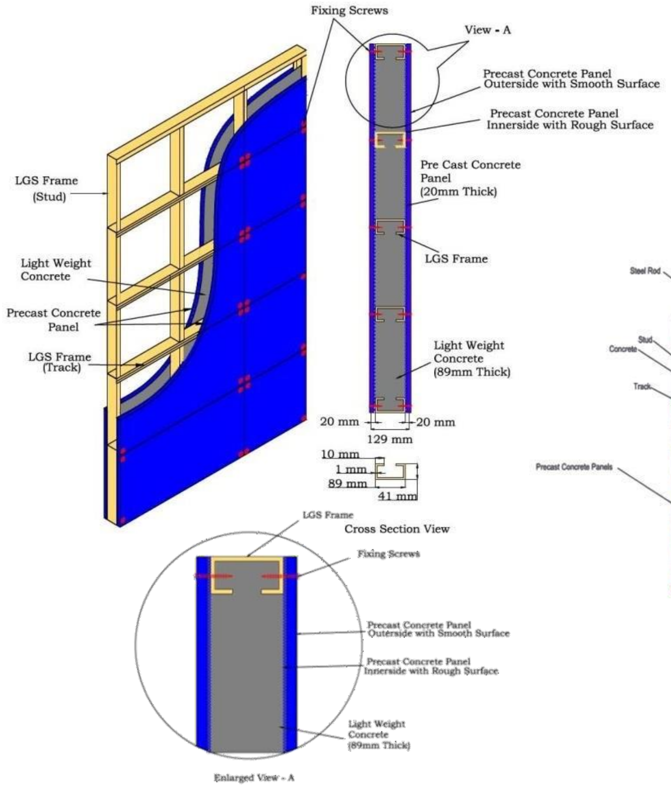
- PM 10, PM 2.5
- Dust, Sooth
- Vegetation

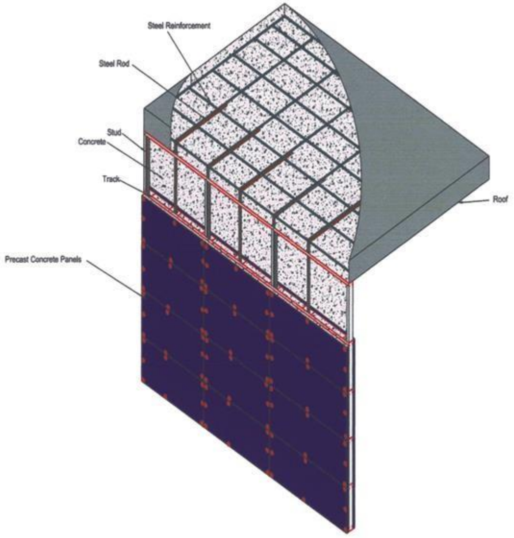
Source: Paolini, R., Zani, A., Poli, T., Antretter, F., & Zinzi, M. (2017). Natural aging of cool walls: Impact on solar reflectance, sensitivity to thermal shocks and building energy needs. Energy and Buildings, 153, 287–296. https://doi.org/10.1016/j.enbuild.2017.08.017

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

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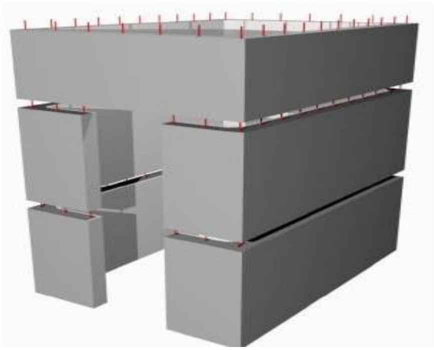
Walling Material Case Studies, Light House Projects

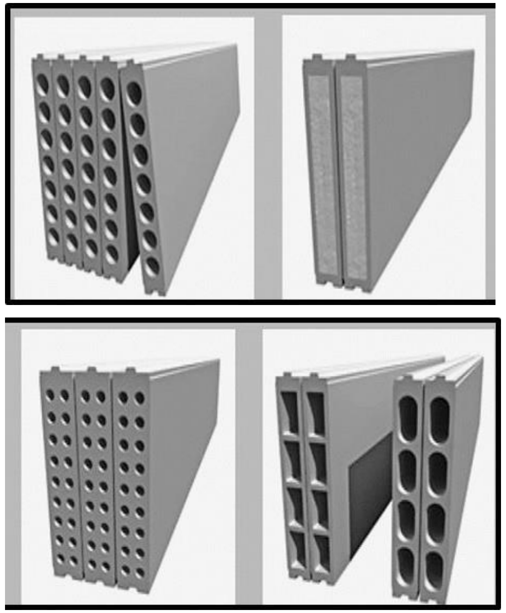
Light House Project: Chennai



- 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.

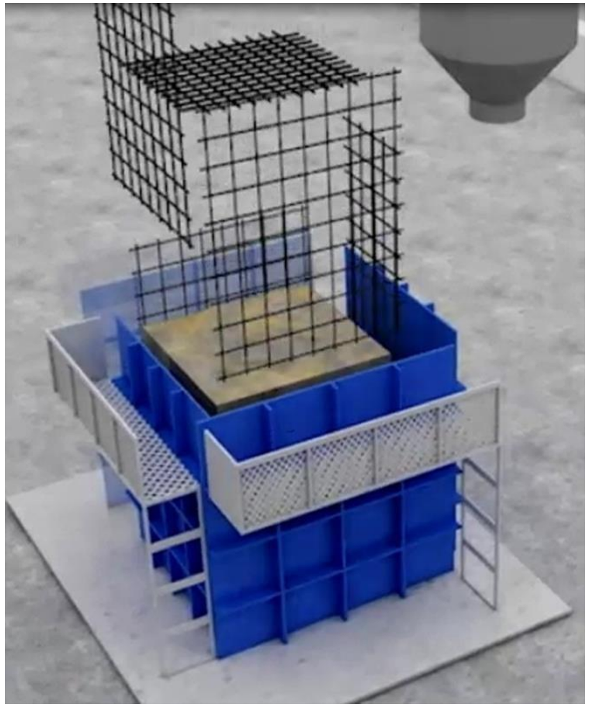
Walling Material Case Studies, Light House Projects

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

High Tea & Networking

Vote of Thanks

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