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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

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RACHNA
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Thermal Comfort in Affordable Housing

Cooling Training, Nairobi, Kenya

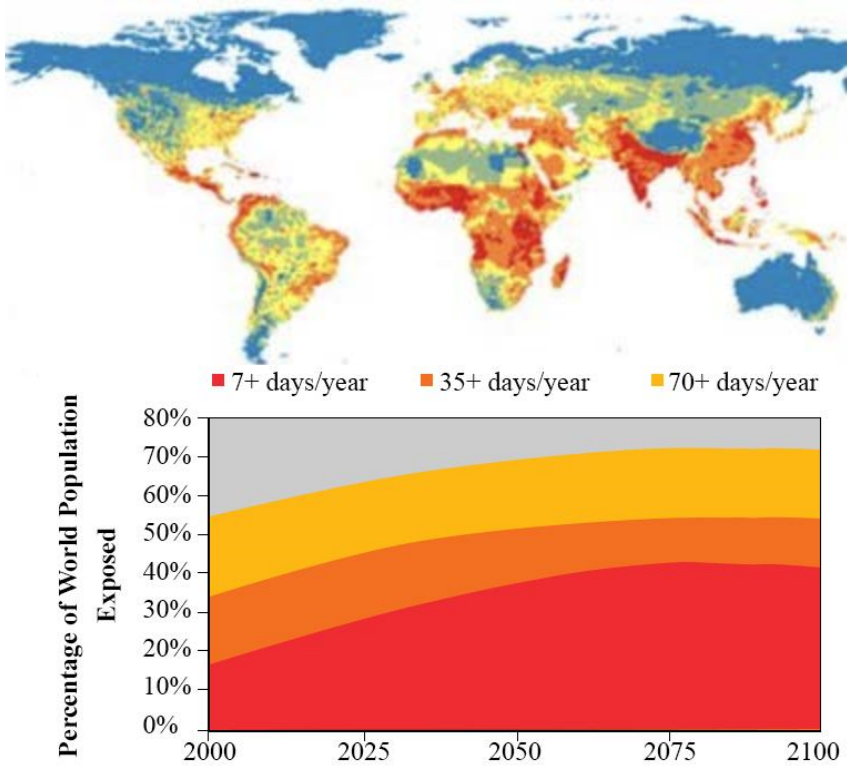
Dr. Yash Shukla

Principal Researcher and Center Head, CARBSE, CEPT University

11h00, December 14, 2022 (online)

Knowledge Partner CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION | CEPT UNIVERSITY

Need for Thermal Comfort

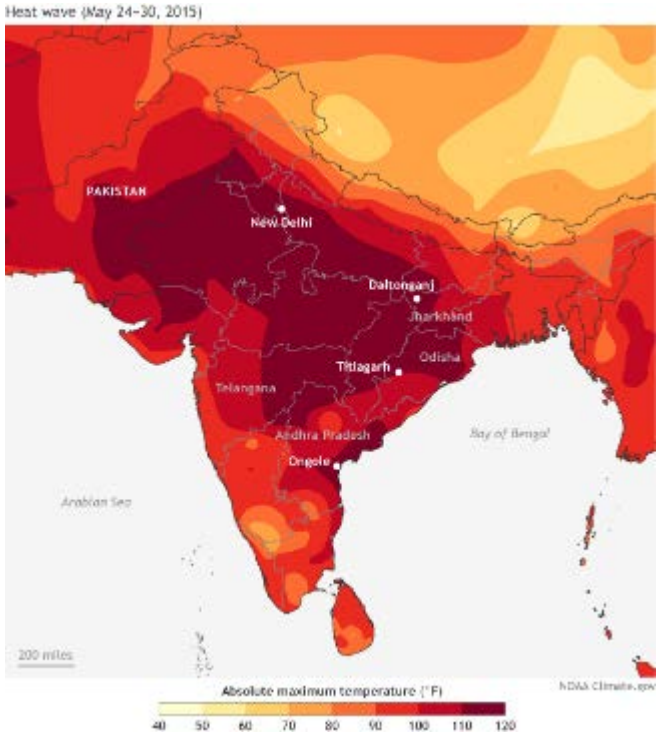


Present-day heat exposure risk

- Perceived luxury to a vital enabler of health, productivity & prosperity
- Worldwide, by 2030, extreme heat could lead to a $2 trillion loss in labour productivity. India's economy alone stands to lose $450 billion

Source: Kjellstrom, T. (2015). Impact of Climate Conditions on Occupational Health and Related Economic Losses. Asia Pacific Journal Of Public Health, 28(2_suppl), 28S-37S. https://doi.org/10.1177/1010539514568711

Need for Thermal Comfort: Affordable Homes



- 495,000 human deaths across the world in 1999–2020
- 12,000 extreme weather events led to losses worth USD 3.54 trillion (measured in terms of purchasing power parity or PPP)
- Housing needs to provide comfort over an extended period
- Less reliance on electro-mechanical systems
- Affordability to achieve comfort

Source: Climate.gov. (2015). India heat wave kills thousands [Image]. Retrieved 12 April 2022, from https://www.climate.gov/news-features/event-tracker/india-heat-wave-kills-thousands

Sustainable Developmental Goals (SDG)

- **SDG 3:** Health and Well Being
- **SDG 7:** Ensure access to affordable, reliable, sustainable, and modern energy for all
- **SDG 9:** Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation *(Industry-focused)*
- **SDG 11:** Make cities and human settlements inclusive, safe, resilient, and sustainable *(Building focused)*

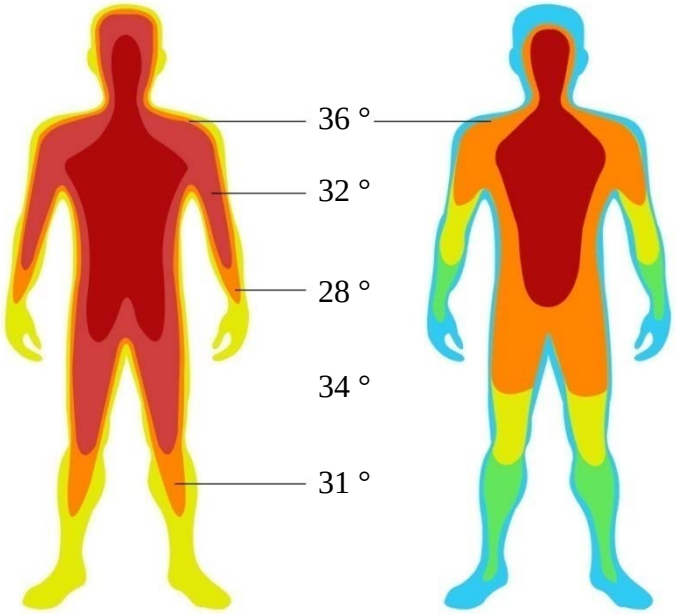
Source: Sustainable Development Goals (SDG) Professional Certificate. Hertie School. Retrieved 12 April 2022, from https://www.hertie-school.org/en/who-we-are/global-public-policy-network/sdg-certificate

Importance of thermal comfort : Body Requirements

- Homo sapiens primate order of the class of mammals
- Body heat is a by-product of metabolism
- A normal core temperature of ~37° C and skin at ~34° C

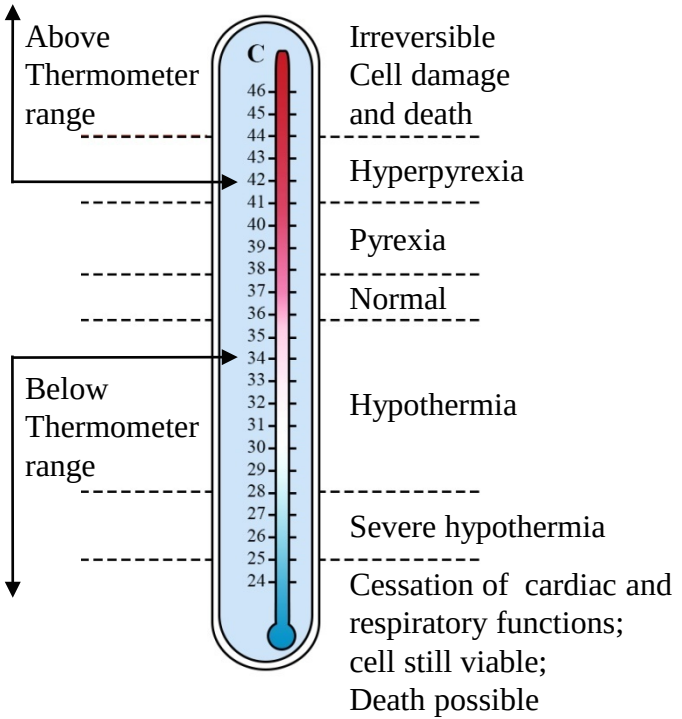
Source: Sunil Kumar Singh. (2016). Alert to heatwaves [Image]. Retrieved 12 April 2022, from https://www.downtoearth.org.in/news/climate-change/alert-to-heat-waves-53459
The Telegraph Online. (2020). Cold conditions continue in Delhi [Image]. Retrieved 12 April 2022, from https://www.telegraphindia.com/india/cold-conditions-continue-in-delhi/cid/1732019

Importance of thermal comfort : Conditioning and Comfort



30 °C – Ambient temperature – 20 ° C

Human Body Condition in two sets of environment



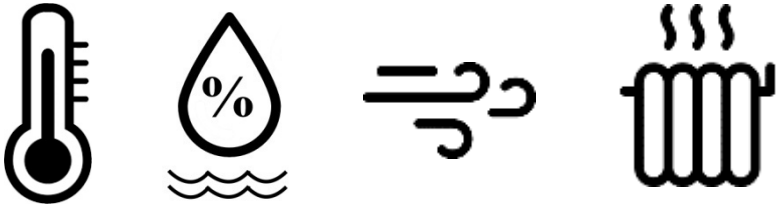
Human Body Condition beyond comfort bands

Importance of thermal comfort : Conditioning and Comfort

- Inability to shed excess heat leads to a rise in core body temperature
- Increase in heart rate
- Loss of concentration
- Irritation
- Sickness and Vomiting
- Unconsciousness
- Death

Source: freepik. Tired student [Image]. Retrieved 12 April 2022, from https://www.freepik.com/photos/tired-student

Factors Affecting Thermal Comfort



- **Environmental Factors**
- Air temperature, *°C*
- Relative Humidity, *%*
- Mean Radiant Temperature (MRT) *°C*
- Air Velocity, *meter/second*

- **Personal Factors**
- Activity (metabolic rate), *MET*
- Clothing, *Clo.*

Factors Affecting Thermal Comfort: Others

Short term physiological adjustments

Long term physiological adjustments

- **Acclimatization**
  - Short-term physiological adjustments
  - Long-term endocrine adjustments
- **Body shape and fat**

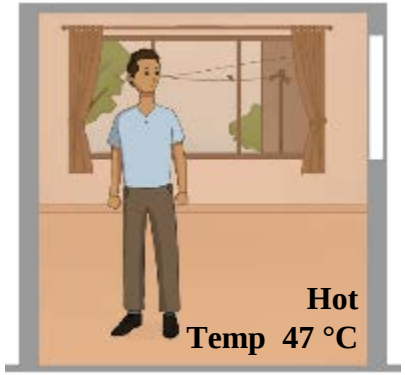
Age

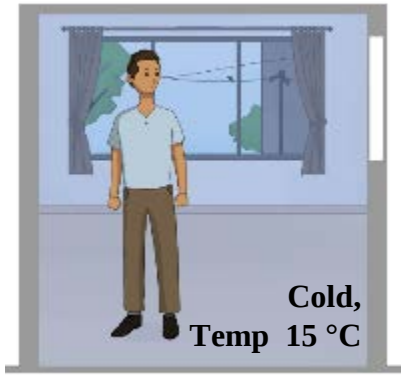
Gender

Health and Wellbeing

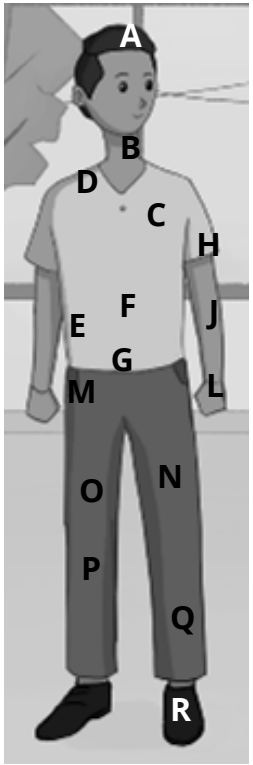
- **Age and gender**
- **Status of health**

Thermal Comfort: Cold – Neutral - Warm



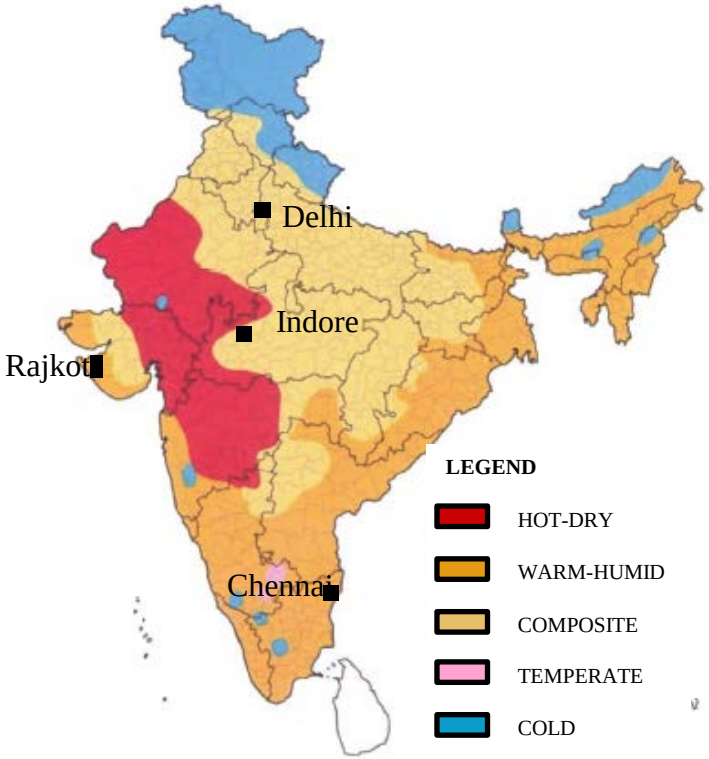


Air Temp 27 °C

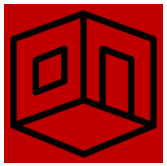


Body Part	Skin Location	Cold (15 °C)	Neutral (27 °C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37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

Context: Affordable Housing



During Peak Summer Period:



36.5 - 42°C.

Peak inside room temperature (operative temperature/ air temperature) can reach anywhere between **36.5 °C and 42 °C**

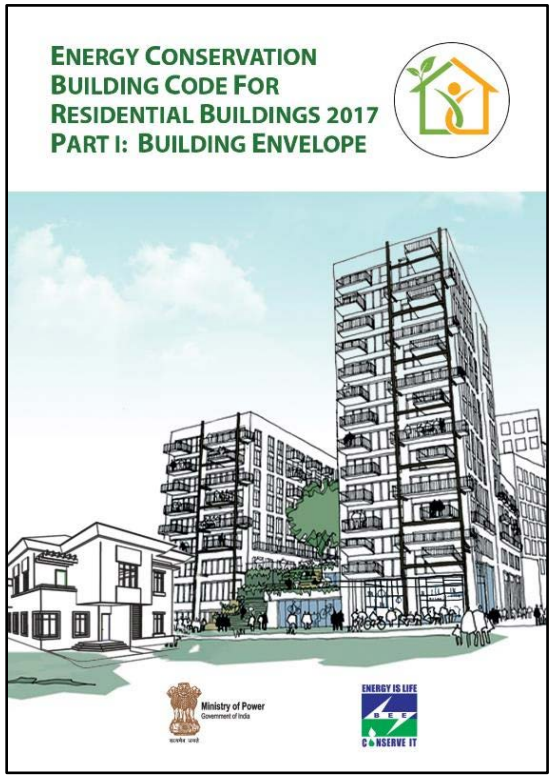
30 - 35 °C

Peak indoor temperatures can be reduced to ~ **30 - 35 °C** by design strategies:

- Reducing heat ingress
- Utilizing natural ventilation,

Source: Bansal, N. K., & Minke, G. (1995). Climatic Zones and rural housing in India: German-Indian-cooperation in scientific research and Technological Development. Forschungszentrum Jülich GmbH, Zentralbibliothek. K

ECO NIWAS Samhita: ECBC Residential



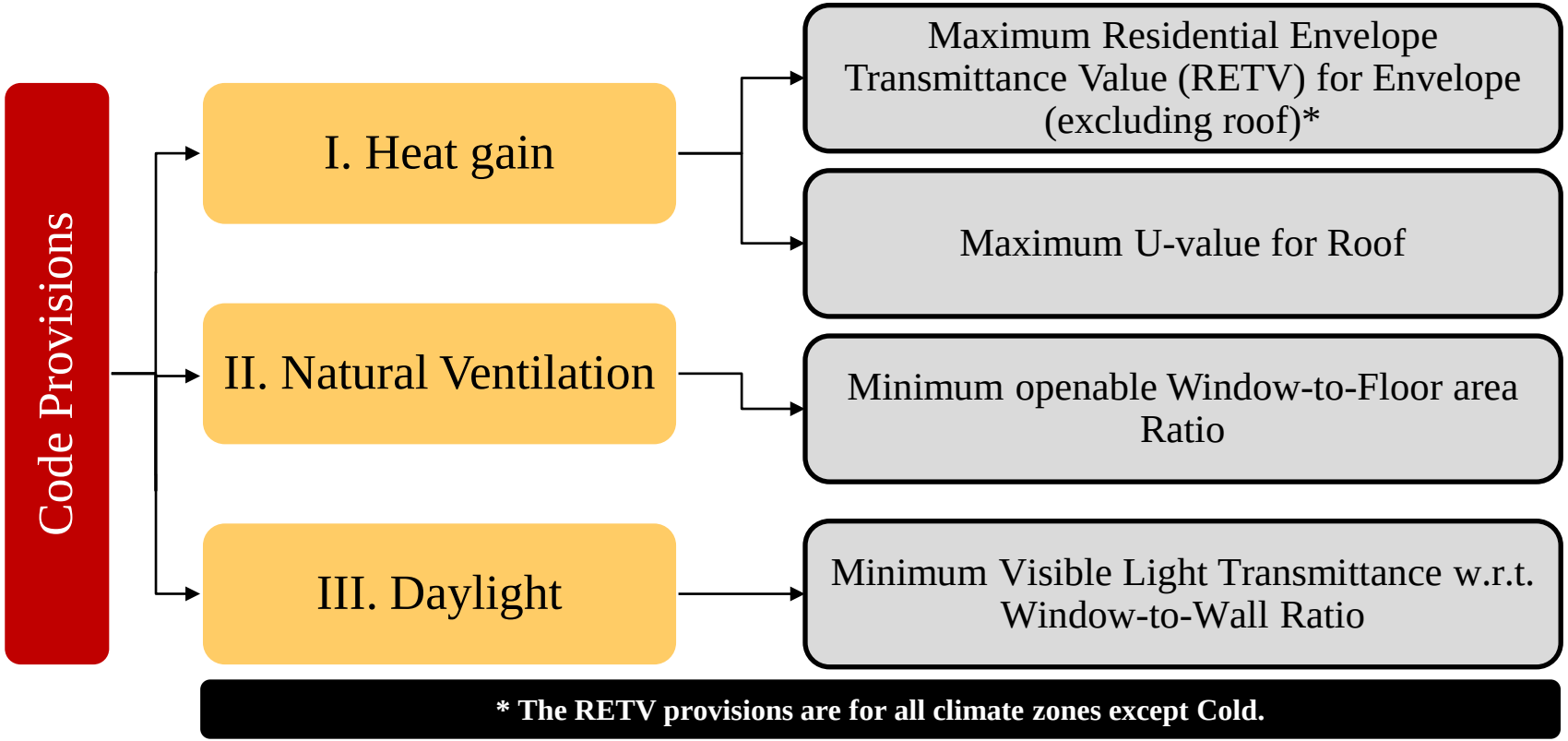
PROVISIONS FOR BUILDING ENVELOPE

- Reduce Heat Gain/Loss
- Improve Natural Ventilation & Daylighting

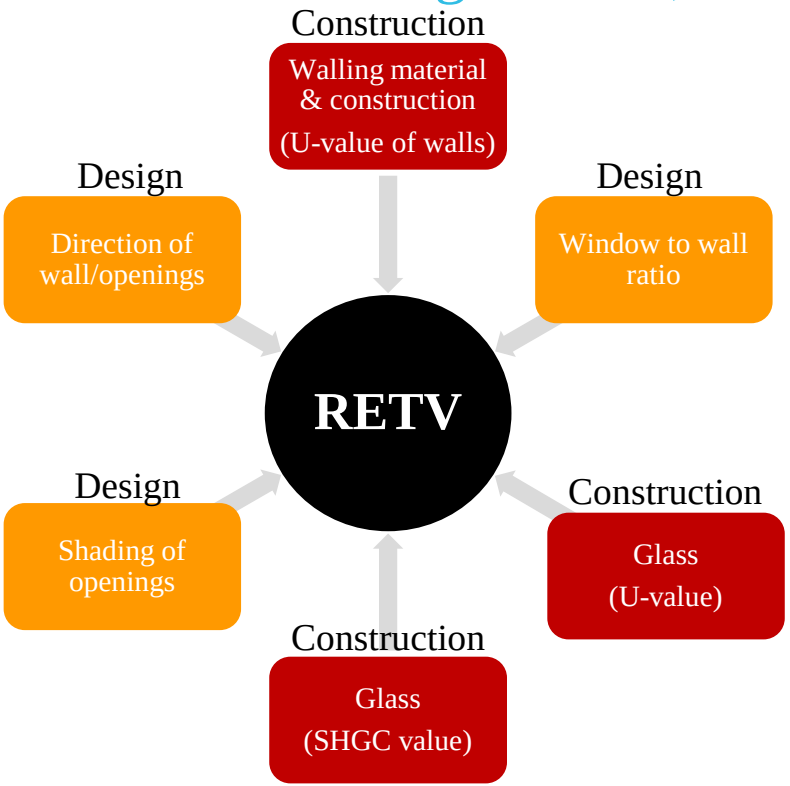
Improved thermal comfort & reduced energy consumption

Source: Bureau of Energy Efficiency, Government of India, & Ministry of Power. (2018). Eco-Niwas Samhita- Part I: Building Envelope. Retrieved from https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf

Overview of Code Provisions



RETV: Influencing Factors, Design and Construction



The net heat gain rate (over the cooling period)

through the building envelope (excluding the roof)

divided by the area of the building envelope (excluding the roof), measured in W/m^2.

Source: Bureau of Energy Efficiency, Government of India, & Ministry of Power. (2018). Eco-Niwas Samhita- Part I: Building Envelope. Retrieved from https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf

Passive Design Strategies: Spatial Configuration

Optimizing Radiation

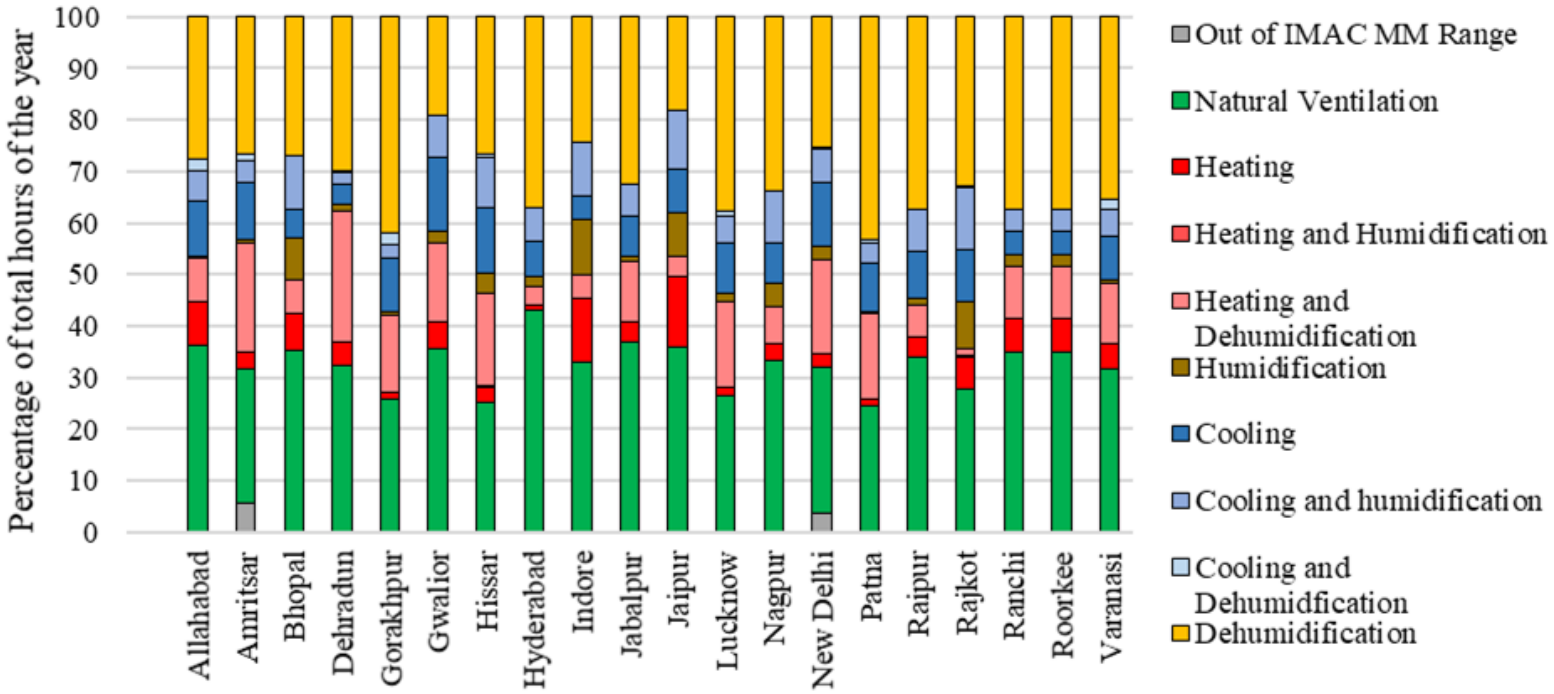
Wind Direction and Speed

Rectangular Plan
Less ‘tight’ buildings

Orientation: Positive, Negative and Neutral

Source: Pinterest. (n.d.). Kutch home called bhoonga. Pinterest. Retrieved from https://in.pinterest.com/pin/355925176772831313/ /, Iyadurai, N. (n.d.). Sangath. Rethinking the future. Rethinking the future. Retrieved from https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a861-recipe-for-a-perfect-architecture-studio/ , Prepp. (n.d.). Kanchanjunga Apartments. Prepp. Retrieved from https://prepp.in/news/g-47340-modern-indian-architecture-art-and-culture-notes

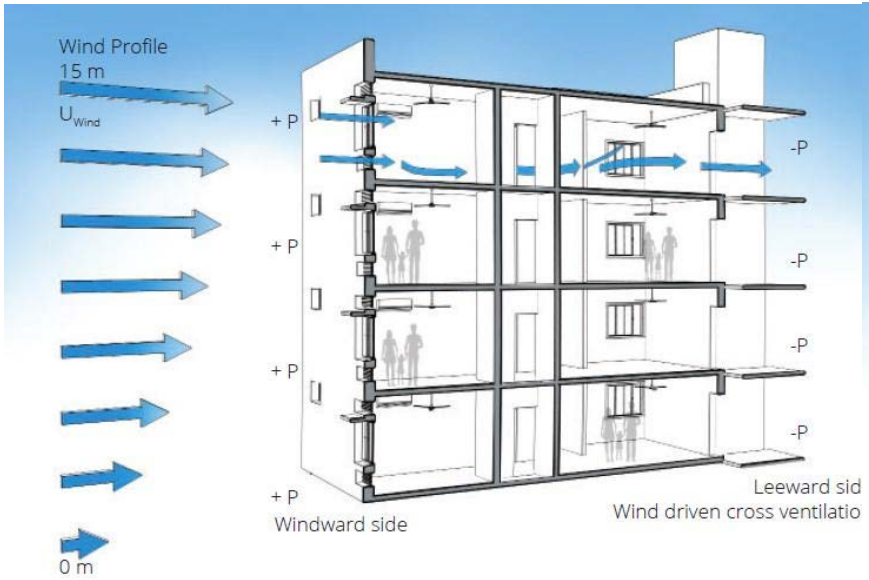
Opportunities to operate buildings with comfort strategies

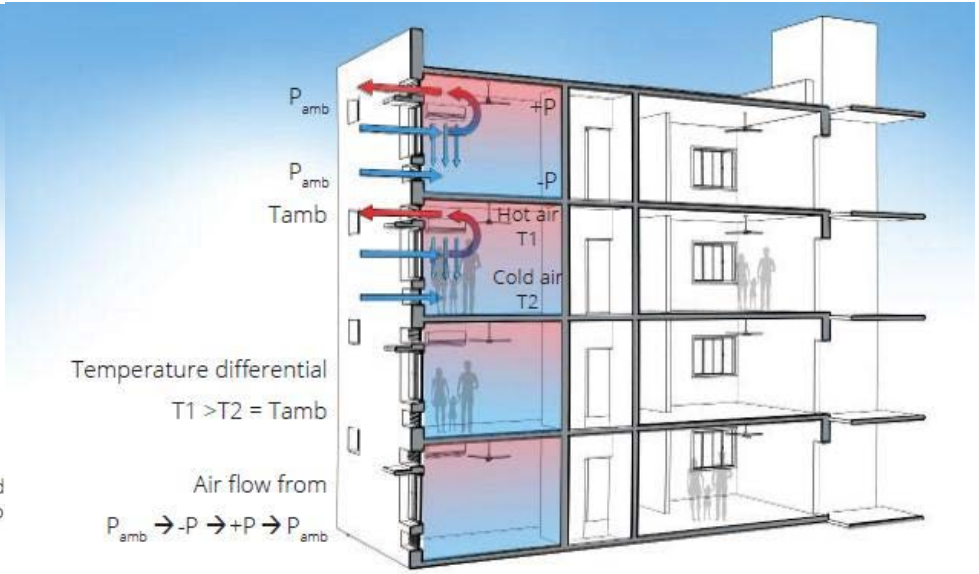


Summary of comfort hours of different operation modes (NBC - IMAC-MM)

Source: Cook, M., Shulka, Y., Rawal, R., Loveday, D., de Faria, L., Angelopoulos, C. (2020). Low Energy Cooling and Ventilation in Indian Residences Design Guide. CEPT Research & Development Foundation & Loughborough University. http://carbse.org/reports-and-articles/

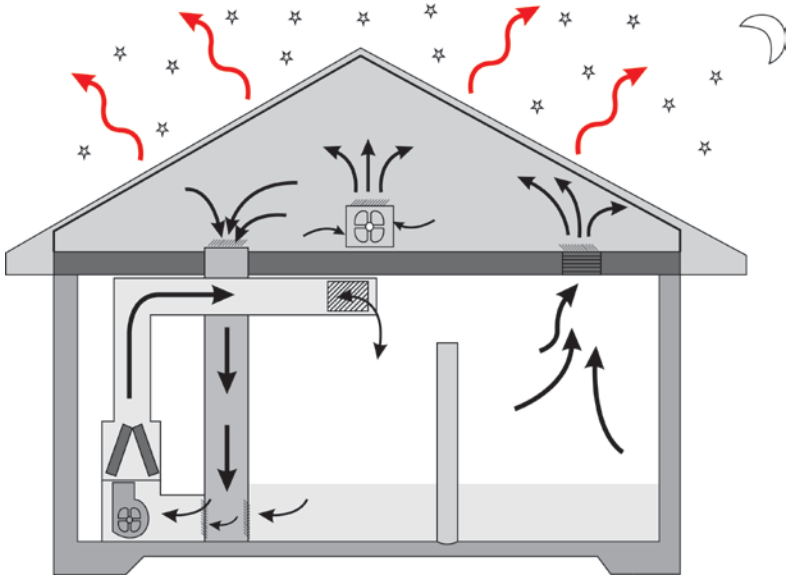
Harnessing Ventilation for Thermal Comfort





Source: Cook, M., Shulka, Y., Rawal, R., Loveday, D., de Faria, L., Angelopoulos, C. (2020). Low Energy Cooling and Ventilation in Indian Residences Design Guide. CEPT Research & Development Foundation & Loughborough University. http://carbse.org/reports-and-articles/

Night Cooling by Mechanical Ventilation

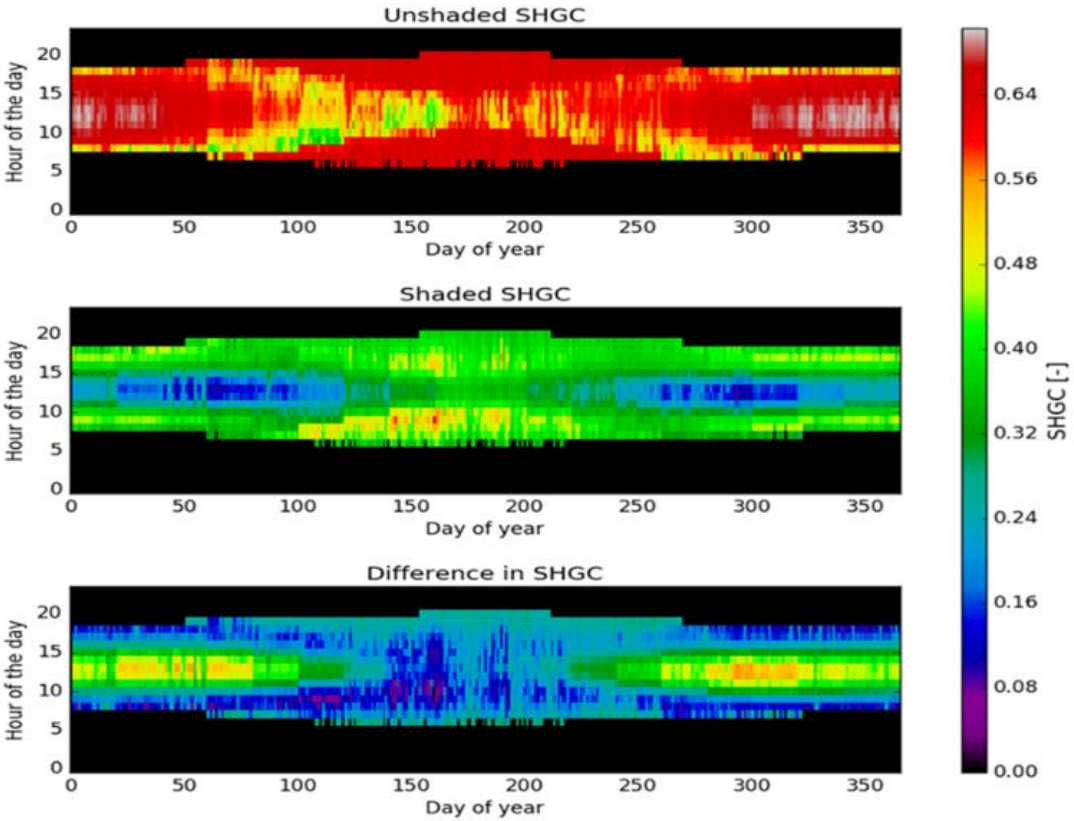


- **Favorable Factors**
  - Low nighttime DBT
  - Less and Periodic internal loads
  - Uninterrupted electricity
- **Unfavorable Factors**
  - No possibility of fresh air intake
  - Low ceiling to floor height
  - Poor insulation / no thermal mass

Highly efficient, low noise fans and low-pressure drop needed, nigh cooling for high mass can offset ~20-30 W/m^2 heat gains

Source: Nwaigwe, K. N., Anthony, O. C., Ogueke, N., Ugwuoke, P. E., & Anyanwu, E. E. (2012). Transient Analysis and Performance Prediction of Nocturnal Radiative Cooling of a Building in Owerri, Nigeria. Retrieved from https://www.researchgate.net/publication/274066021_Transient_Analysis_and_Performance_Prediction_of_Nocturnal_Radiative_Cooling_of_a_Building_in_Owerri_Nigeria

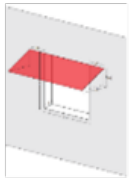
Passive Design Strategies: Shading



Improved SHGC for the Window

- Shading devices
- Change in Glass Material

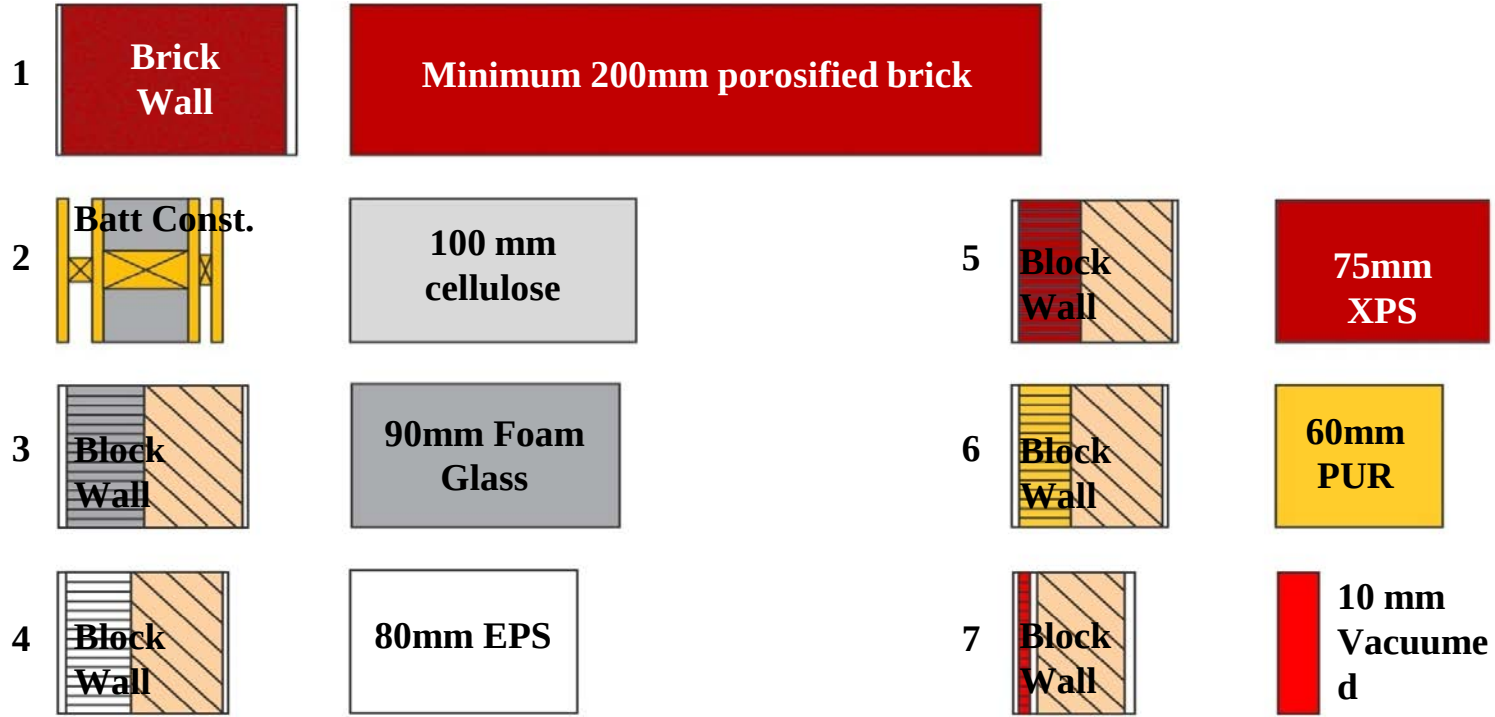

Type: 01


Type: 02


Type: 03


Type: 03 angle input

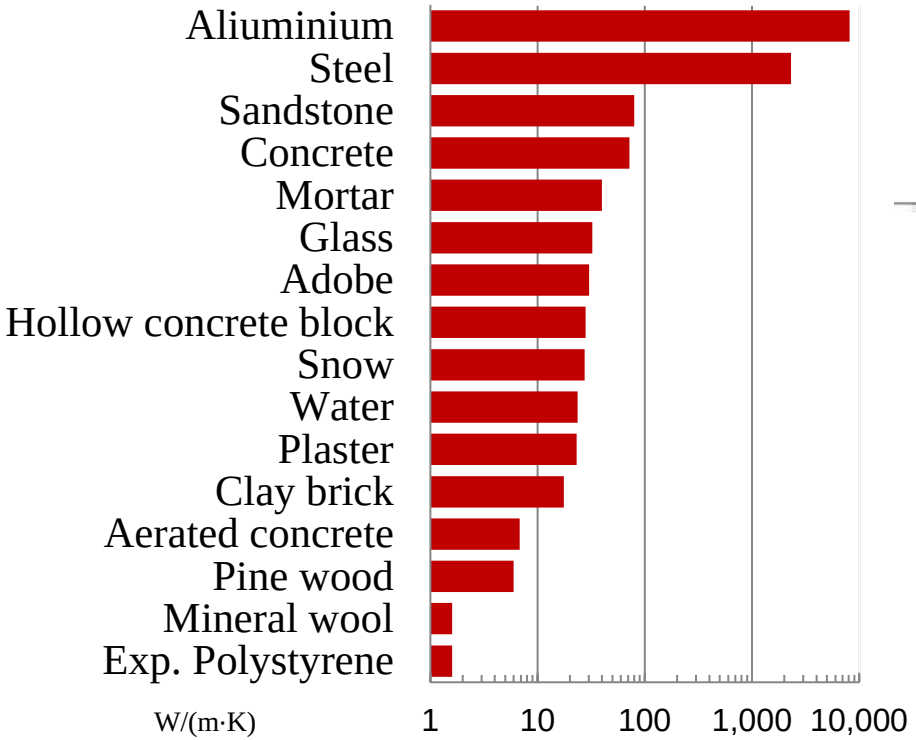
Envelope Materials and Methods : Construction

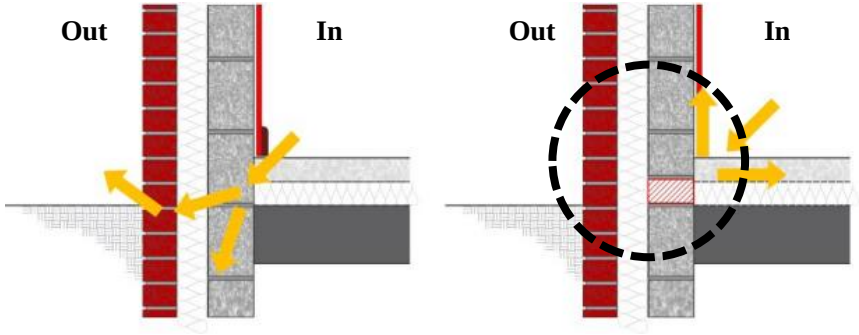


Minimum Thickness Needed to Achieve U value of < 0.40W/m²K

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

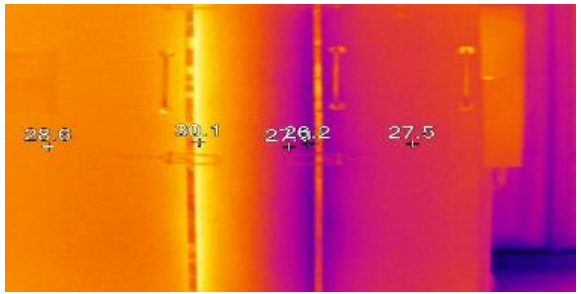
Envelope Materials and Methods: Thermal Bridge





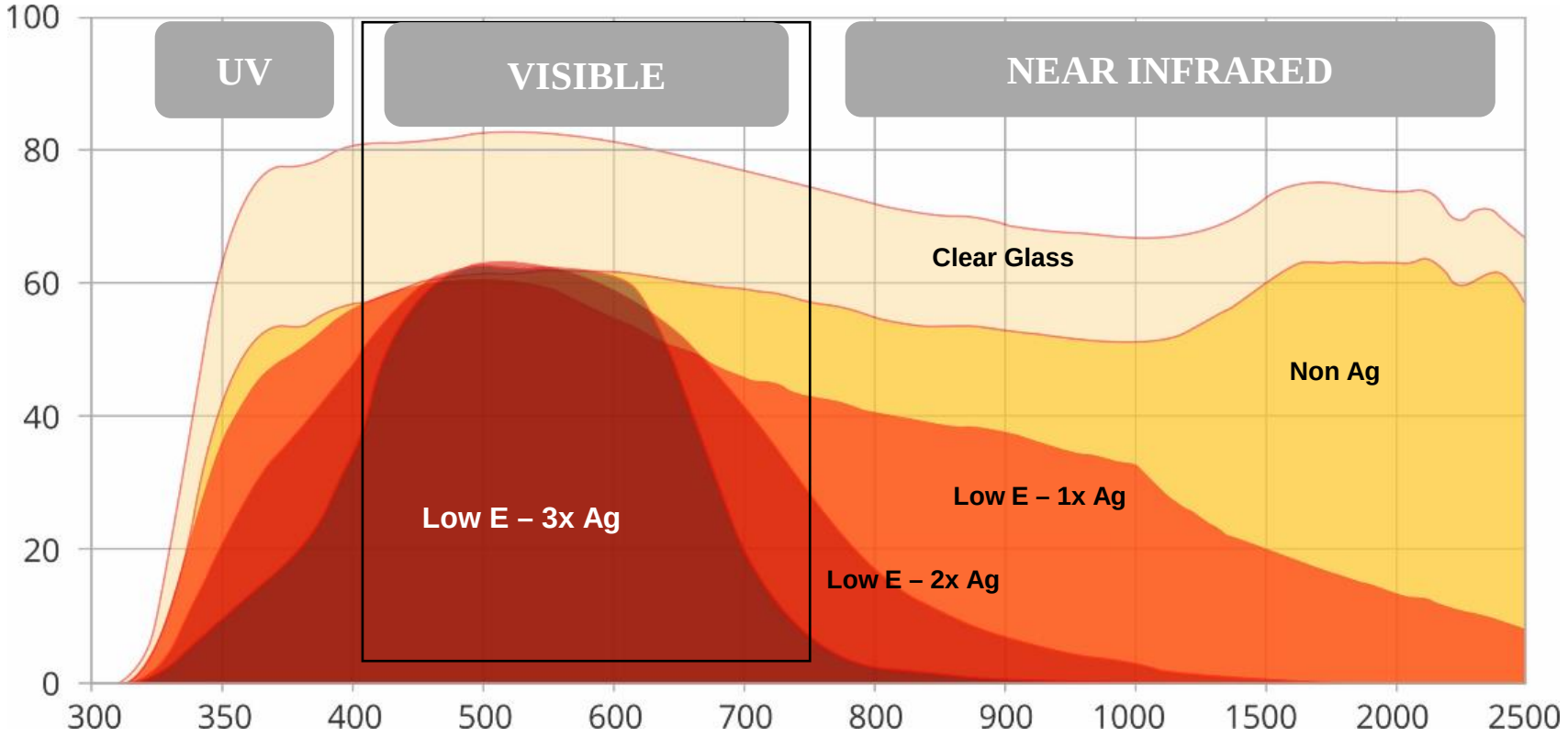
Air = 1

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



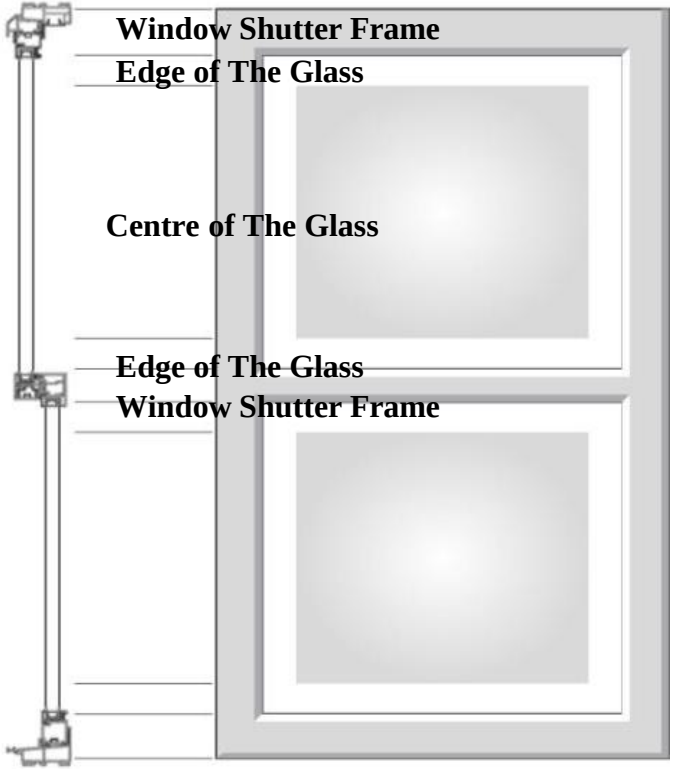
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

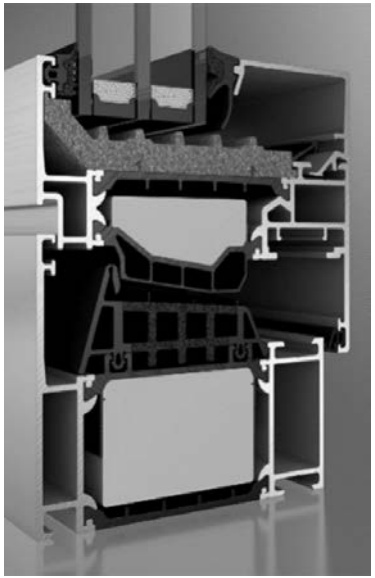
Glazing Material and Methods : Solar Control



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

Glazing Material and Methods : Window Frame

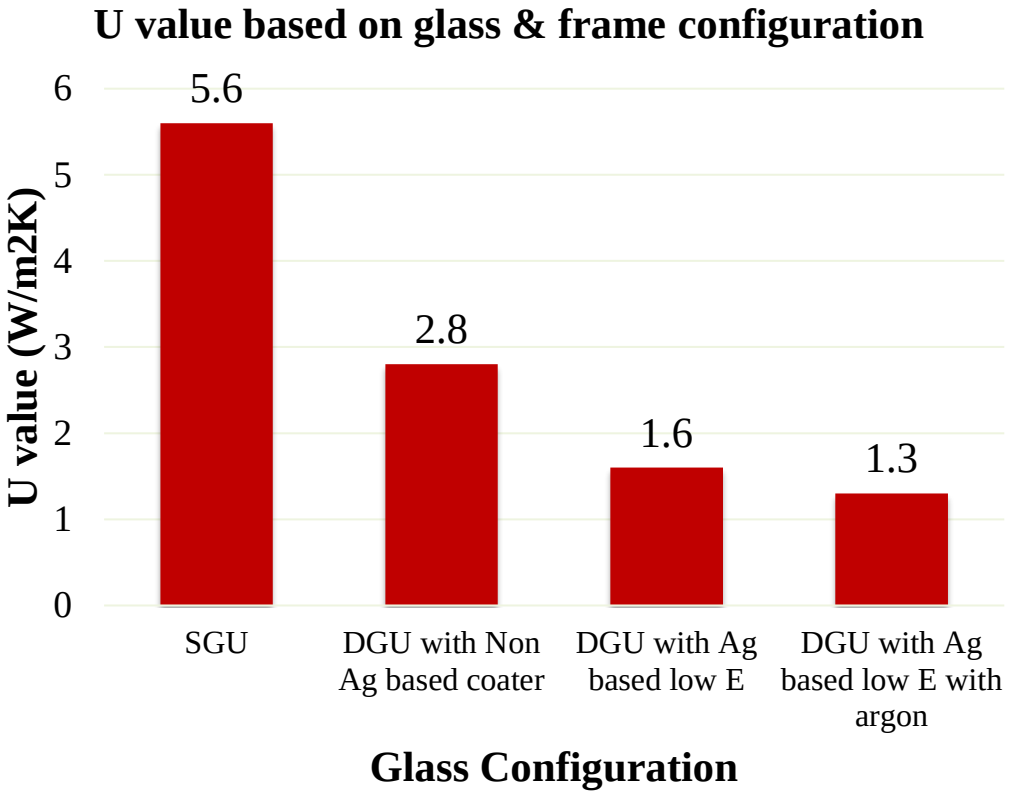




Thermal Break Window Frames
Airtightness of window frame (Mixed-mode buildings)

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-doors/cf68-bi-fold-doors/

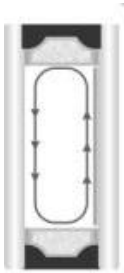
Glazing Material and Methods : Window Frame



SGU

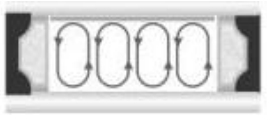
DGU with air

DGU with Argon gas



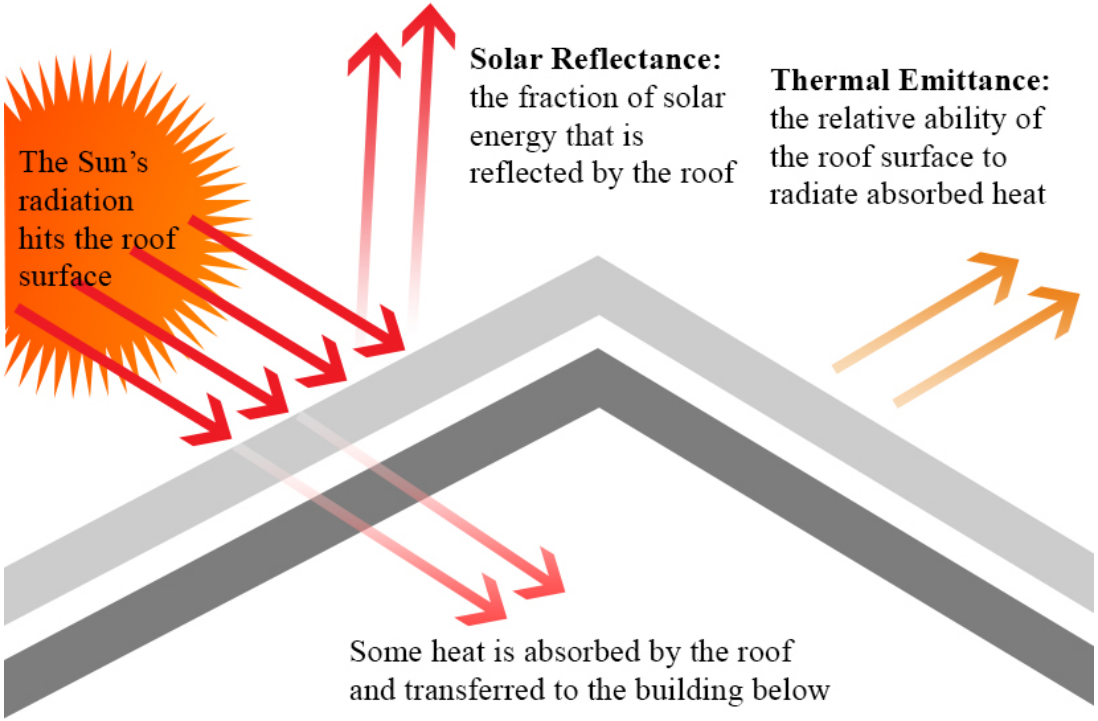
1.1 W/m^2.K

1.5 W/m^2.K



1.7 W/m^2.K

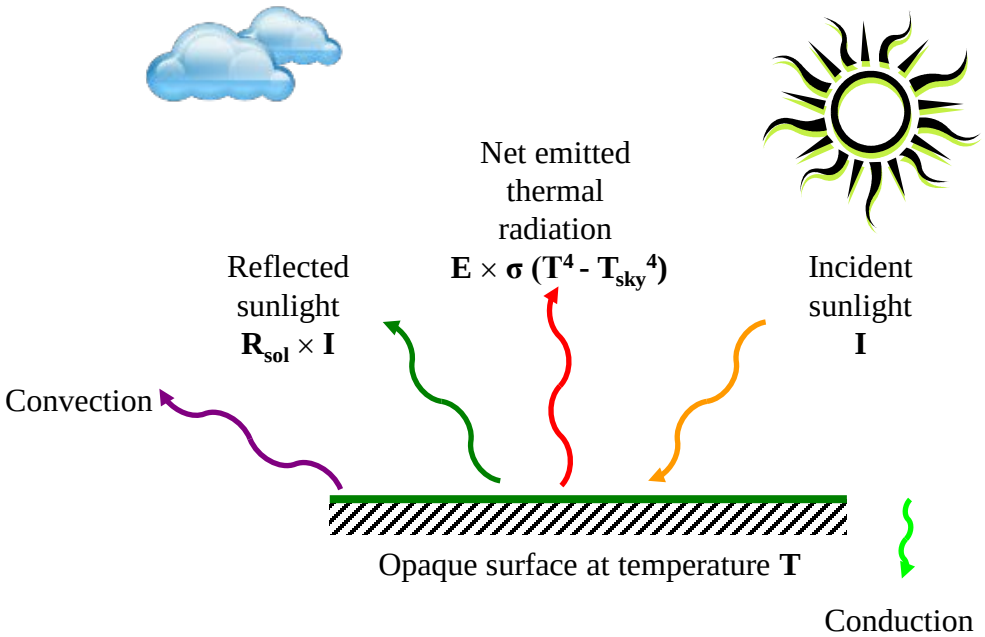
Roofing Coating Material and Solar Reflectance Index

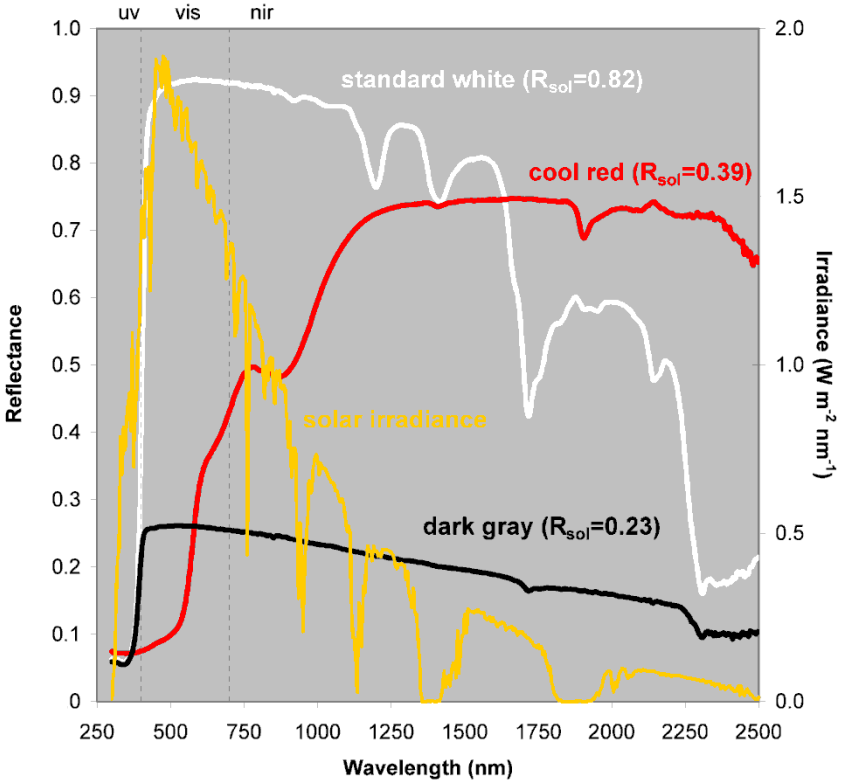


- Reflectance
- Thermal Emittance.
- Emissivity
- Solar Reflectance Index (SRI)

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/.

Roofing Coating Material and Solar Reflectance Index



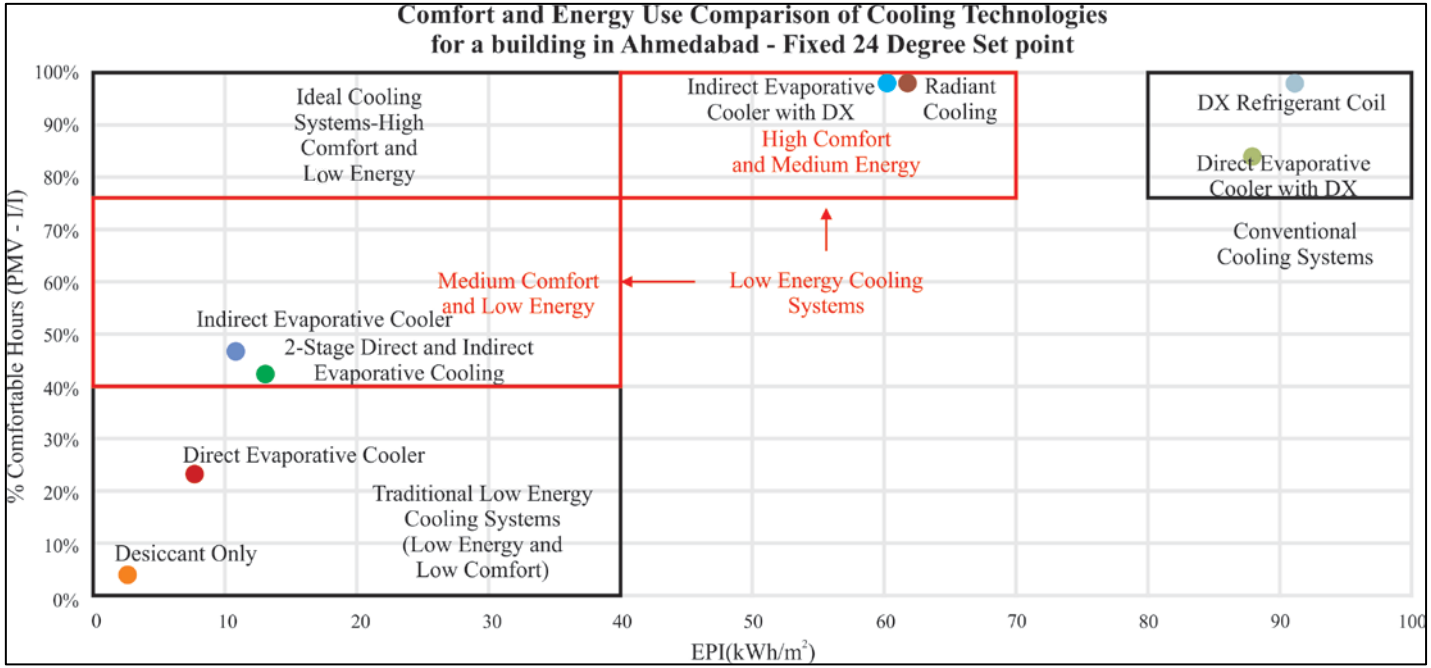


- High solar reflectance (R_{sol}) lowers solar heat gain (0.3 - 2.5 µm)
- High thermal emittance (E) enhances thermal radiative cooling (4 - 80 µm)

Low Energy Cooling Systems

Establish the relevance of Low Energy Cooling

Evaluate – Improve - Deploy



THERMAL COMFORT AND AFFORDABLE HOUSING TRAINING

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