Eco-Niwas Samhita 2018: Part I (Building Envelope)

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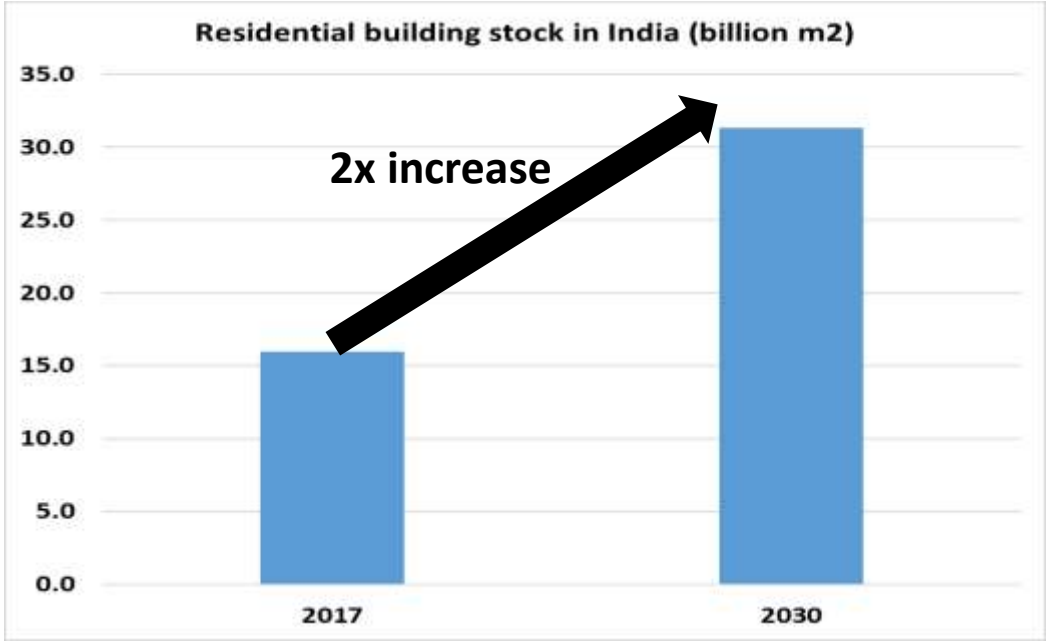
Building Envelope Design is the key for Energy Efficient & Thermally Comfortable Residential Buildings

a) Cooling loads in commercial buildings are usually dominated by internal loads; while in residential buildings dominated by heat gains from the envelope as exposed envelope area to built-up area ratio 2 -3 times more in residential buildings.
b) Peak occupancy of residential buildings during the night, and hence greater role of natural ventilation
c) Greater relevance of adaptive thermal comfort as most of the houses are not air-conditioned

Residential Buildings Construction

- The residential buildings expected to increase 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 comfort to occupants through design is of prime importance



12 Million New Affordable Houses in Urban Areas

Adaptive Comfort

India

Model for

Adaptive

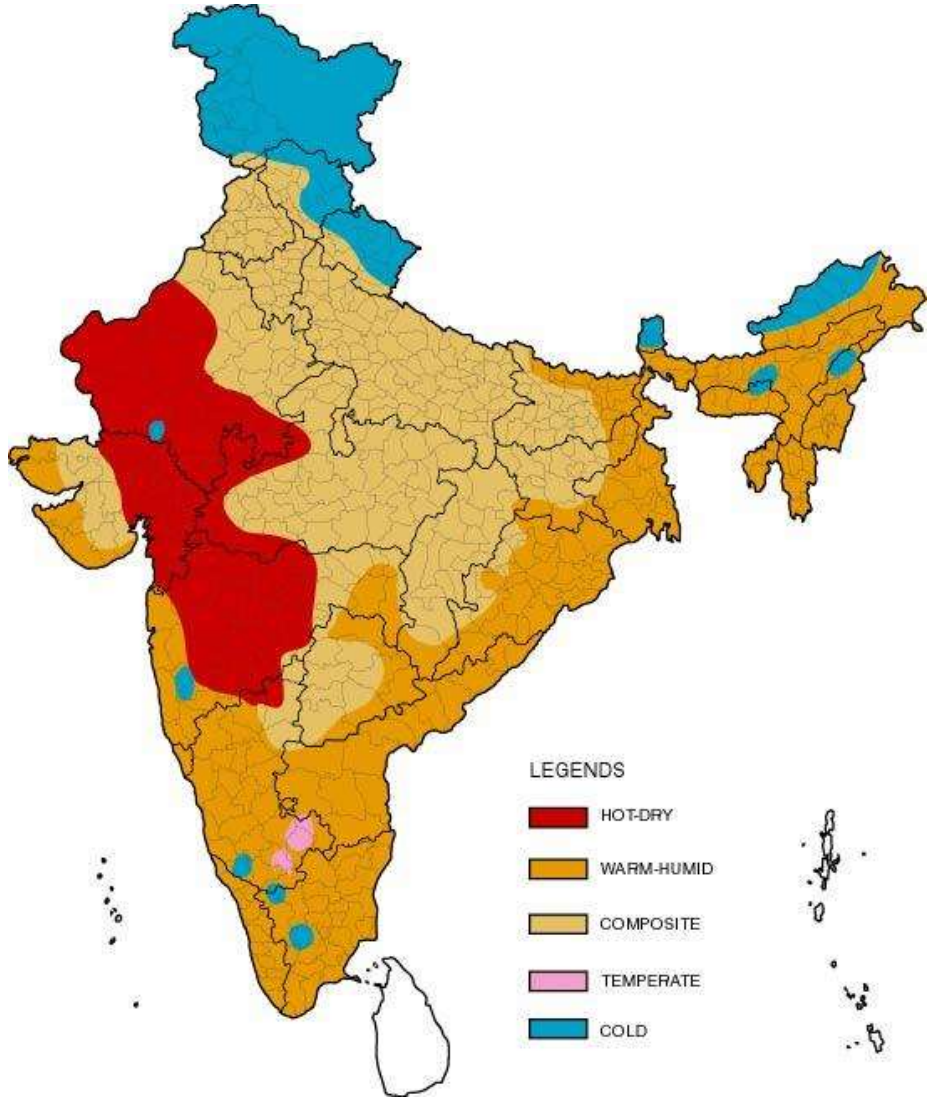
Comfort

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

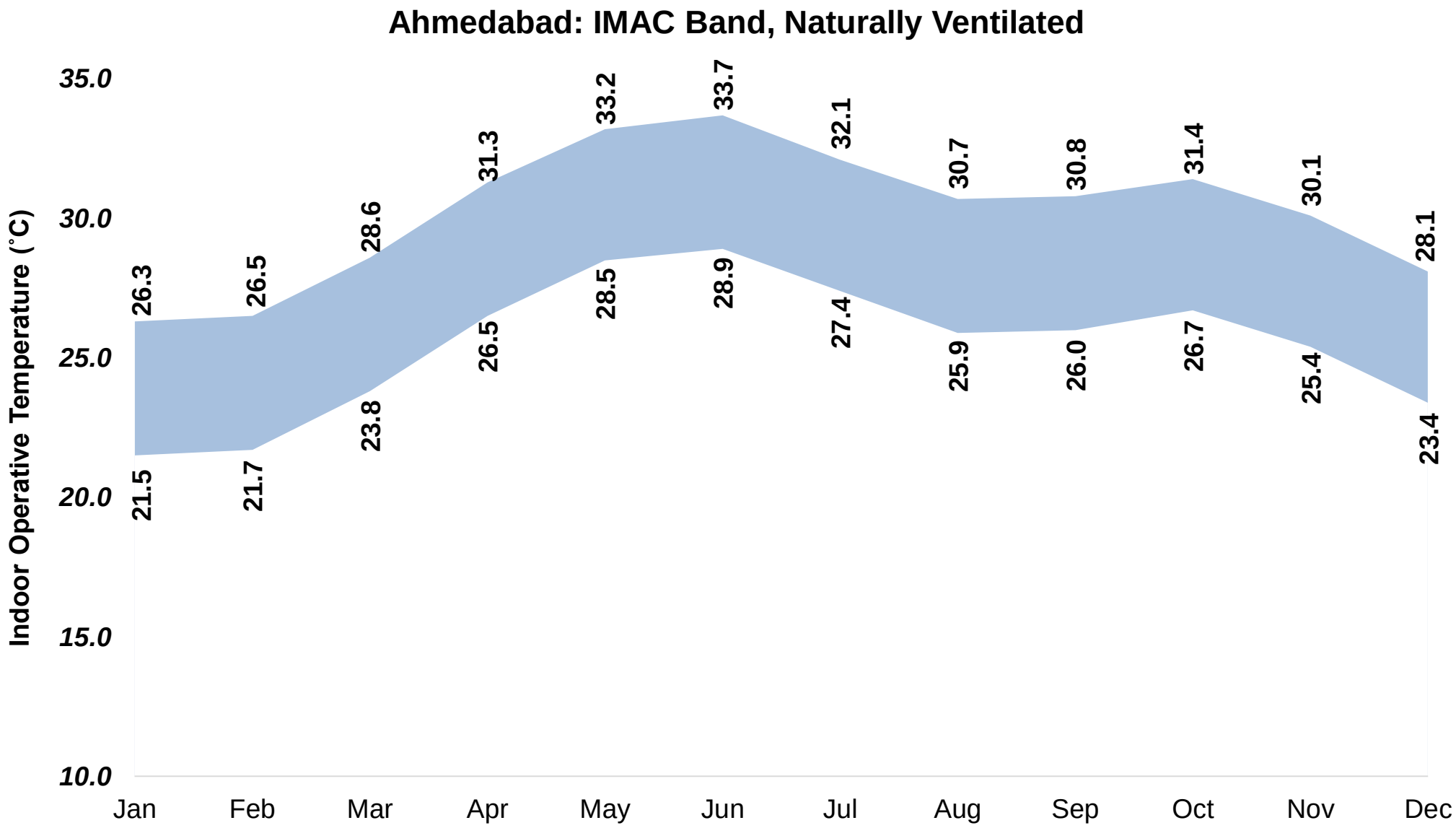
Applicable for air conditioned, naturally ventilated and mixed-mode buildings

Includes the wide temperature ranges in all Indian climate zones

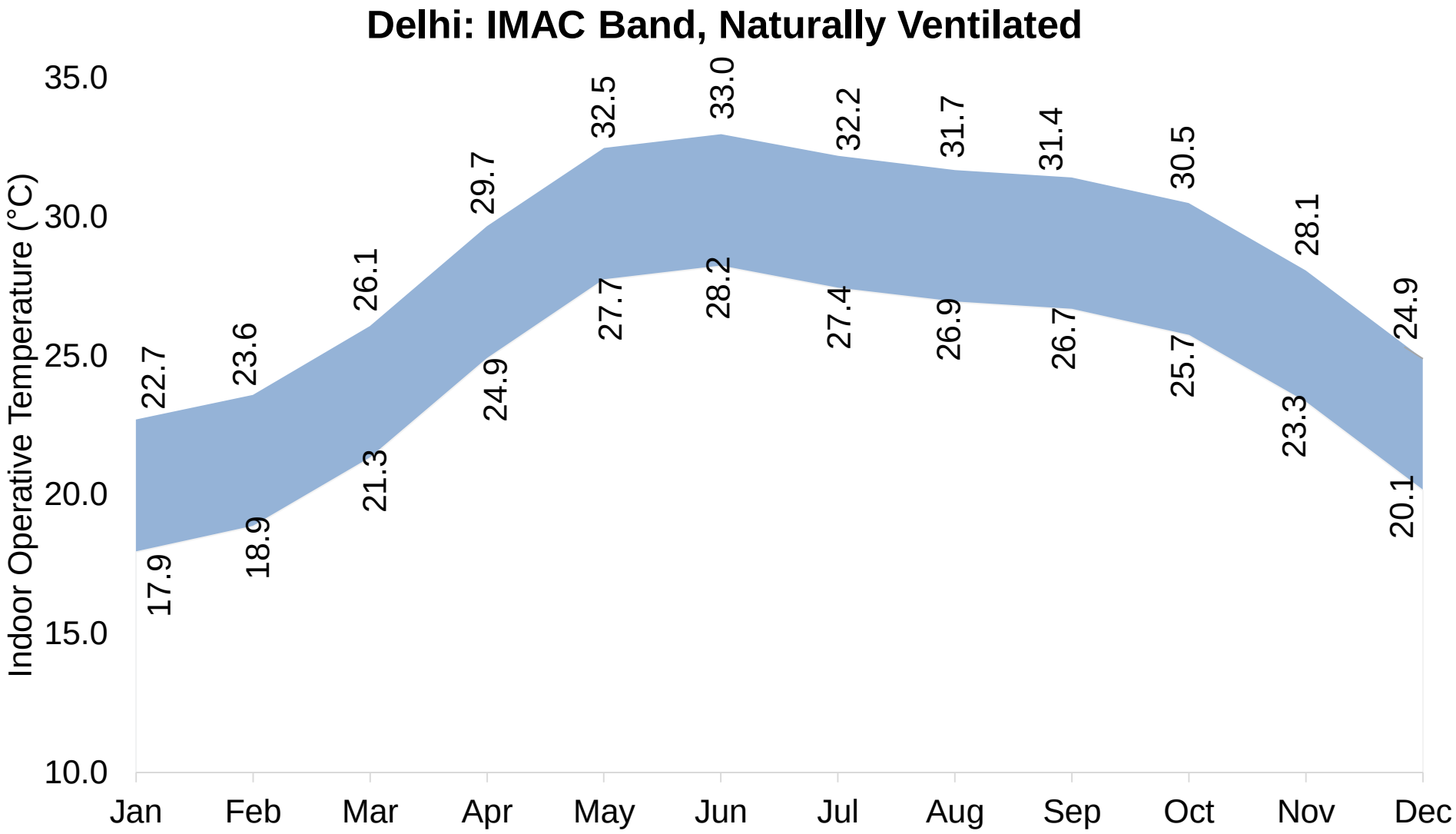
Shows 90% and 80% acceptability bands



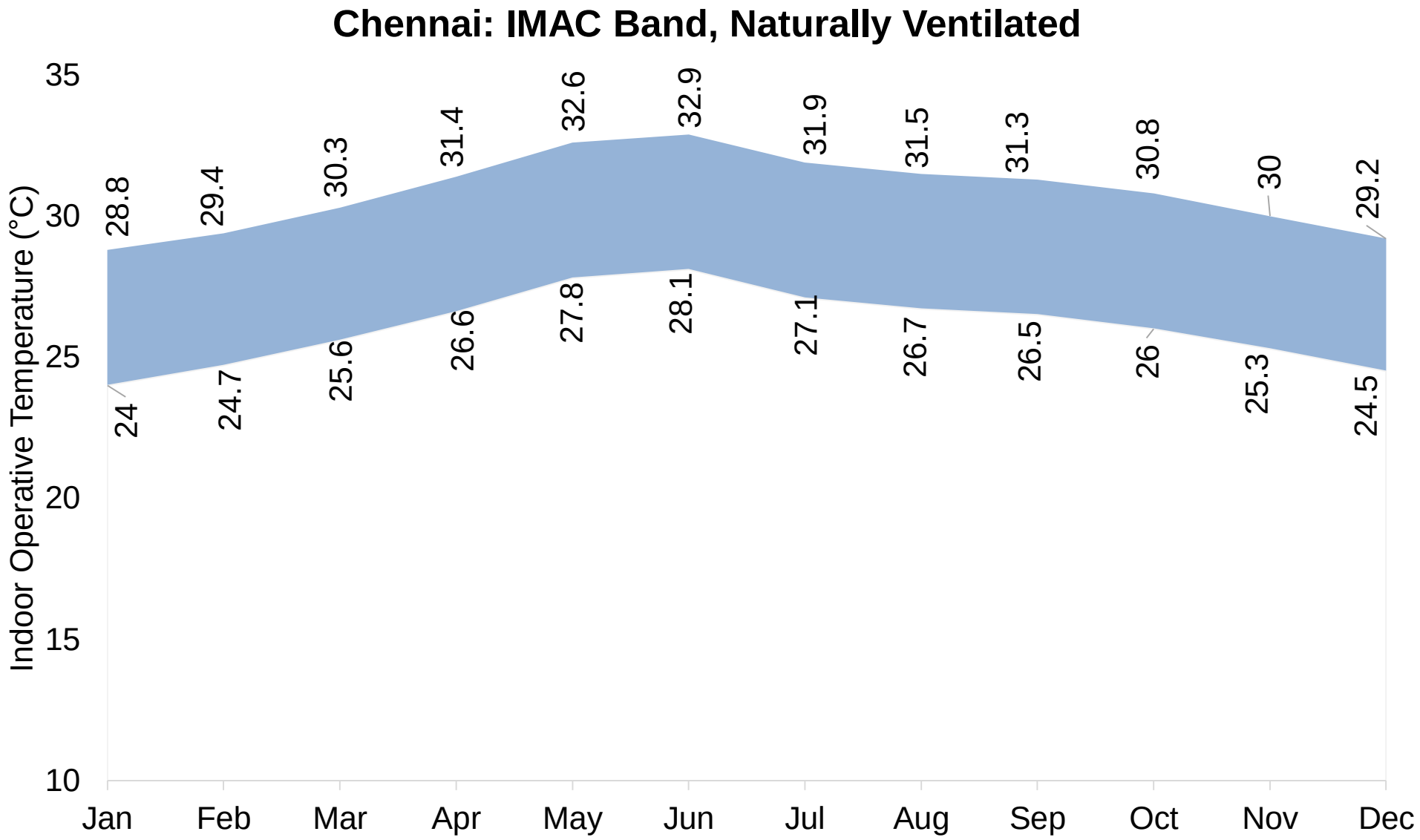
Hot & Dry Climate



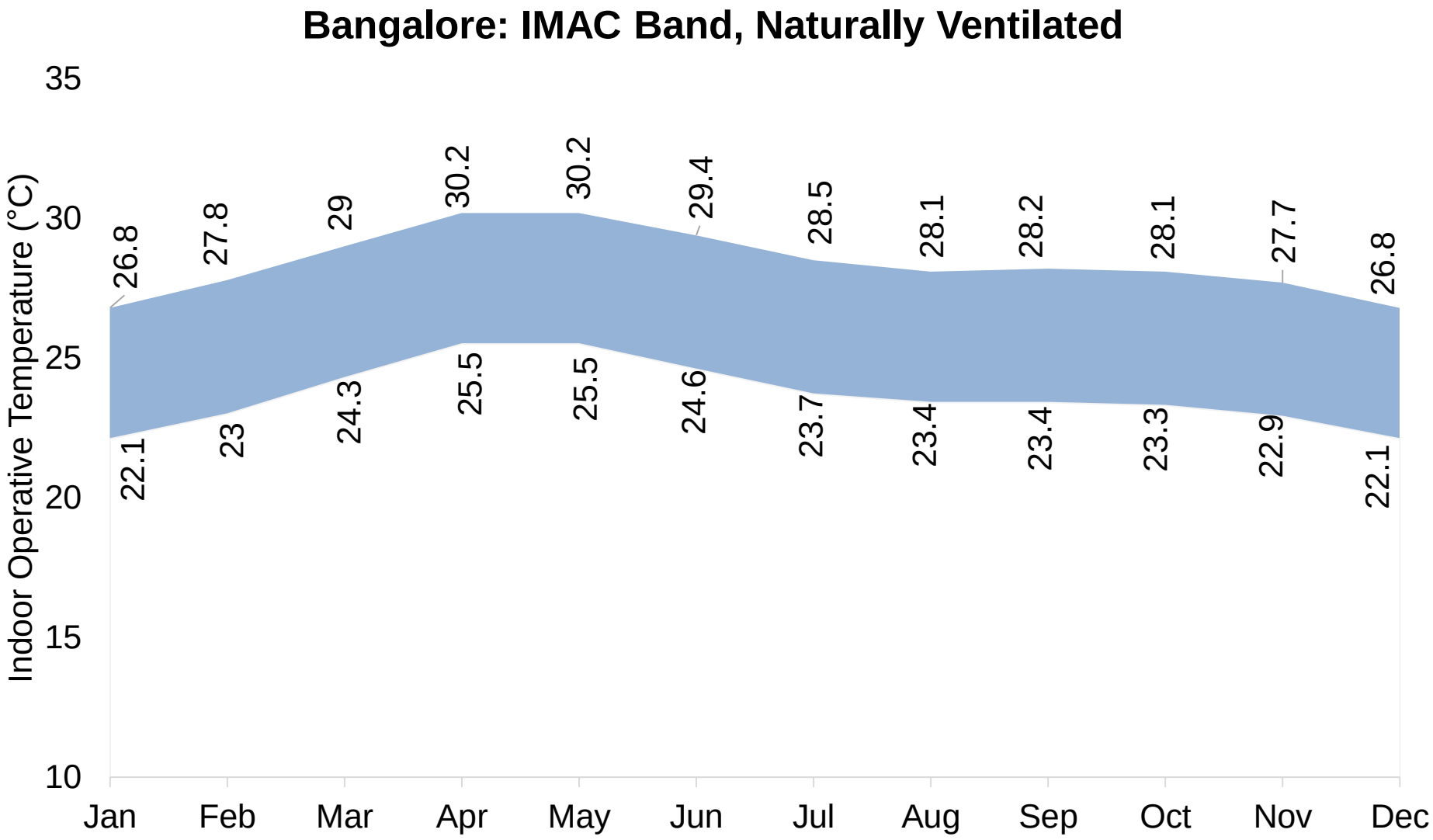
Composite Climate



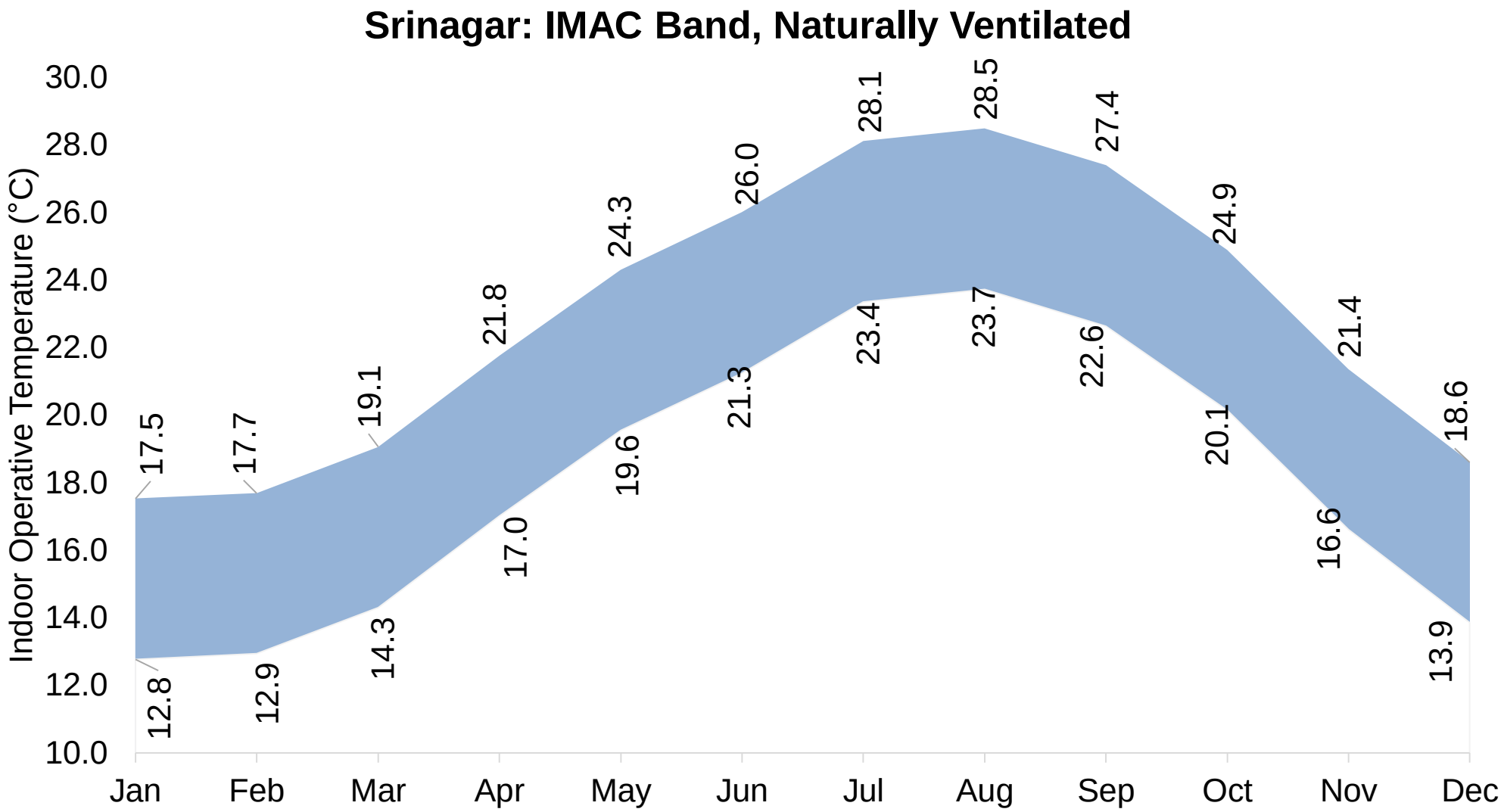
Warm and Humid Climate



Temperate Climate



Cold Climate

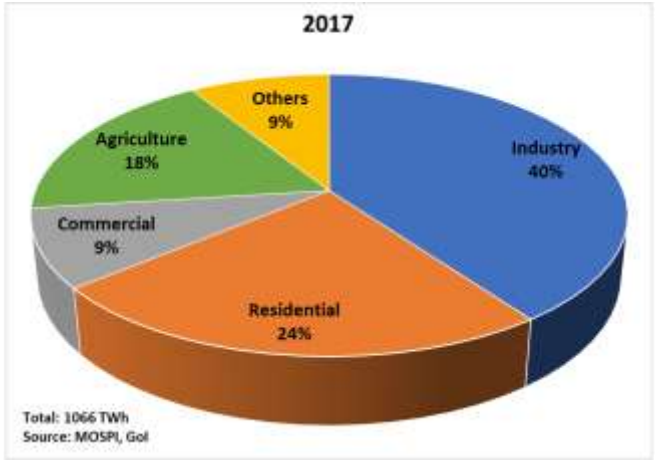


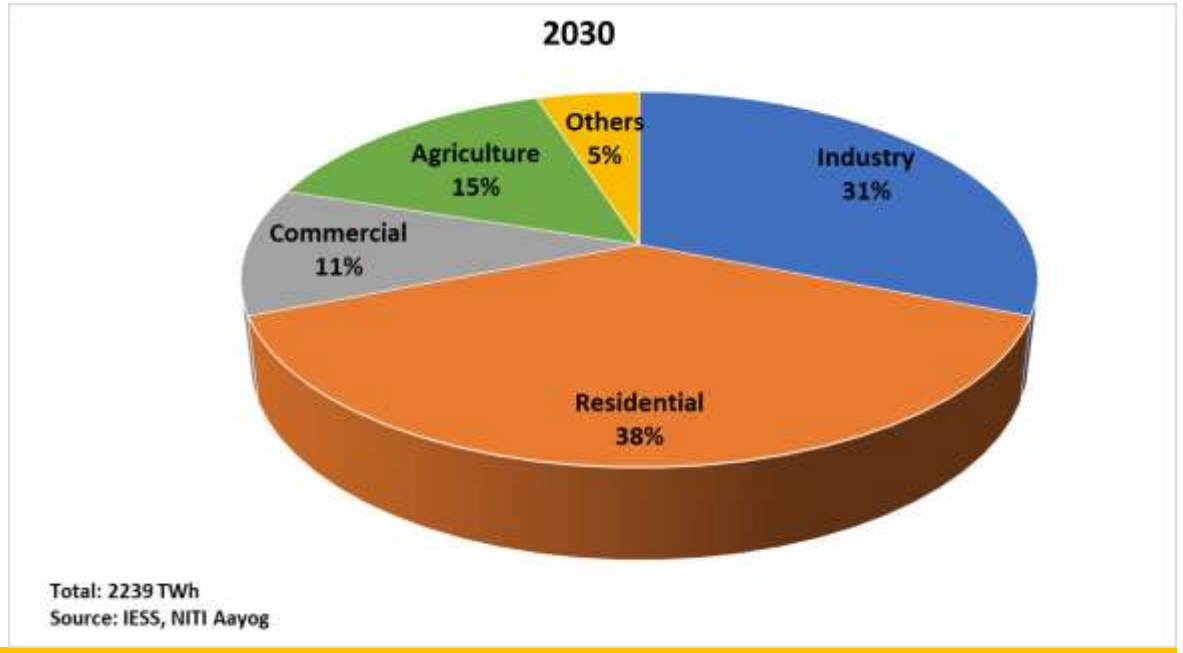
Thermal Comfort - Health & Socio- Economic Impacts

- Majority (~90%) of the households does not have access to air-conditioning
- The maximum air temperature limit for thermal comfort (with fan) is around 32-34^{o}C [NBC]
- As room air temperature and the wall surface temperatures approach 35^{o}C, then the ability of the human body to loose heat reduces drastically.
- Thermal discomfort results in
  - Loss of concentration, nausea or irritability, muscle cramps or weakness, headache, fatigue, etc.
  - Negative impact on health of the occupants, children unable to study, loss of income due to poor productivity

Thus while designing houses care should be taken that the peak indoor operative temperatures does not exceed comfort band during peak summer period. This is the basic strategy for curtailing the growing use of air conditioning to alleviate discomfort.

Residential Buildings: Fast Growth in Electricity Consumption





- 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** 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**.

Building Energy Efficiency - Overview

- The Bureau of Energy Efficiency (BEE) has adopted a multi-pronged approach to conserve energy in building sector:
  - Energy Conservation Building Code (ECBC) for commercial buildings (2007 & 2017).
  - Star rating system for various types of commercial buildings
  - Star rating for appliances, which cover air conditioners, fans, lighting, etc.

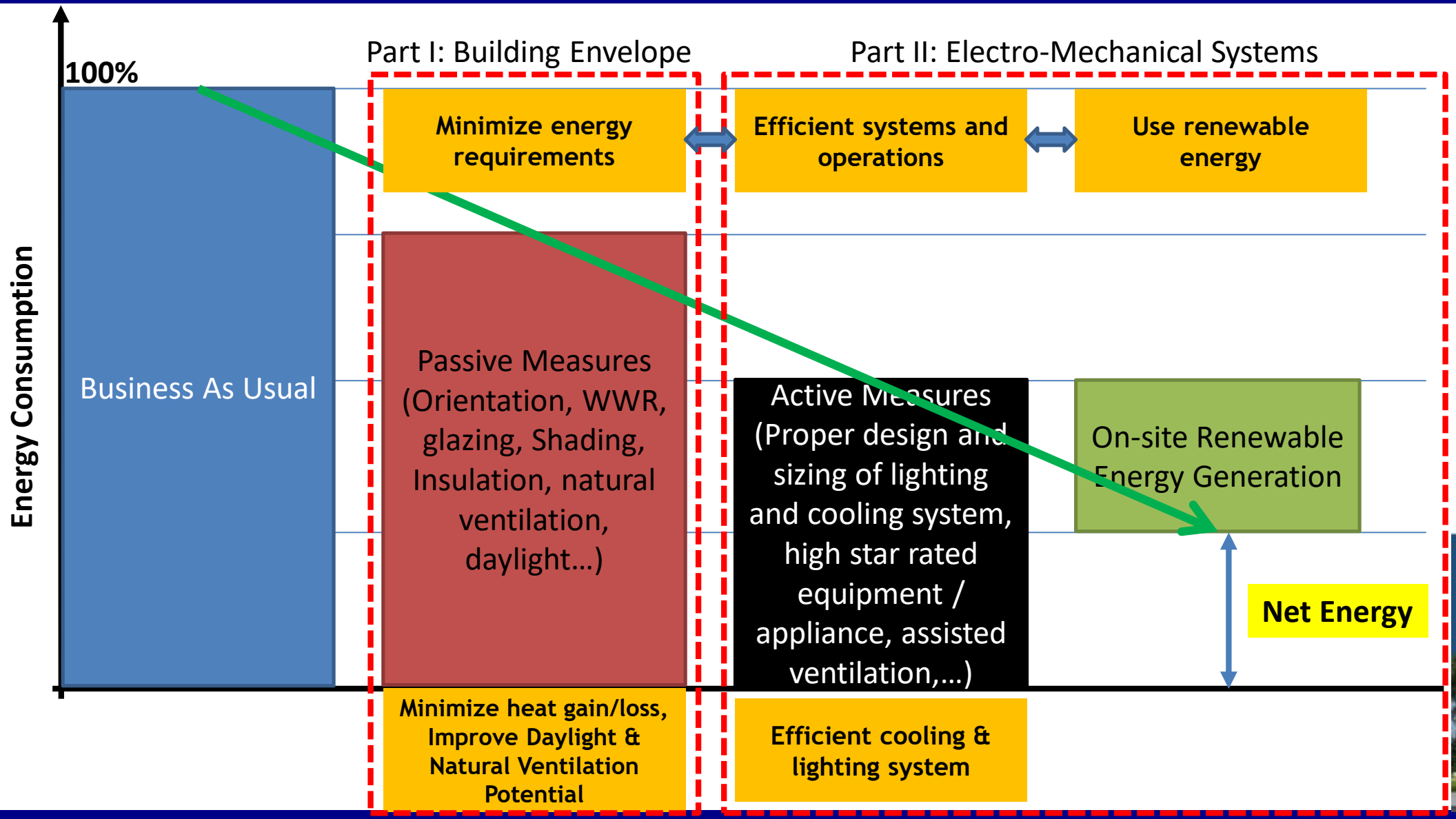
- BEE now plans to aggressively push for energy efficiency in new housing through the **Energy Conservation Building Code for Residential Buildings (Parts 1 & 2)** and through the Residential Building Labelling Programme.

Eco-Niwas Samhita 2018

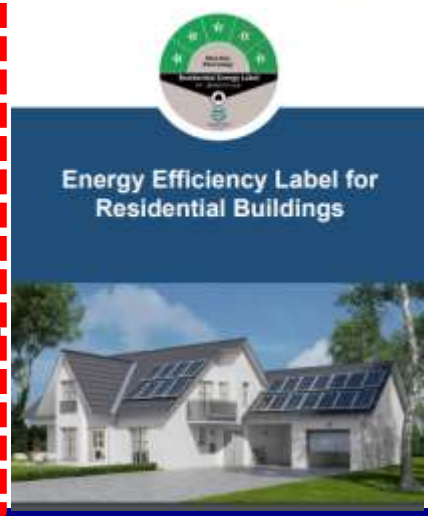
- Eco-Niwas Samhita 2018 (Part I: Building Envelope) is the new Energy Conservation Building Code for Residential Buildings; launched by Ministry of Power (MoP) on 14 December 2018.

Building envelope provisions to improve thermal comfort and reduce energy consumption

Approach for reducing energy consumption in building

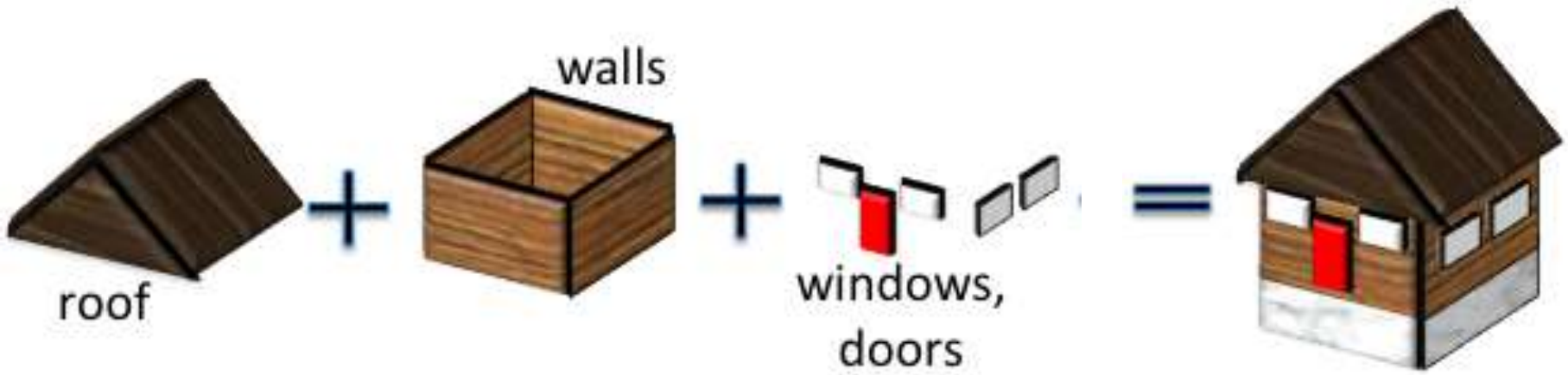


Residential Labelling Program



Building Envelope

- The **building envelope** is the physical barrier between the exterior and interior environments enclosing a structure.

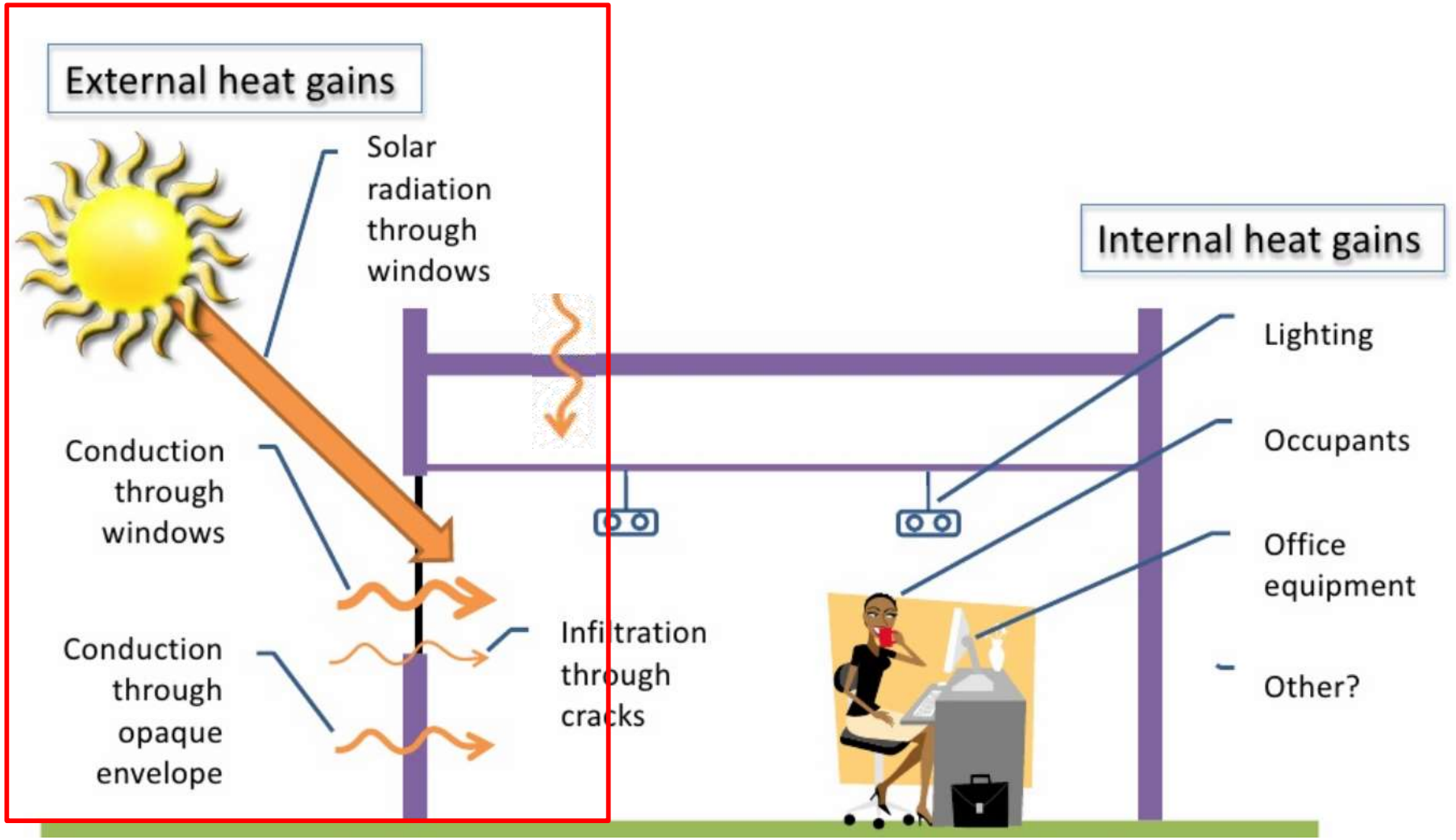


Building Envelope

Source: https://energyeducation.ca/encyclopedia/Building_envelope

Heat Exchange in a Building

Design & material selection



Energy efficient appliances

Energy Conservation Building Code-Residential: Objective

PROVISIONS FOR BUILDING ENVELOPE

- Reduces Heat Gains/Loss
- Improve Natural Ventilation & Daylighting Potential

Improved thermal comfort & reduced energy consumption

Scope and Code Provisions

ENS: Scope

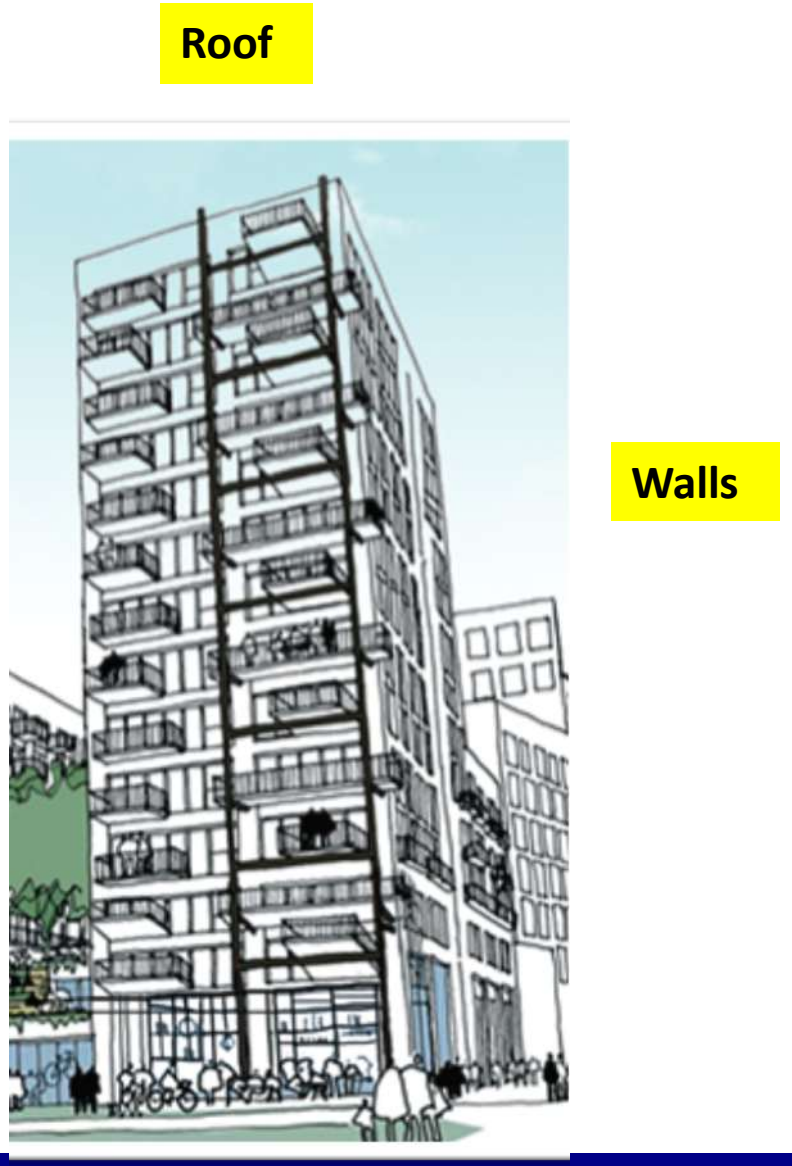
- Code is applicable to:
  - ‘Residential buildings’ built on a plot area ≥ 500 m^2
  - Residential part of ‘Mixed land-use building projects’, built on a plot area of ≥ 500 m^2.

  [‘Residential building’ includes any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities.]
  - Inclusions: a) One or two family private dwellings and b) Apartment houses including group housing
  - Exclusions: a) Lodging and rooming houses, b) Dormitories and c) Hotels.

[States and Municipal Corporations can lower this limit]

ENS: Scope

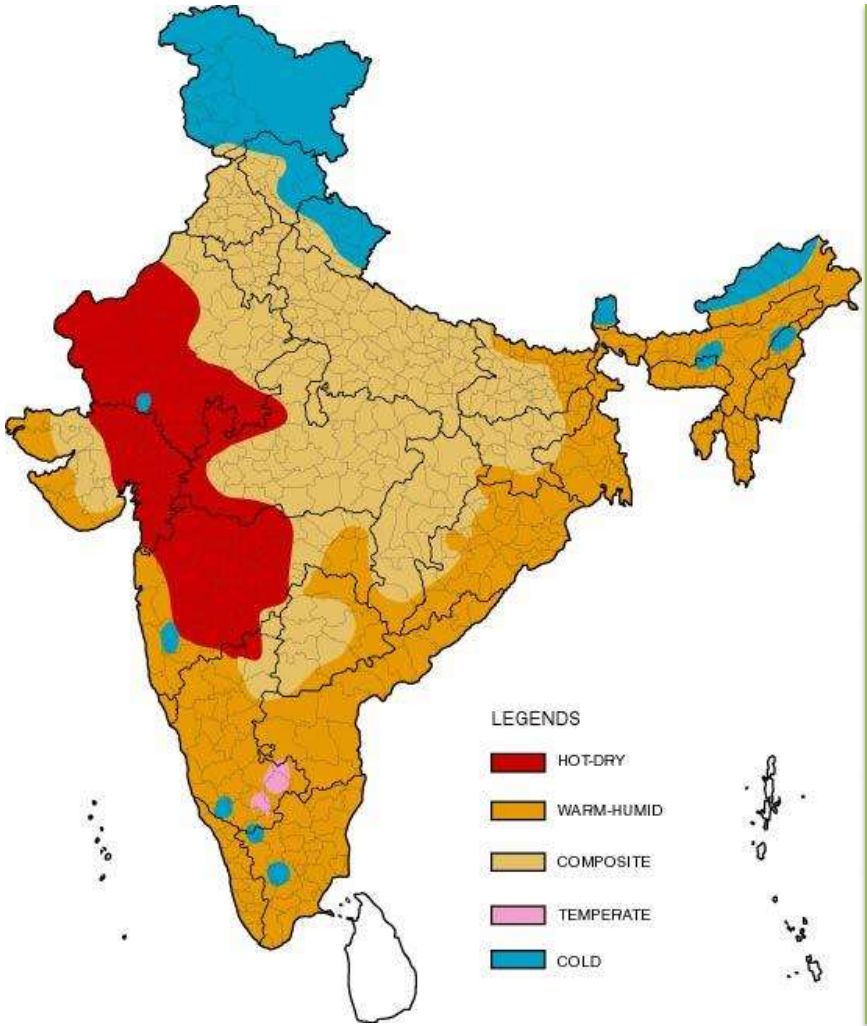
- Building envelope (roof, walls, windows and outside openings)
- Sets minimum building envelope performance standards to
  - Limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climates)
  - Ensuring adequate natural ventilation potential
  - Ensuring adequate daylighting potential.



Climate Zones & Basis of Climate Classification

- **Composite & Hot-dry, Warm-humid, Temperate**: Cooling dominated climates, responsible for fast growth in air-conditioning electricity requirement; accounts for >96% of the population and new construction
- **Cold**: Heating dominated climate

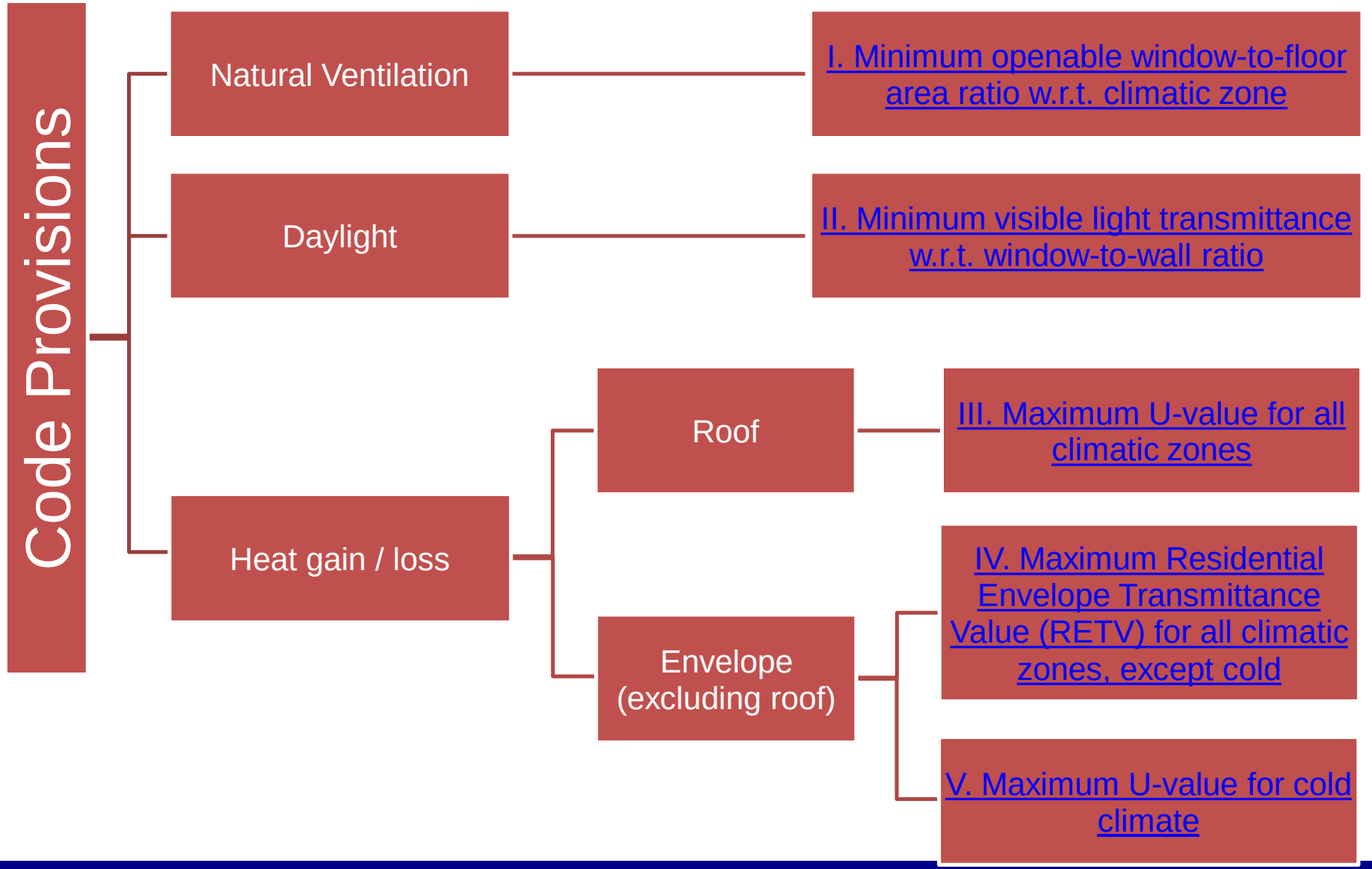
[Refer Annexure 2]



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

As per National Building Code of India-2005, India has been divided into five climatic regions which have the following conditions for six months or more

Eco-Niwas Samhita 2018: Code Provisions



ENS Part 1 Summary

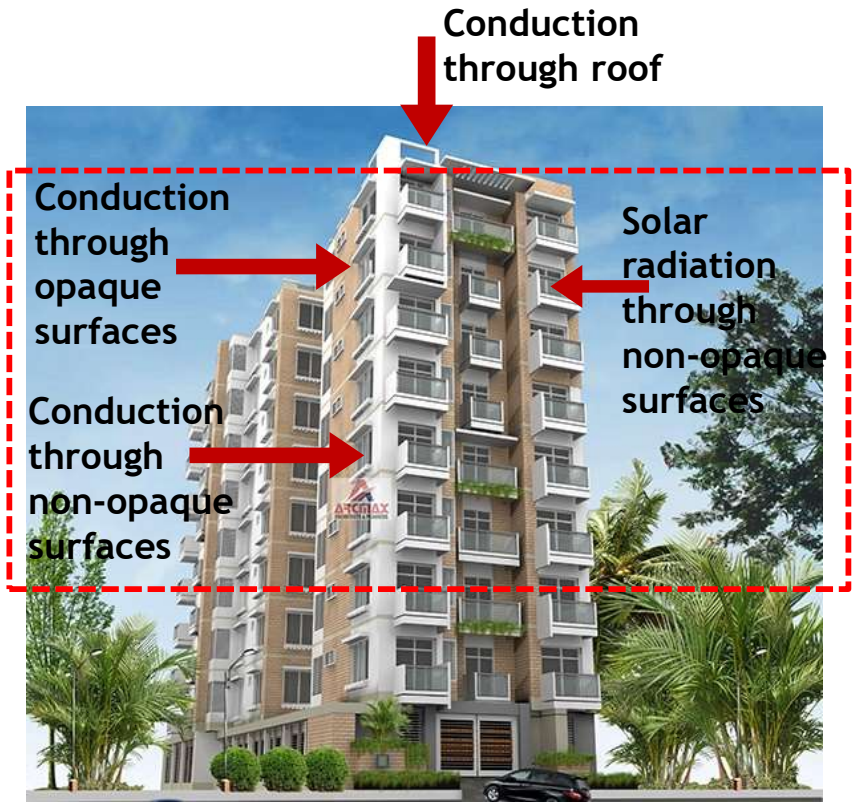
- Deal with building envelope
- Sets permissible standards for
  - Minimum natural ventilation potential
  - Minimum daylight potential
  - Maximum heat gains / loss from roof
  - Maximum heat gains/ loss through building envelope (except roof)

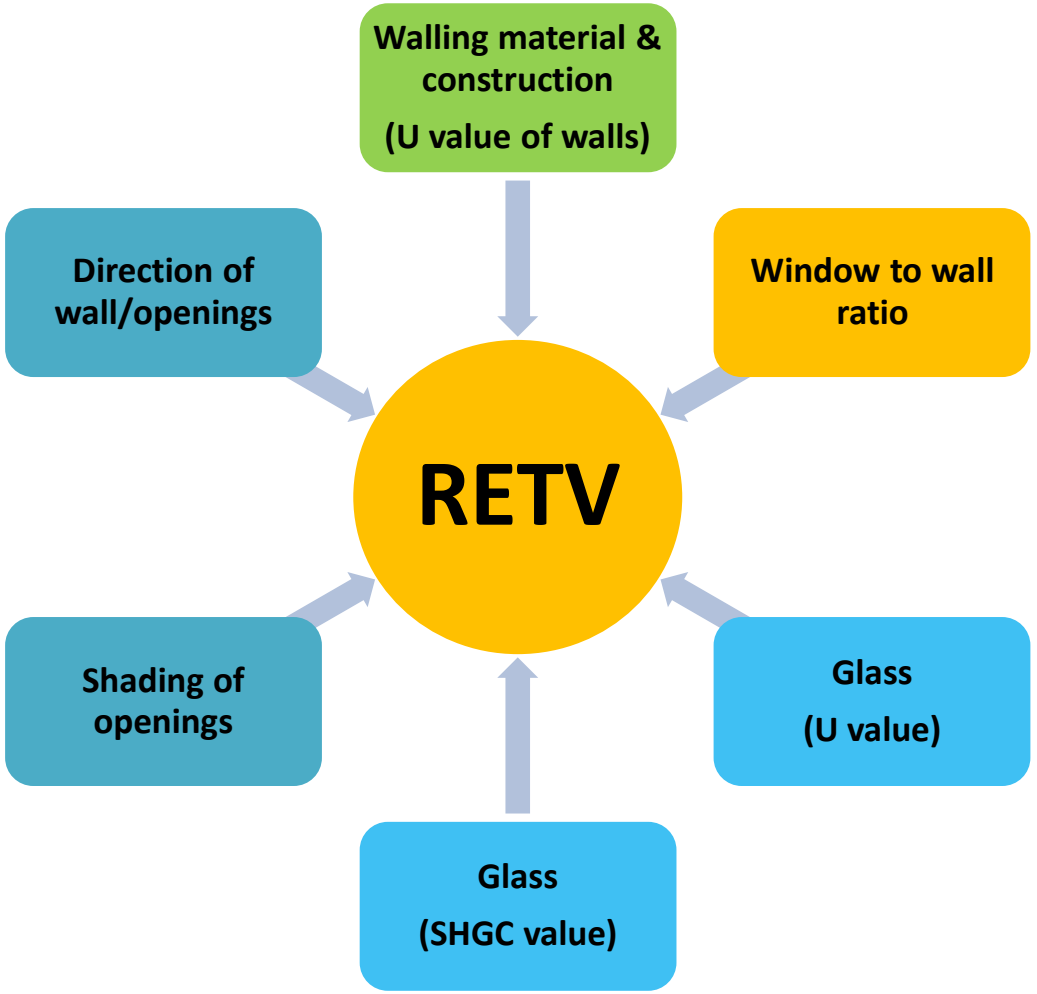
Resources

- Code document: https://www.beepindia.org/wp-content/uploads/2013/12/ECBC_BOOK_Web.pdf
- https://beeindia.gov.in/content/ecbc-residential
- Brochure: https://www.beepindia.org/wp-content/uploads/2013/12/Brochure.pdf
- Compliance check tool: https://www.beepindia.org/wp-content/uploads/2013/12/EcoNiwasSamhita_ComplianceCheckTool.zip
- Film: English short version (https://www.youtube.com/watch?v=zg515mlU0dc)
- Film: English long version (https://www.youtube.com/watch?v=EG44gdSuWNE)
- Film: Hindi short version (https://www.youtube.com/watch?v=nyweHmqAPxw)
- Film: Hindi long version (https://www.youtube.com/watch?v=LEAb-iviwRc)
- ECBC-R Compliance tool video tutorial: https://www.youtube.com/watch?v=2SQyKekxpiM
- Support email: pmtu@beepindia.org, saswati@gkspl.in, anandh@gkspl.in

Thank You !

Combined heat gains from the building envelope (except roof)





RETV: Residential Envelope Transmittance Value

IV. Residential envelope transmittance value (RETV) for building envelope (except roof) for four climate zones, except cold

- Provision: **RETV ≤ 15 W/m²**. (Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate)
- RETV is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units.

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

Dependent on wall properties

Dependent on window properties

Dependent on window properties & shading

a, b, c: coefficients, based on climatic zone

$A_{envelope}$: envelope area (excluding roof) of dwelling units (m^2)

A_{opaque_i}: areas of wall / opaque part (m^2)

$A_{non-opaque_i}$: areas of glass / non-opaque part (m^2)

U_{opaque_i}: thermal transmittance values of wall / opaque part ($W/m^2.K$)

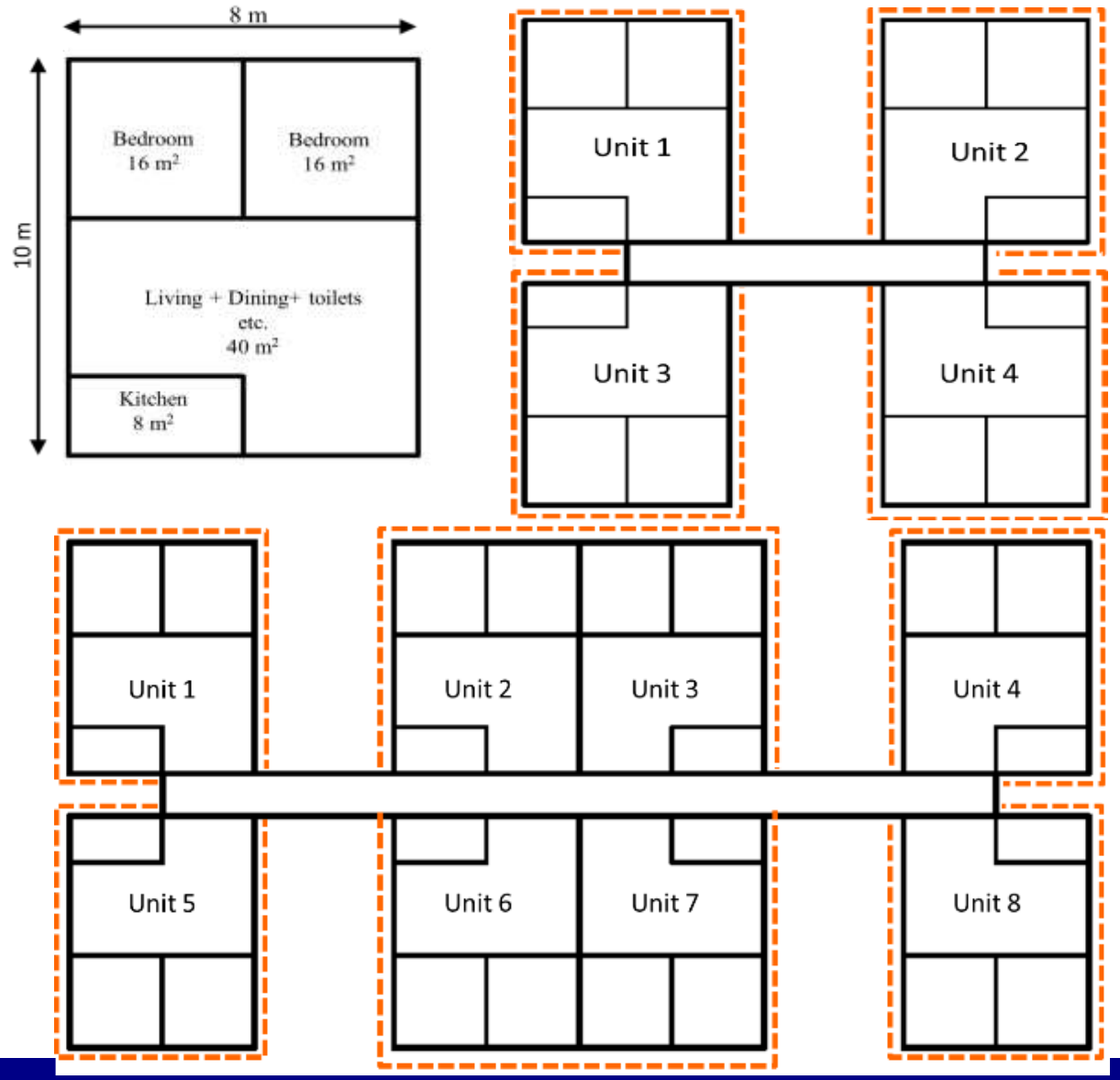
$U_{non-opaque_i}$: thermal transmittance values of glass / non-opaque part ($W/m^2.K$)

$SHGC_{eq_i}$: equivalent solar heat gain coefficient values of glass / non-opaque part

ω_i: orientation factor

Development of RETV Formula

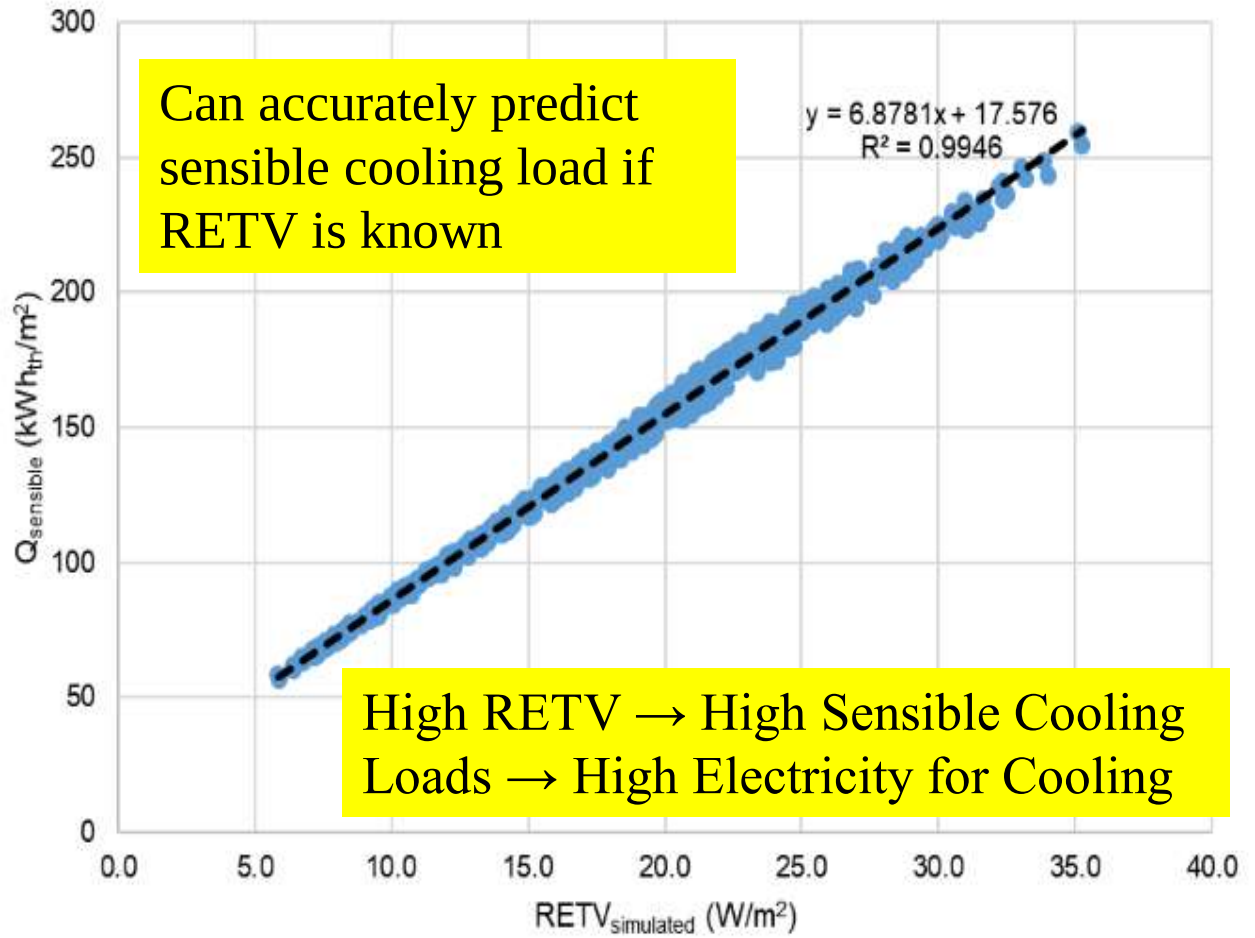
- Climatic zone segregation and city selection in climatic zone
- Preparing typical building floor plans
- Input parameters and their values for energy simulation
- Simulation results and their post processing
- Calculation of orientation factor & external shading factor
- RETV formulation
- Regression analysis for determination of coefficients
- Validation of results
- Final formula with coefficients



Development of RETV Formula

Variable	No. of values
Locations	7
Floor plan	2
External Wall	5
Glazing	4
Shading	3
WWR	6 (for 3 locations of composite / hot-dry climatic zone) 5 (for 4 locations of warm-humid / temperate climatic zone)
Openable area	2
Orientation	1 (for point block) 2 (for doubly loaded corridor)
Cooling scenario	2

27,360 simulation cases

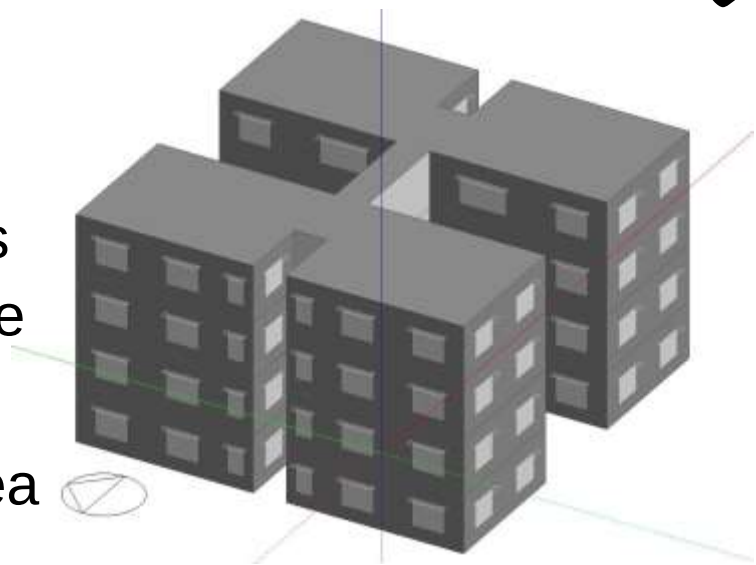


Correlation between $Q_{sensible}$ and $RETV_{simulated}$ for point block model at Delhi

What does RETV formula do?

Energy Simulation

- Prepare energy model (drawings, construction, internal load, schedule, cooling & ventilation system, etc.)
- Do energy simulation
- Extract net heat results for all building envelope components
- Divide by envelope area to calculate RETV



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RETV Formula

- Get the areas from architectural drawings
- Get the construction details of building envelope
- Use RETV formula to calculate RETV

Simplified calculation to predict cooling requirement of building. Results very close to detailed energy simulation.

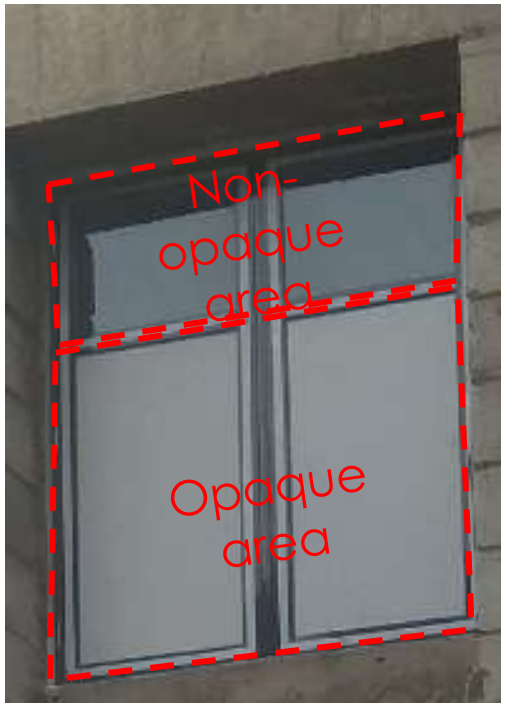
Coefficients of RETV Formula

TABLE 3 Coefficients (a, b, and c) for RETV formula

Climate zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperate	3.38	0.37	63.69
Cold	Not applicable (Refer Section 3.5)		

Non-opaque Area & Envelope Area (Excluding Roof)

Non-opaque Area

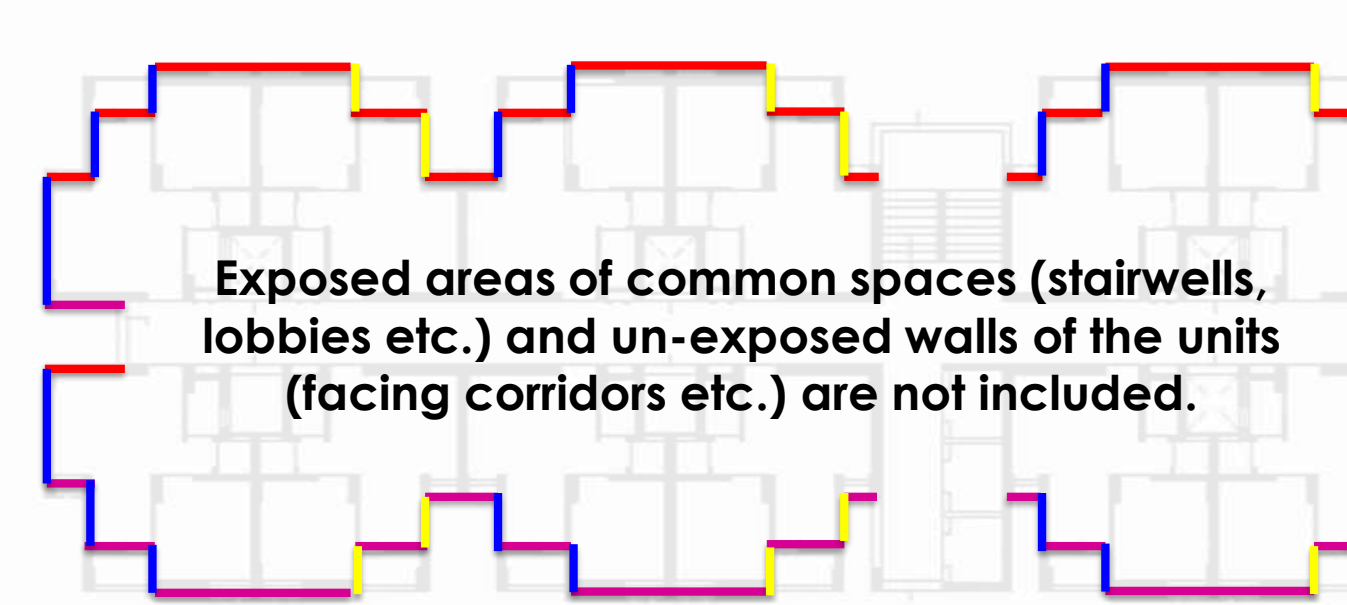


*Frame area is not taken in calculation

Non-opaque area:
100% opening area

Non-opaque area:
33.3% opening area

Envelope Area (Excluding Roof)



Envelope area =
Total wall length (m), exposed to ambient x
Total wall height (m), exposed to ambient

Definition of Thermal transmittance (U value)

It is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. Unit of U value is W/m^2.K.

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o} + \sum_{i=1}^{n} \frac{t_i}{k_i}}$$

h_i is the inside air heat transfer coefficient, W/(m^2.K)

h_o is the outside air heat transfer coefficient, W/(m^2.K)

t_i is the thickness of material i, m

k_i is the thermal conductivity of material i, W/(m.K)

U value for the wall/roof/glazing indicates its ability to transfer heat through conduction. Higher the U-value, higher the heat transfer

III. Thermal Transmittance of Roof (U_{roof})

- Provision: **$U_{roof} \leq 1.2$ W/m^2.K**

Roof construction type	U value (W/m2.K)
100 mm RCC	3.66
Finishing tile + Concrete laid to slope (min. 50 mm) + 100 mm Foam Concrete + Water-proofing + 20 mm Screed + 150 mm RCC slab	0.62
Finishing tile + Concrete laid to slope (min. 50 mm) + 50 mm Expanded Polystyrene + Water-proofing + 20 mm Screed + 150 mm RCC slab	0.54

U value of few wall and glazing types

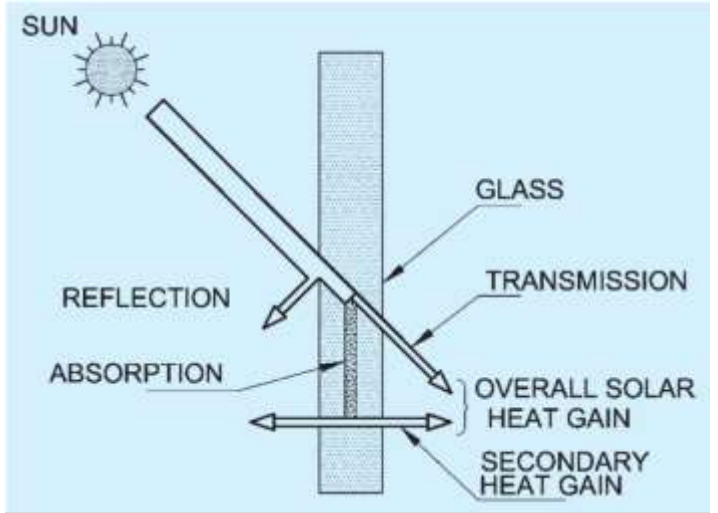
Wall construction type	U value (W/m2.K)
150 mm RCC (No plaster)	3.77
200 mm Solid Concrete Block with 15 mm plaster on both sides	2.8
230 mm Brick with 15 mm plaster on both sides	1.72-2.24
200 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both sides	0.77
300 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both sides	0.54

Glazing type	U value (W/m2.K)
Single pane glass	5.0 - 5.8
Double pane glass	1.8 - 2.7

Definition of Equivalent SHGC ($SHGC_{eq}$)

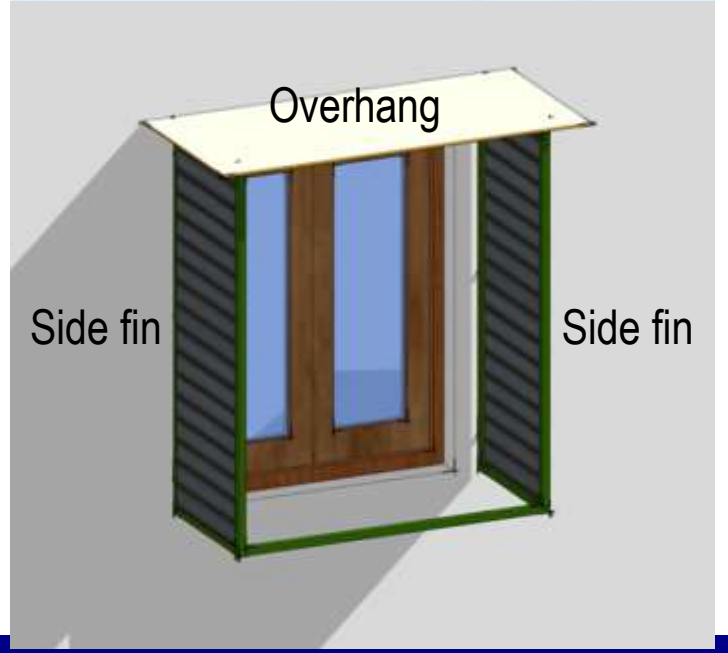
- Solar heat gain coefficient (SHGC) is the fraction of incident solar radiation admitted through a fenestration, both directly transmitted, and absorbed and subsequently released inward through conduction, convection and radiation.

$$SHGC_{unshaded} = \frac{\text{Transmission} + \text{Secondary heat gain}}{\text{Incident solar radiation}}$$

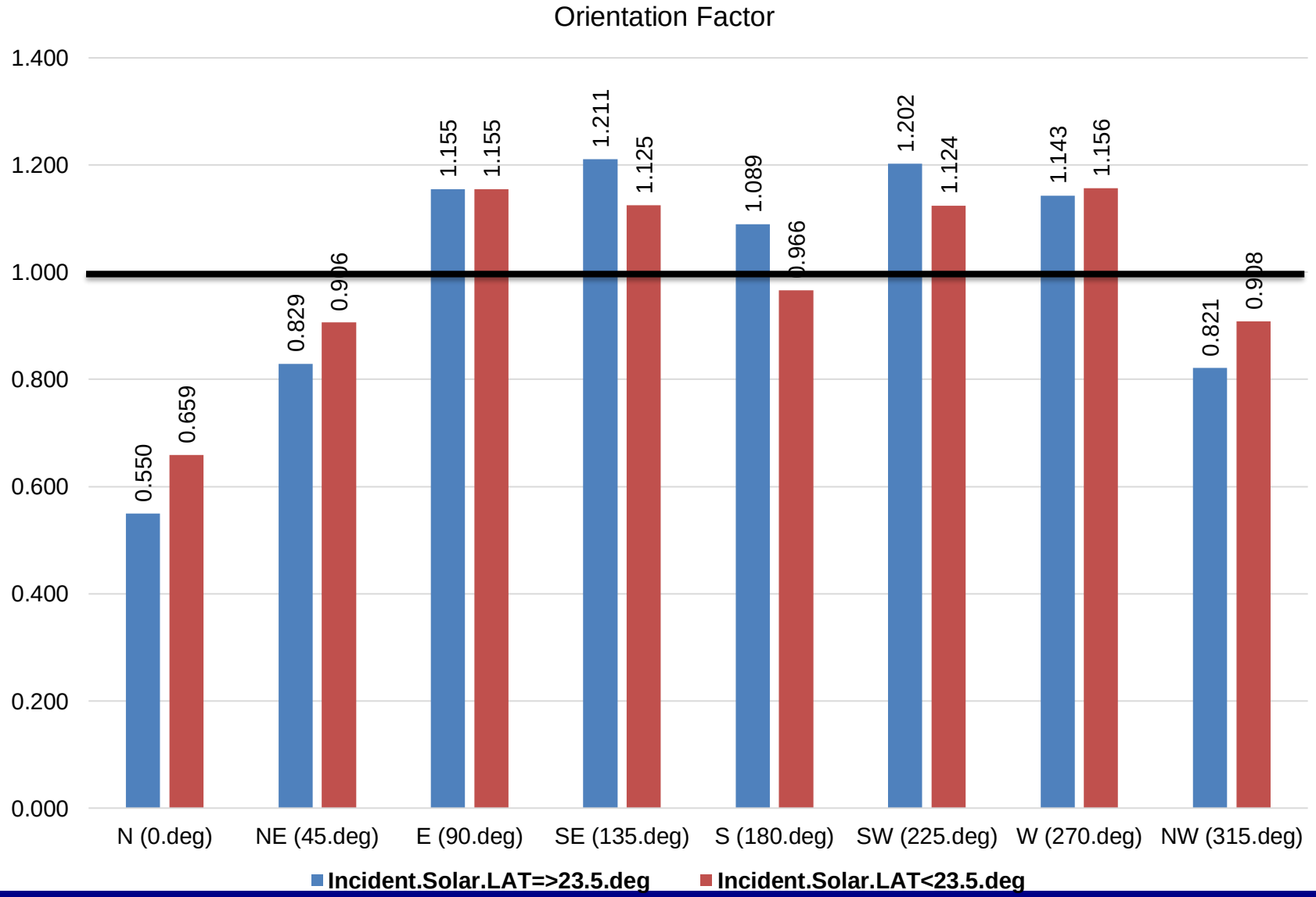


- External shading (overhang, side fins) cut the solar radiation; "External Shading Factor ($ESF_{total} \leq 1$) accounts the impact of shading.

$$SHGC_{\text{eq}} = SHGC_{unshaded} \times ESF_{\text{total}}$$



Orientation has an impact on solar radiation falling on walls

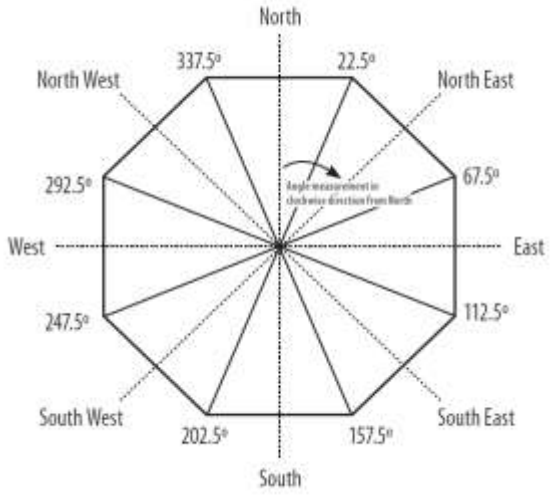


- E.g. For Chennai (LAT<23.5˚N), if total solar radiation falling on ‘North’ façade during the cooling period (Mar-Oct) is “$I_{incident}$”, then the same on ‘West’ façade would be 1.156 x $I_{incident}$ / 0.659 OR 1.75 x $I_{incident}$

Orientation Factor

TABLE 9 Orientation factor (ω) for different orientations

Orientation	Orientation factor (ω) Latitudes ≥23.5°N	Orientation factor (ω) Latitudes <23.5°N
North (337.6°–22.5°)	0.550	0.659
North-east (22.6°–67.5°)	0.829	0.906
East (67.6°–112.5°)	1.155	1.155
South-east (112.6°–157.5°)	1.211	1.125
South (157.6°–202.5°)	1.089	0.966
South-west (202.6°–247.5°)	1.202	1.124
West (247.6°–292.5°)	1.143	1.156
North-west (292.6°–337.5°)	0.821	0.908



Accounts for variation in incident solar radiation falling on walls with different orientations; Worst orientations must be treated first

V. Thermal transmittance of building envelope (except roof) for cold climate ($U_{envelope,cold}$)

- Provision: **$U_{envelope,cold} \leq 1.8$ W/m².K**

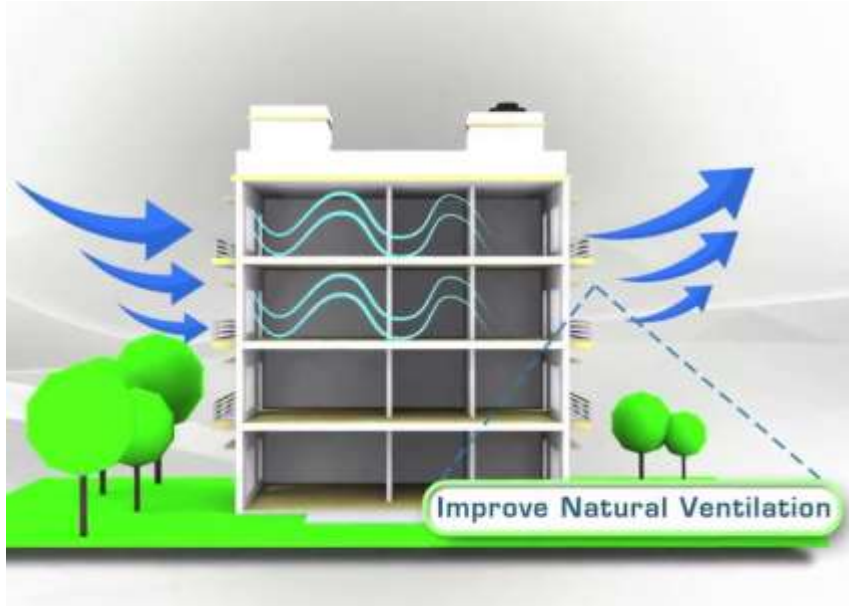
$$U_{envelope,cold} = \frac{1}{A_{envelope}}\left[\left(U_{opaque} \times A_{opaque}\right) + \left(U_{non-opaque} \times A_{non-opaque}\right)\right]$$

I. Openable Window-to-Floor Area Ratio (WFR_{op})

- Provision: **Minimum openable window-to-floor area ratio** (WFR_{op}) with respect to the climatic zone.

- It is the ratio of openable area ($A_{openable}$) to the carpet area (A_{carpet}) of dwelling units.

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}}$$



Climatic zone	Minimum WFR_{op} (%)
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33

Openable Area & Carpet Area

Openable Area

Windows: Only openable area; fixed panes excluded

Casement window: 90% openable

Two pane sliding window: 50% openable

Outside Doors:

Opening in Balcony ✓

Opening in Corridor ✗

Top hung ventilator: 90% openable

Three pane sliding window: 66.6% openable

Carpet Area

Net usable floor area of a dwelling unit; excludes: area covered by the external walls, areas under services shafts, balcony or verandah area
includes: area covered by internal partition walls

II. Visible Light Transmittance (VLT)

- Provision: **Minimum VLT** of the glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) **with respect to the window-to-wall ratio (WWR)**
- WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.

$$WWR = \frac{A_{non-opaque}}{A_{envelope}}$$

It is advised that:
a) the WWR ≤ 0.15, minimum VLT should be 40% and
b) the WWR in residential buildings may not exceed 0.40

WWR	Minimum VLT
0 - 0.30	0.27
0.31 - 0.40	0.20
0.41 - 0.50	0.16
0.51 - 0.60	0.13
0.61 - 0.70	0.11