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

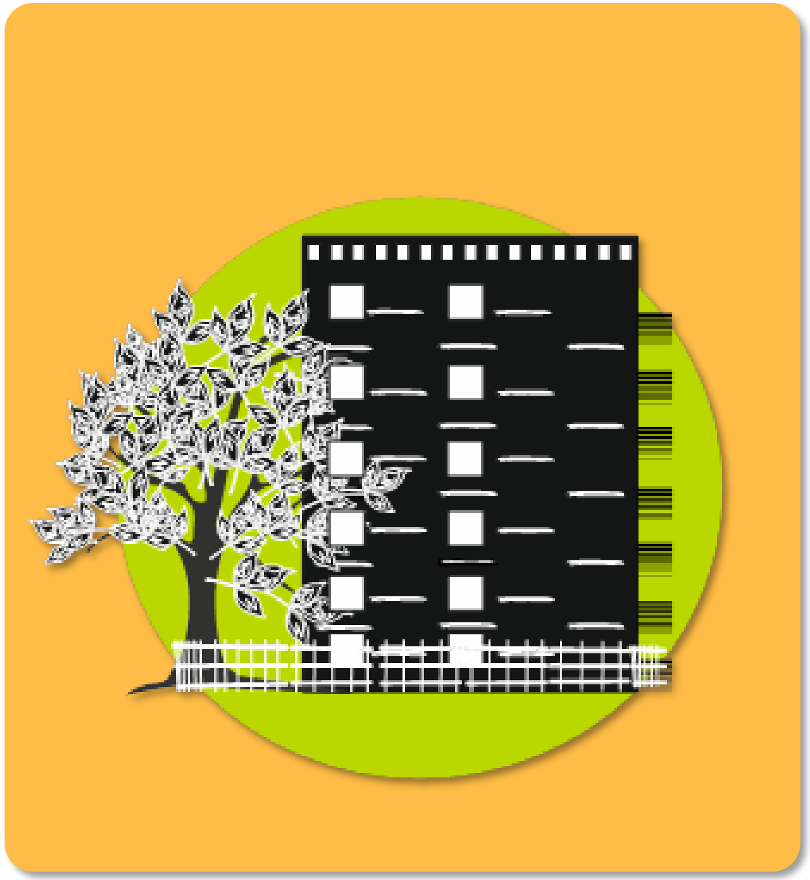
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

bmtpc

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH



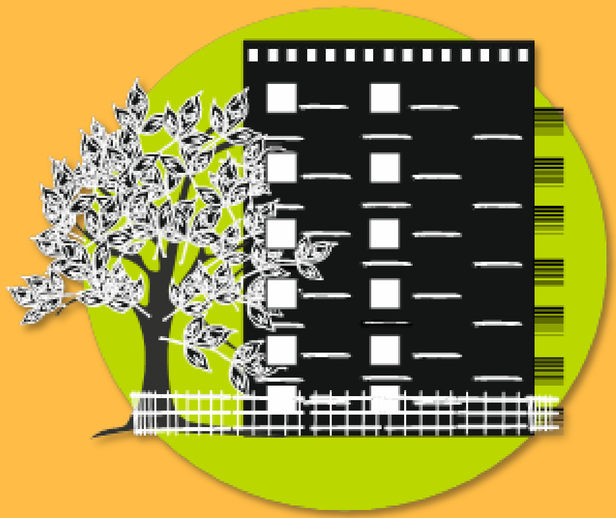
Overview of Design Standard for Thermal Comfort Performance

Date | Place

eds environmental design solutions

Wuppertal Institut

hunnarshālā FOUNDATION



Context and background

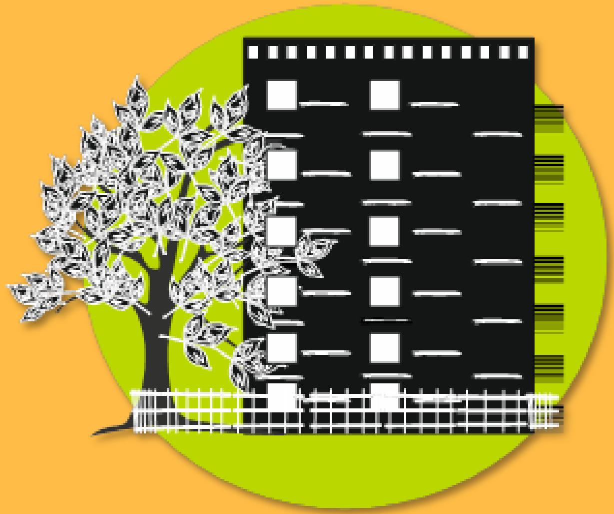
Establishes the need for Thermally Comfortable Housing

Context

1. India is rapidly urbanizing.
   - Urban population will nearly double by 2051 to 880 Million
2. So is the demand for affordable housing.
   - Nearly 90% of affordable housing demand is unmet.
3. Inadequate housing increases vulnerability to climate change
   - about a quarter of India's urban population—live in informal settlements, vulnerable to climate risks

Affordable, low-carbon, climate-resilient housing is critical to improving quality of life and supporting economic development in cities around the world.

Source:
1. Affordable And Quality Housing Is Still A Dream For Many In India
2. Resilient and affordable housing for all: Lessons on house building from Kochi and Trivandrum, India, Coalition for Urban Transitions



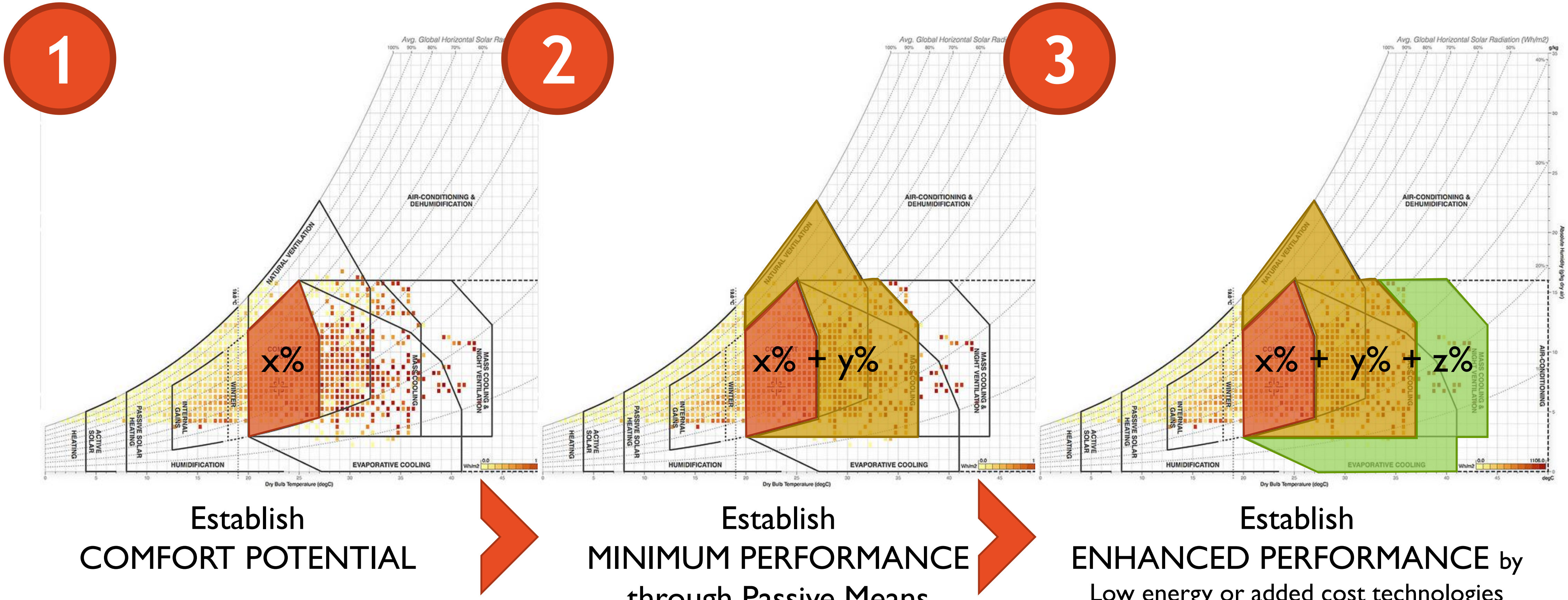
Development Approach

Outlines the guiding principles and conceptual approach towards standard development.

Guiding principles for developing standard

1) Target enhancing thermal comfort by 50 % (over existing performance)
2) Employ passive design strategies to enhance comfort (i.e. without mechanical conditioning systems)
3) Through standard promote use of,
   - local building materials (also low in embodied energy),
   - low or 'No' cost strategies to enhance comfort, and,
   - expeditious construction techniques/technologies

Approach to standard development

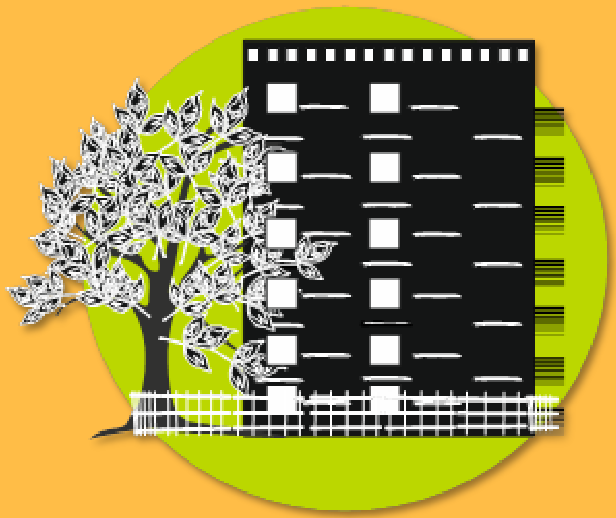


Establish
COMFORT POTENTIAL

Establish
MINIMUM PERFORMANCE
through Passive Means

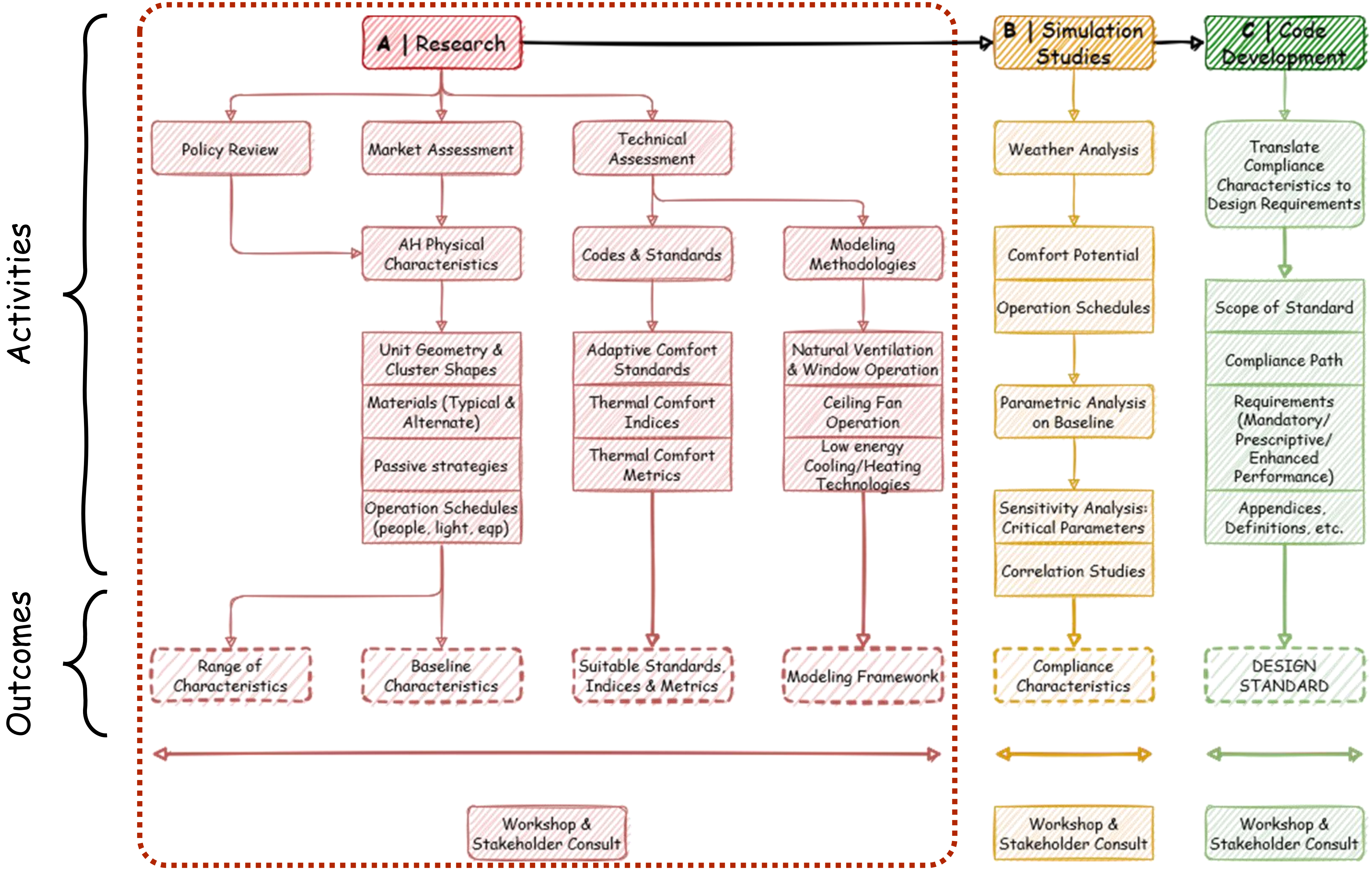
Establish
ENHANCED PERFORMANCE by
Low energy or added cost technologies

Image Credit: Andrew Marsh



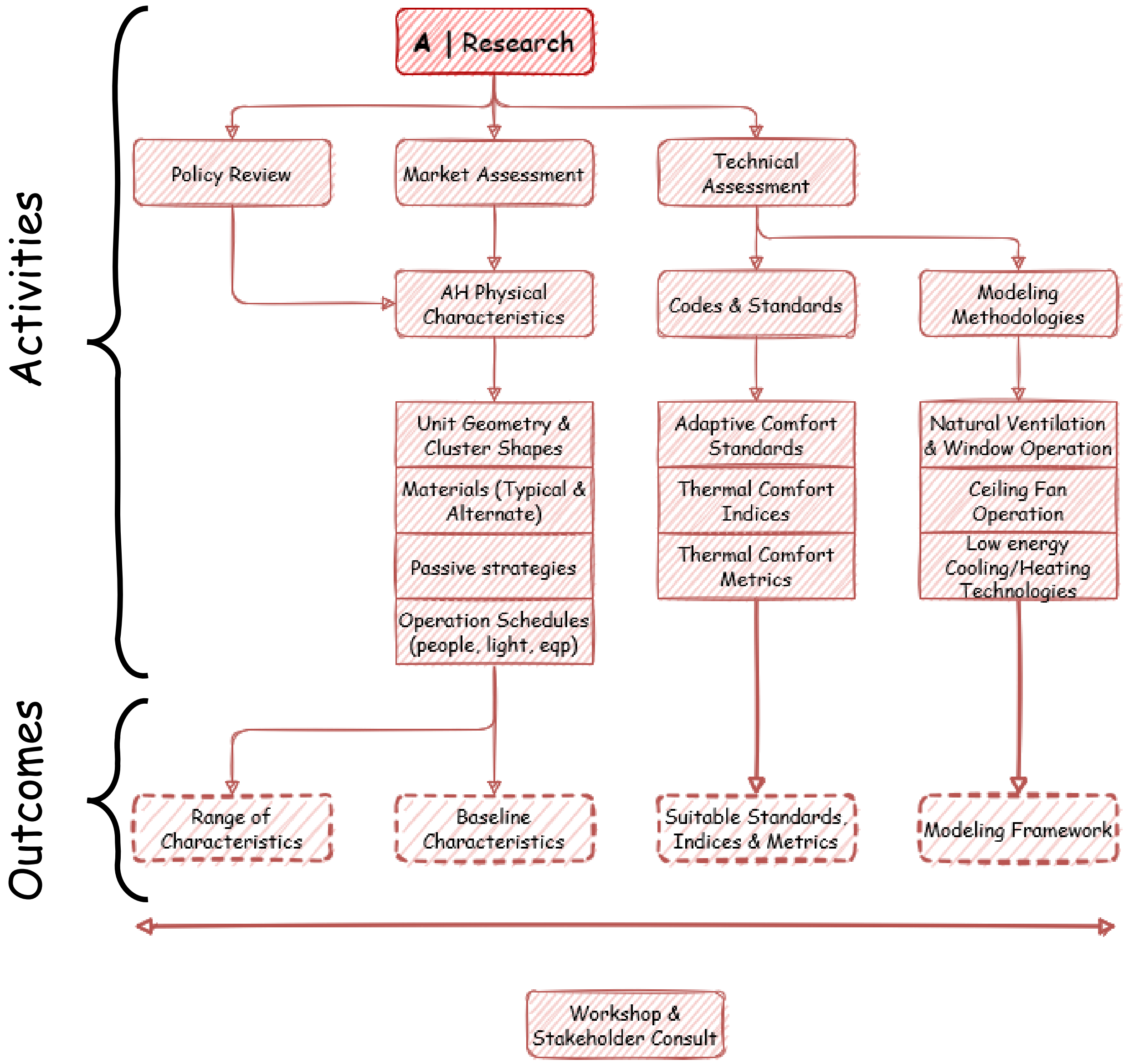
Development Methodology

Outline key steps/tasks in developing standard.


Activities
Outcomes
A | Research
B | Simulation Studies
C | Code Development
Policy Review
Market Assessment
Technical Assessment
AH Physical Characteristics
Codes & Standards
Modeling Methodologies
Unit Geometry & Cluster Shapes
Materials (Typical & Alternate)
Passive strategies
Operation Schedules (people, light, eqp)
Adaptive Comfort Standards
Thermal Comfort Indices
Thermal Comfort Metrics
Natural Ventilation & Window Operation
Ceiling Fan Operation
Low energy Cooling/Heating Technologies
Range of Characteristics
Baseline Characteristics
Suitable Standards, Indices & Metrics
Modeling Framework
Workshop & Stakeholder Consult
Weather Analysis
Comfort Potential
Operation Schedules
Parametric Analysis on Baseline
Sensitivity Analysis: Critical Parameters
Correlation Studies
Compliance Characteristics
Workshop & Stakeholder Consult
Translate Compliance Characteristics to Design Requirements
Scope of Standard
Compliance Path
Requirements (Mandatory/ Prescriptive/ Enhanced Performance)
Appendices, Definitions, etc.
DESIGN STANDARD
Workshop & Stakeholder Consult

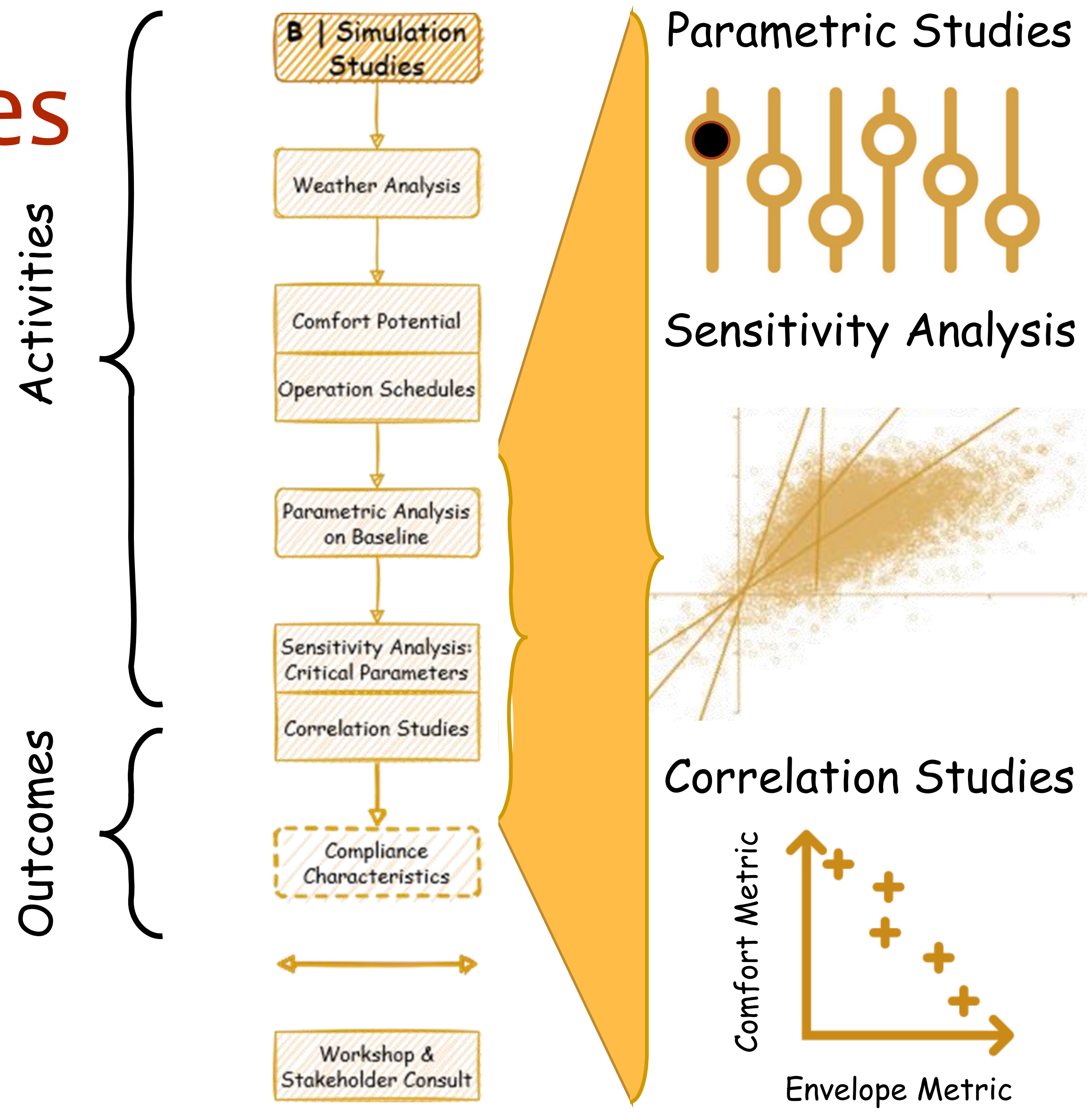
A| Research

1. Review policies to outline affordable housing typologies and their attributes (area, family characteristics, etc.)
2. Conduct market analysis through data in public domain (journals, industry & technical reports, project information – pvt. & govt., case studies) to outline:
   1. typical building characteristics,
   2. range of attributes
   3. exemplary building practices
3. Review technical documents (codes, standards, peer reviewed journals, technical reports, etc.) to outline suitable:
   1. adaptive comfort models
   2. thermal comfort indices & metrics
   3. energy modeling best practices



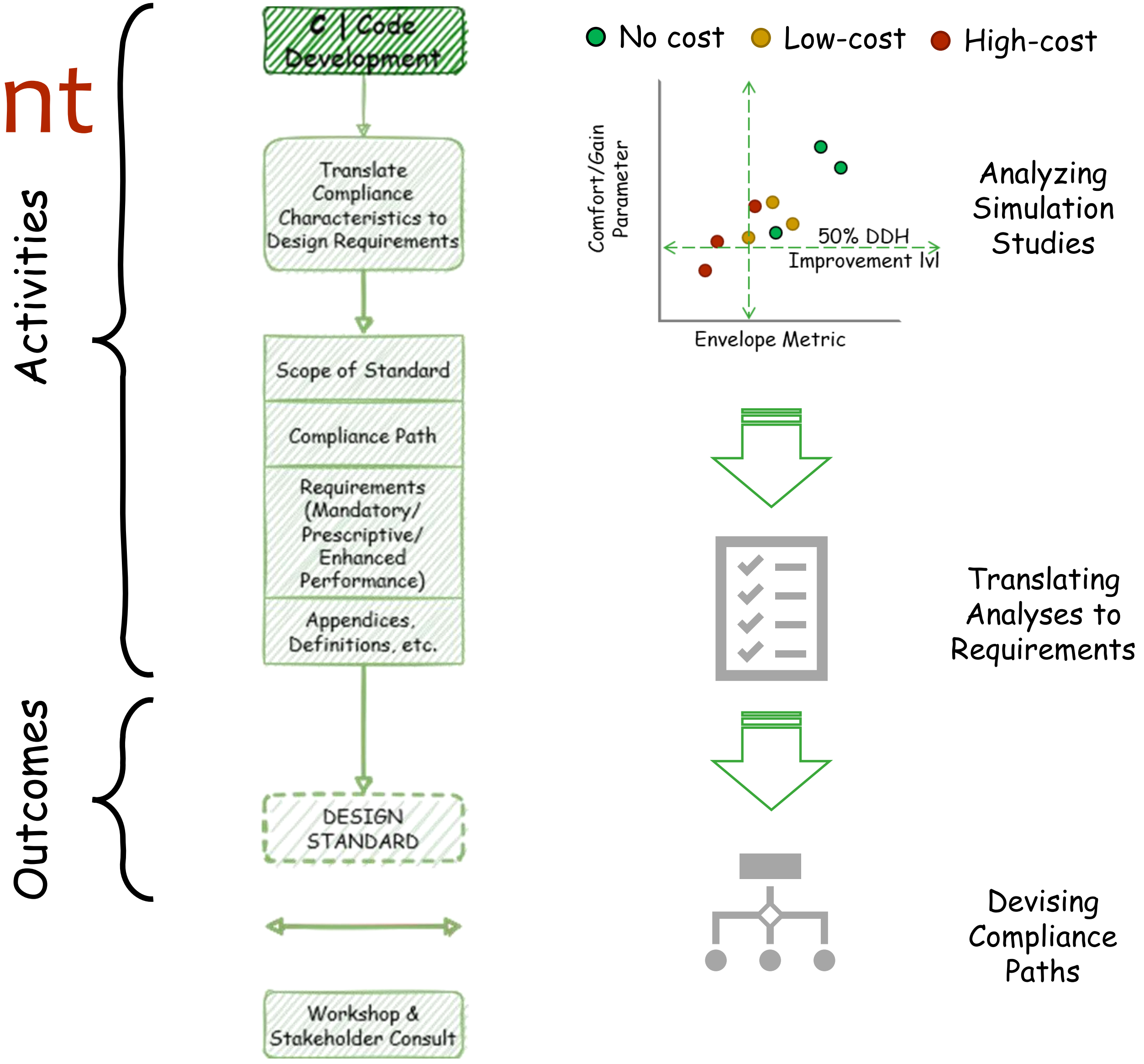
B| Simulation Studies

1. Weather analysis to
   1. realize comfort potential for climate zone
   2. outline natural ventilation and window operation potential
2. Parametric studies to identify
   1. Sensitivity and Correlation of building parameters to comfort performance
3. Establish minimum and enhanced performance characteristics



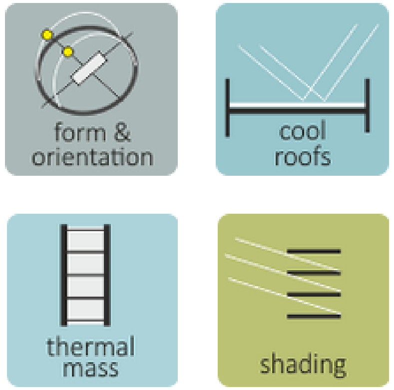
C| Code Development

1. Translate performance characteristics to Design features
2. Frame prescriptive Requirements
3. Devise compliance paths and adapt requirements for Mandatory/Prescriptive/ Enhanced Performance
4. Compile Design Standard

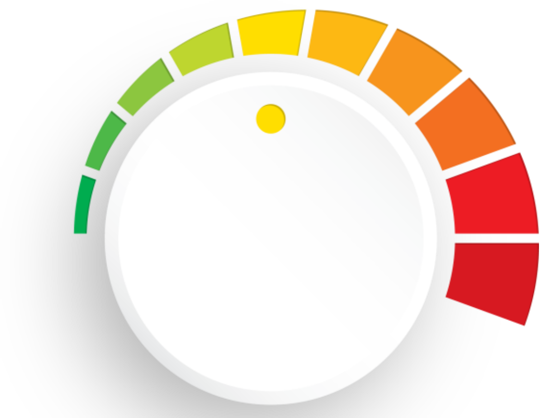


Outcomes

A Standard based on
Adaptive Comfort
Models



A Standard focused on
Envelope Measures &
Passive Design



A Standard that establishes
Minimum & Enhanced
Performance Criteria

Ease of Compliance – key to uptake & adoption

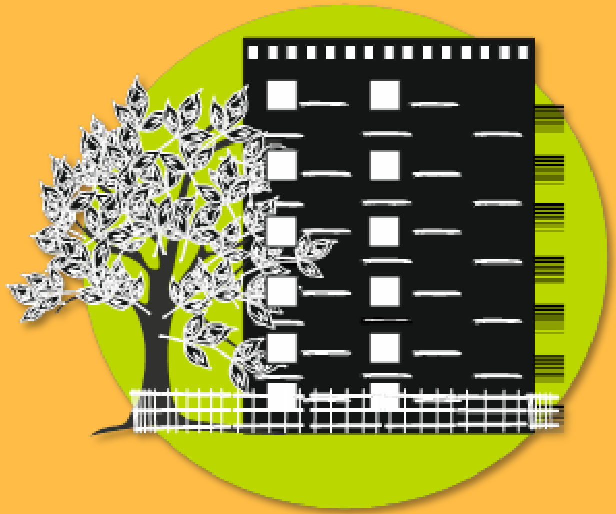
Easy to Interpret
Outline Min. performance criteria
Layout standard by Sections
Examples of calculations

Easy to Comply with
Form based Prescriptive approach
Alternative paths to document
beyond code performance

Easy to Verify
Checklist based compliance.

Prescriptive approach
Easy to adopt and document.

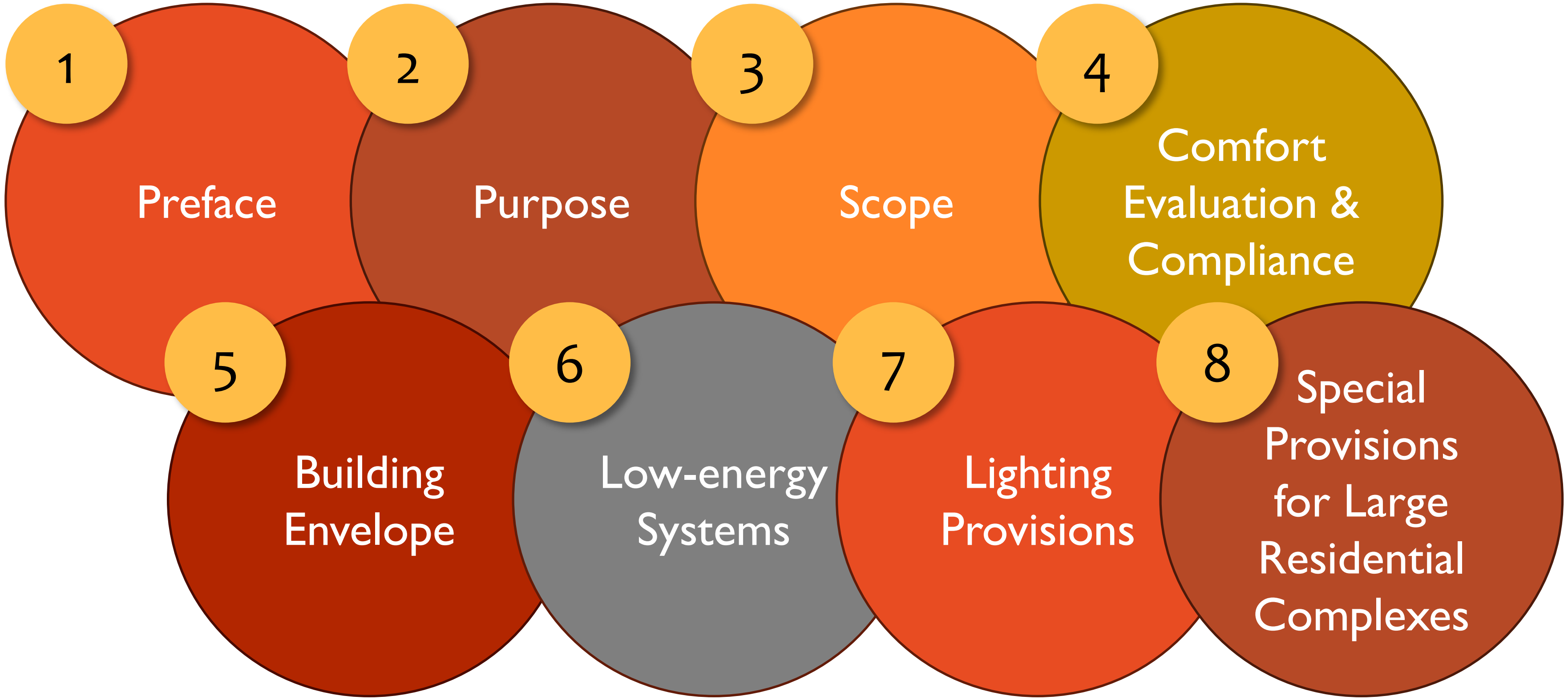
Performance bundles approach
Pre-defined design bundles to reduce burden of compliance on end user

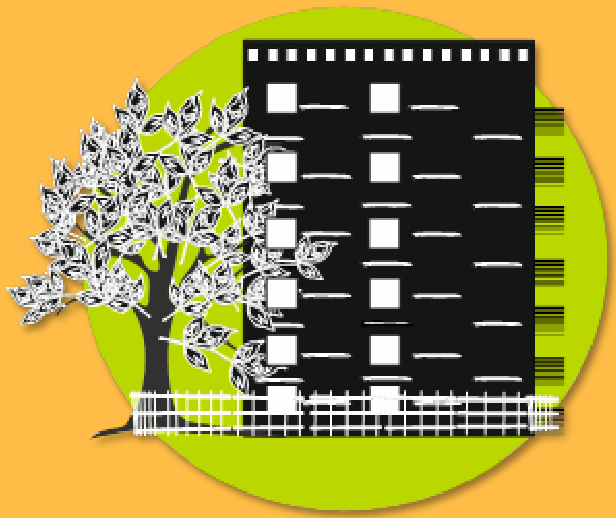


Design Standard for Thermal Comfort Performance

Layout of the design standard and key details

Overview of Sections in the Standard





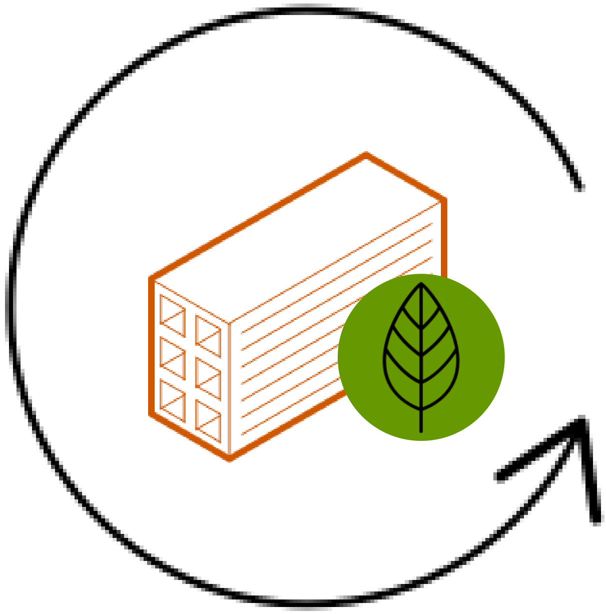
2

Purpose

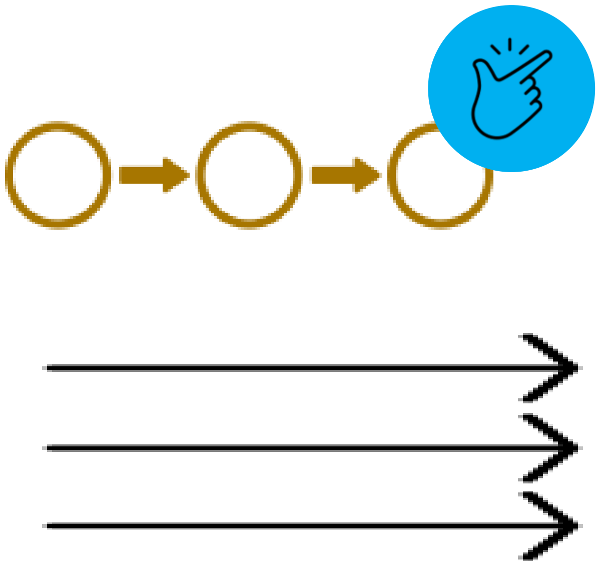
Purpose

Ideology and vision behind the standard

Ideology: Transformative, Implementable & Future Proof



Market Transformation towards low embodied energy & natural materials.

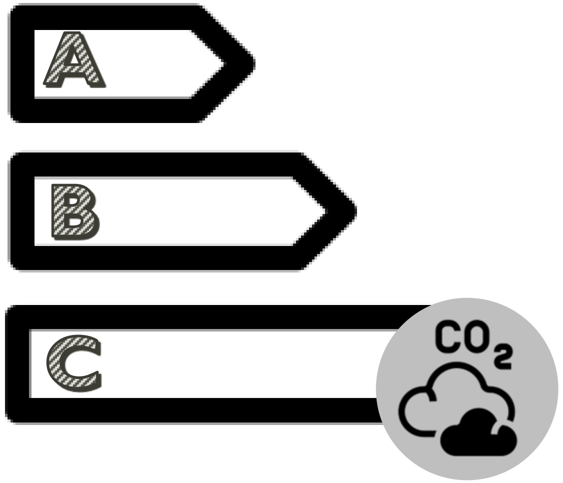


Easy and hassle-free compliance process without compromising on stringency

Forward looking code that acknowledges cooling & heating requirements of the future

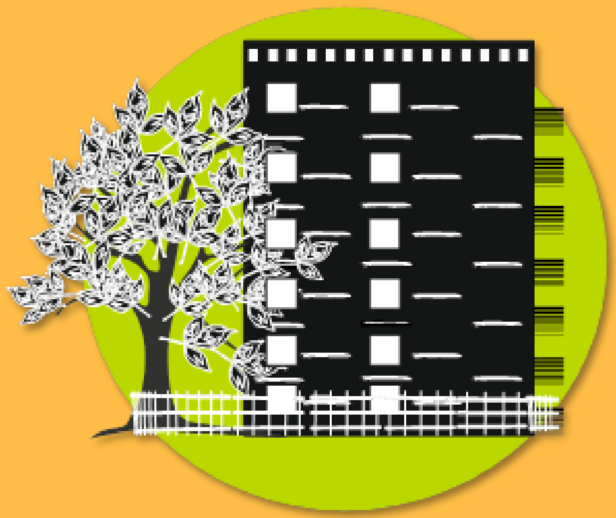
Purpose: Enhance thermal comfort, Achieve EE goals & Promote social equity

Enhance thermal comfort over prevalent construction practices.



Enhance comfort while meeting energy efficiency standards and decarbonization goals.

Enhance comfort with specific emphasis to affordability.



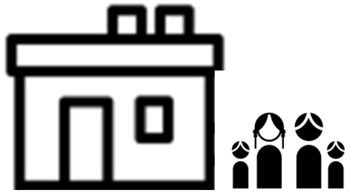
3 Scope

4 Comfort Evaluation & Compliance

Scope, Comfort Evaluation & Compliance

Applicability of standard, and performance Scope

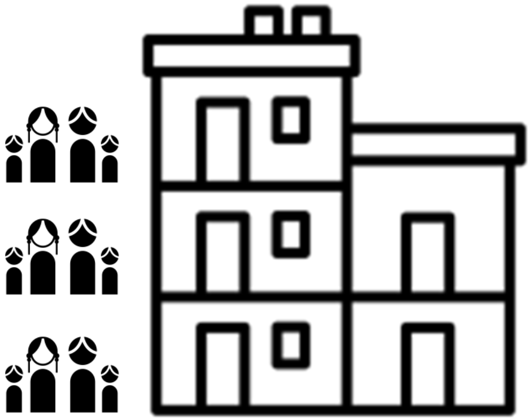
Scope – Building Classification



Single Family Homes

- Independent Homes
- Row Housing

Applicable to Beneficiary Led Construction (**BLC**) and Credit Linked Subsidy Scheme (**CLSS**).



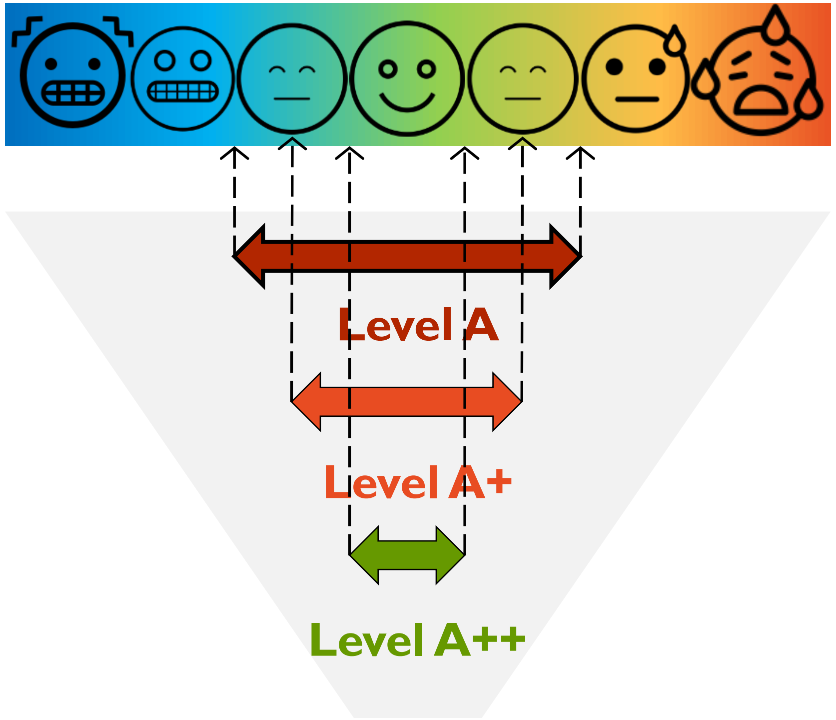
Multi Family Homes

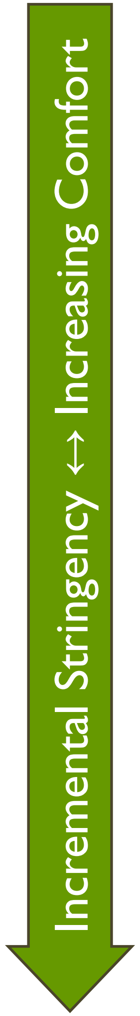
- Multi-story apartments (High and Low-rise)

Applicable to Credit Linked Subsidy Scheme (**CLSS**), Affordable Rental Housing Complex (**ARHC**), 'In-Situ' Slum Redevelopment (**ISSR**) & Affordable Housing in Partnership (**AHP**)

Scope includes both New and Existing Residential. The Standard will outline what constitutes as addition/alteration for Standard Compliance.

Scope: Performance Classification





Mandatory Requirement

Minimum Comfort Performance
[Level A]

- No/Low-cost Passive design measures
  - Insulation/WWR/Shading
  - Adaptive comfort principles

Optional Requirement

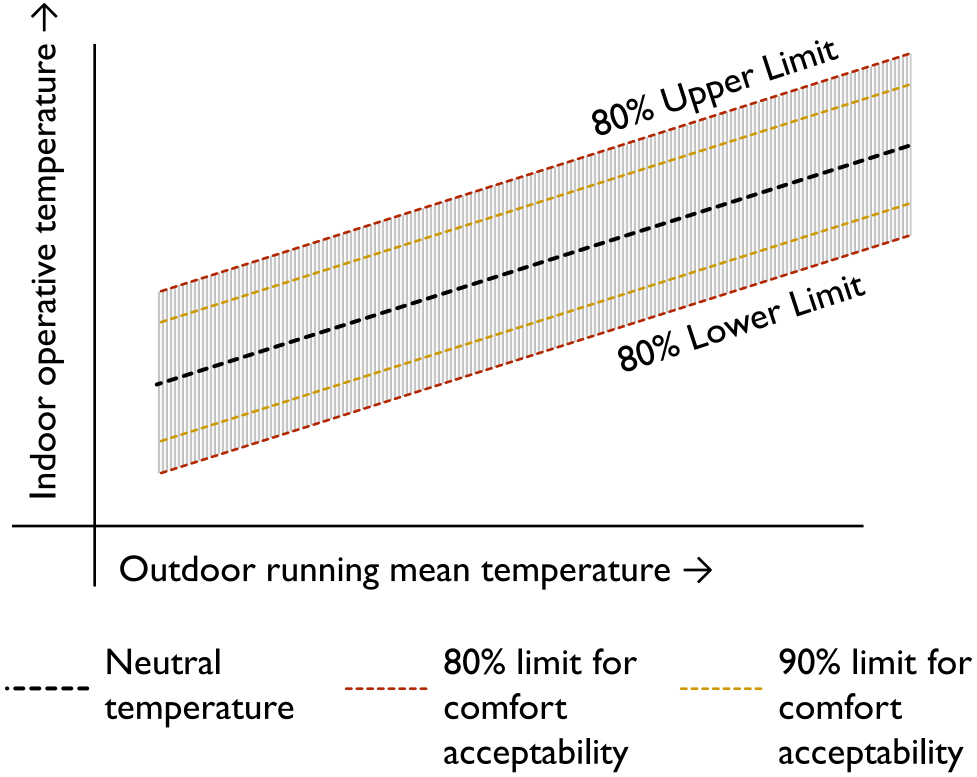
Enhanced Comfort Performance
[Level A+]

- Additional investment for enhanced envelope
  - Insulation, DGU, etc.

Enhanced Comfort Performance with Systems
[Level A++]

- Low energy systems

Performance Scope: Comfort Index and Metrics



Adaptive comfort chart

Comfort Index	Indoor Operative Temperature
Annualized discomfort metric – Degree Discomfort Hours (DDH)	$DDH = \sum_{i=1}^{8760} \left| T_{neut}^{i} - T_{op}^{i} \right|$
Peak discomfort metric – Maximum/ Minimum Indoor Operative Temperature	$T_{op}^{max} = \max(T_{op}^{1}, \dots, T_{op}^{8760})$ $T_{op}^{min} = \min(T_{op}^{1}, \dots, T_{op}^{8760})$

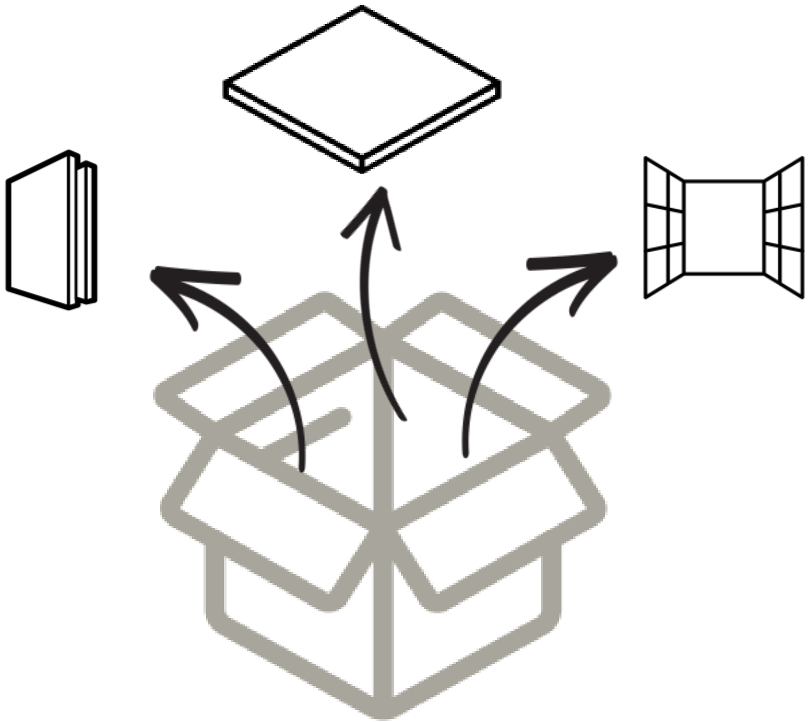
Comfort Performance

	Cold	Composite	Hot-Dry	Temperate	Warm-Humid
Comfortable Hours (%)	55%	65%	80%	95%	90%

Note: (Considering 80% acceptability as per IMAC-R model)

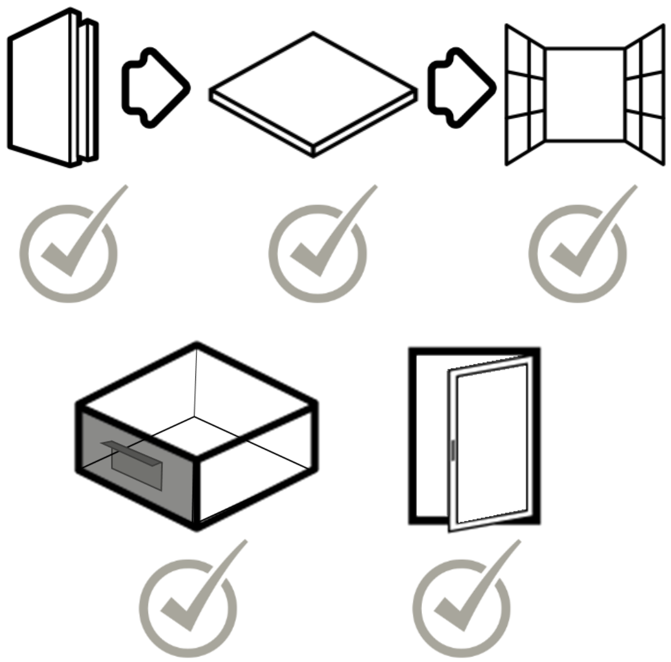
Climate	**Peak temperature difference (in °C)**			**DDH Avoided (in %)**	
Level of performance	A+	A++	Season	A+	A++
Cold	1.00	2.50	Winter	10%	25%
Composite	1.00	1.50	Summer	10%	25%
Hot-dry	0.90	1.20	Summer	8%	15%
Temperate		0.60	Summer		5%
Warm-humid	0.60	0.80	Summer	10%	20%

Compliance Approaches



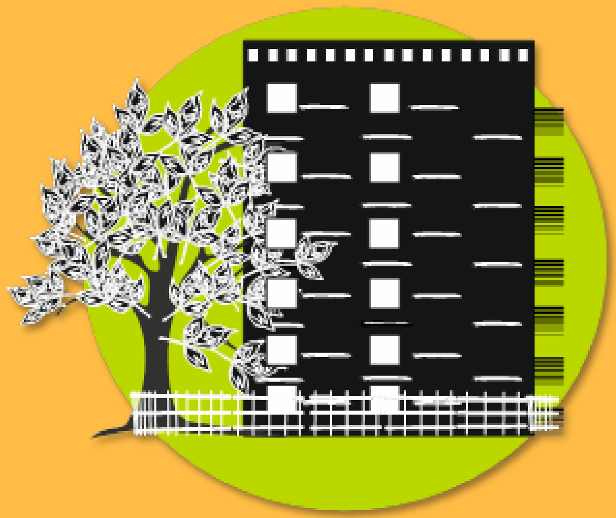
Bundle Approach

Pre-defined set of assemblies that can be used 'off the shelf'. Eases the designer's load and compliance requirements.



Prescriptive Approach

Specifications prescribed for each component. Allows design flexibility outside of the short-listed bundles.

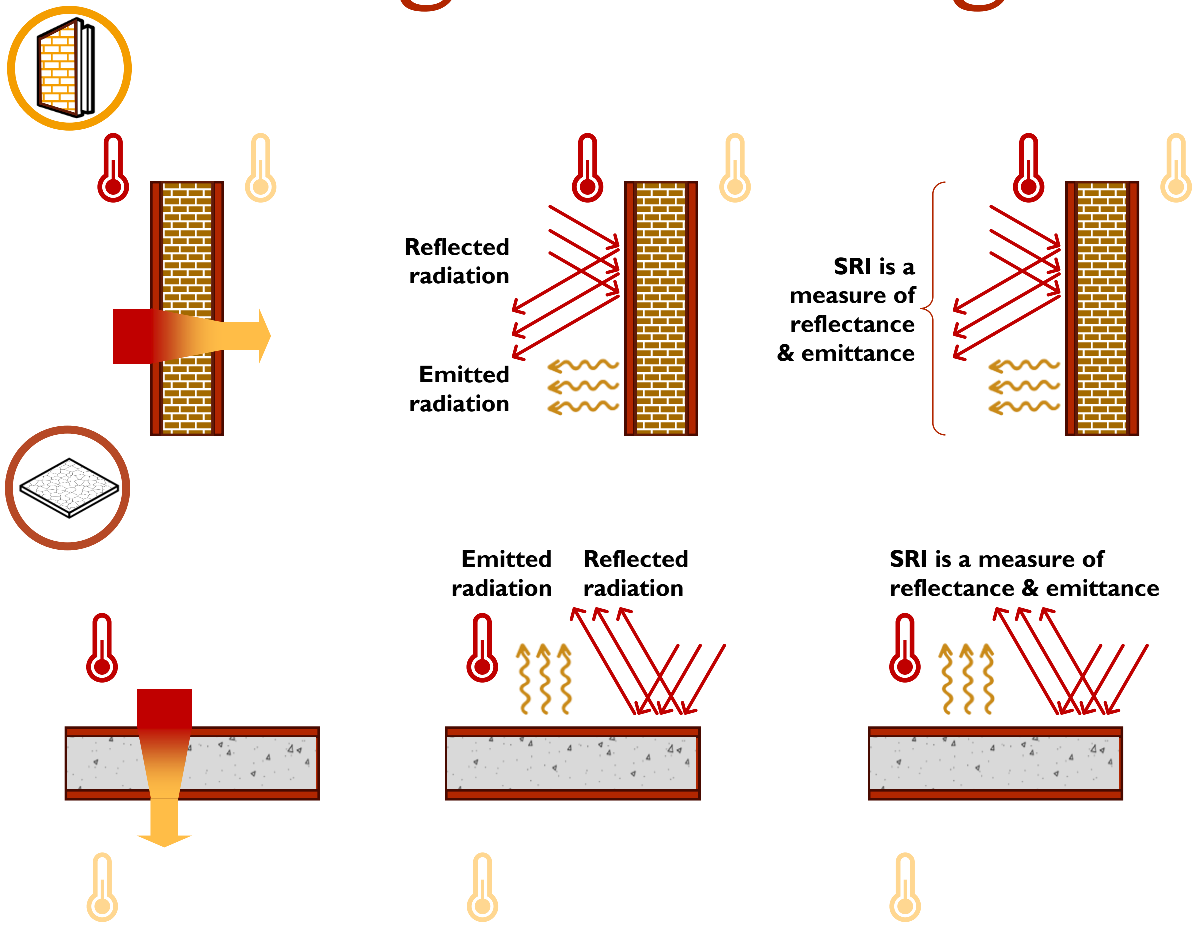


5

Building Envelope

Building Envelope

Testing of building assemblies



1

Thermal Conductance (U-factor)

U-factor of an opaque construction assembly is a measure of heat conducted through a unit area of material for 1°C temperature difference.

ISO 6946 provides method for testing thermally homogeneous (including assemblies with air layers) assemblies. It also provides an approximate method for evaluating inhomogeneous layers.

2

Reflectance & Emittance

As solar radiation strikes an opaque surface, a part of it gets absorbed, while the rest gets reflected. The portion absorbed by the surface is 'emitted' out as long-wave infra-red radiation. The reflected component is termed as 'Reflectance' and the emitted component is termed as 'Emittance'. Both are expressed as a ratio between 0 and 1.

For external wall surfaces, the test procedures for evaluating reflectance and emittance are detailed out in Wall Product Rating Program Manual CRRC-2.

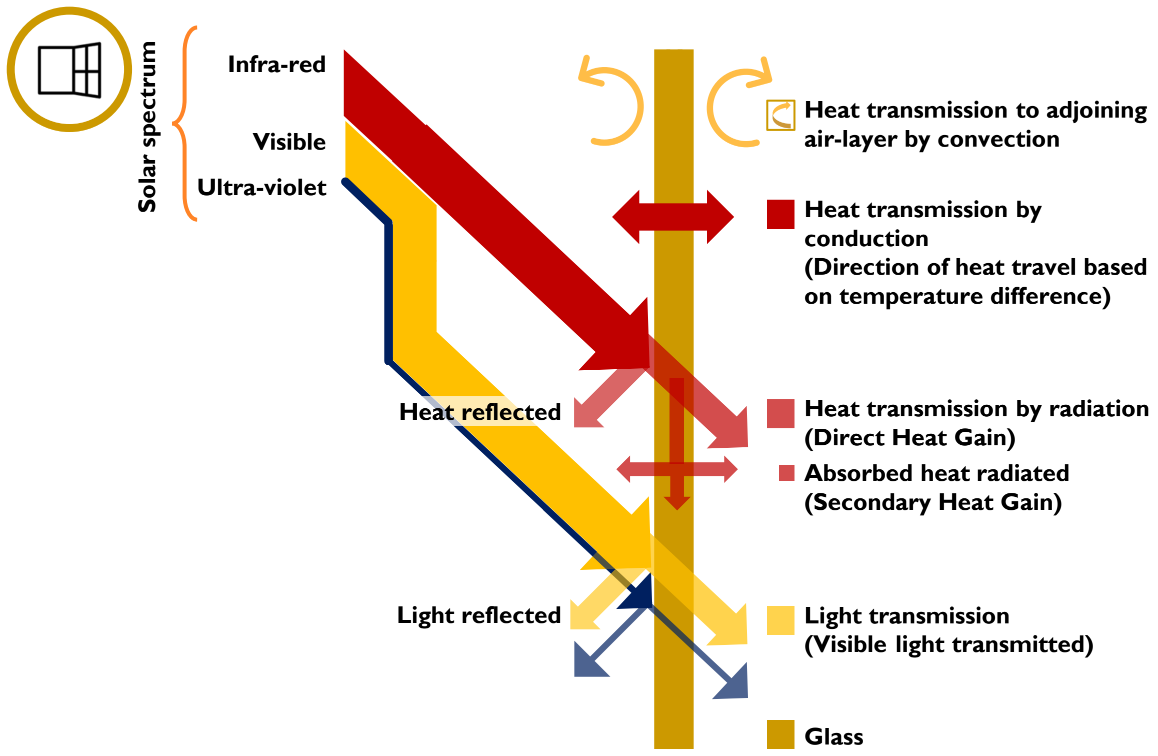
3

Solar Reflective Index (SRI)

Solar reflective index is a metric that combines the effect of a material's ability to reflect incident solar radiation as well as its ability to emit thermal radiation.

The SRI value of a product shall be tested as per ASTM E 1980. This standard defines the method to determine the solar reflectance, the thermal emittance and the subsequent calculation for SRI.

Testing of building assemblies



1

Thermal Conductance (U-factor)

The thermal conductance of glass is the amount of non-solar heat (i.e. heat flow via conduction and convection) transmitted through a glazing of unit area for 1°C temperature difference.

U-factor may also be used to represent the thermal conductance across a glazing construction assembly, i.e. glass along with frame, spacer material and other components.

2

Solar Heat Gain Coefficient (SHGC)

SHGC is a measure of heat transmitted through the glazing via radiation. It is a unitless metric and expressed as a number between 0 and 1.

SHGC is the fraction of solar heat gain radiated through the glazing either directly or after absorption.

3

Visible Light Transmittance (VLT)

VLT is a measure of light entering into the space through the glazing. It is a unitless metric and expressed as a number between 0 and 1.

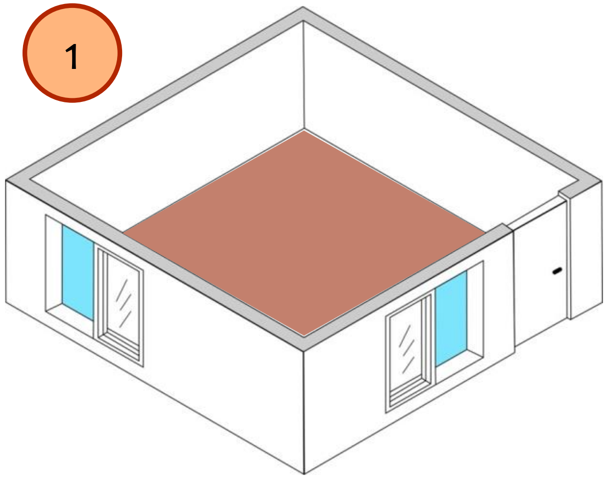
VLT is the fraction of light in the visible spectrum transmitted through the glass. VLT is arrived at after weighting for sensitivity of the human eye.

Performance tests for U-factor, SHGC and VLT for glazing and glazing assemblies (U-factor)

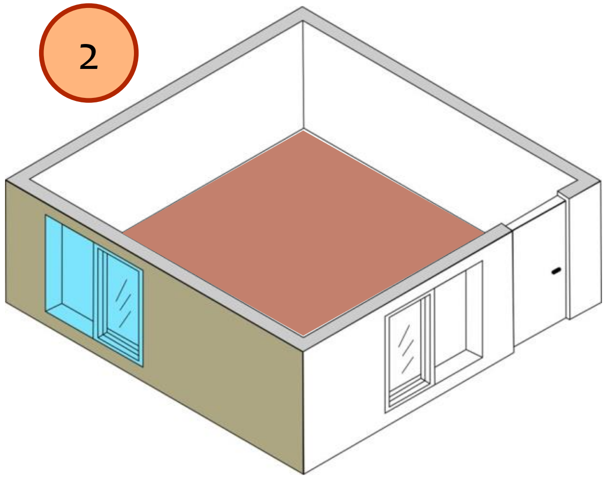
ISO-9050 provides methods for testing glass for, U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Light Transmittance (VLT).

ISO 12576-1 provides test methods for testing complete glazing construction assemblies, i.e. glass along with frame, sash, shutter, etc. for U-factor, SHGC and VLT.

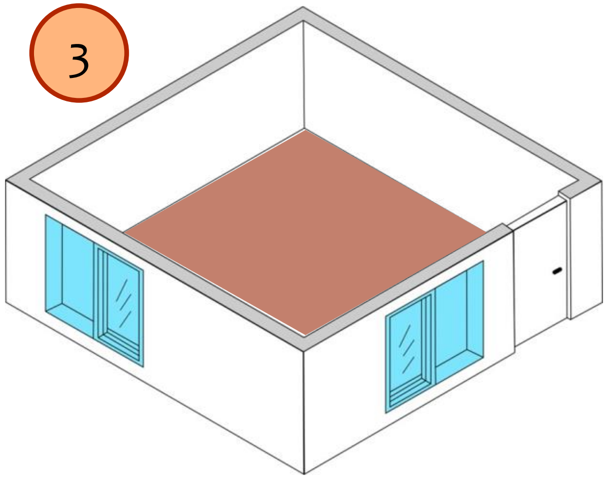
Enhanced Natural Ventilation



$$\text{Openable Window Area}/\text{Carpet Area} \geq 1/x$$



$$\text{Window Area}/\text{Wall Area} \leq 1/4$$



$$\text{Window Area}/\text{Carpet Area} \leq 2/5$$

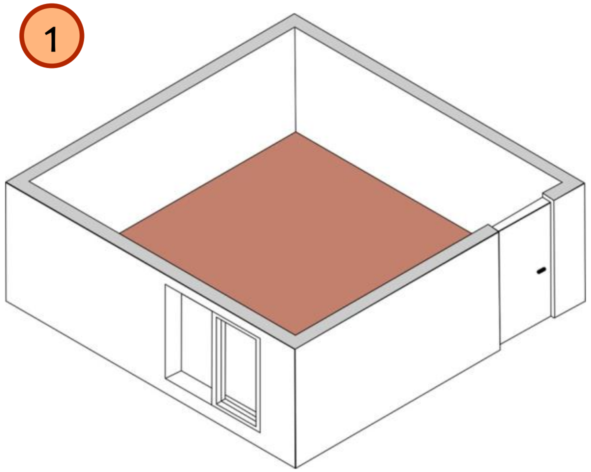
**Perform check for each external wall with windows*

Operable window area ratio
At least 1/xth of window area serving habitable spaces should be openable. This will ensure all habitable spaces are adequately ventilated.
Windows serving habitable spaces must open to the exteriors.

Window to wall area ratio
No wall should have window exceeding 1/4th of its area.
Large windows have the potential to cause hot pockets within a room due to direct radiation.

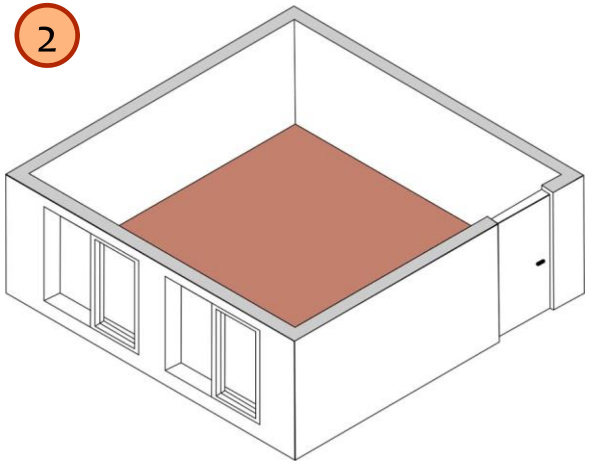
Operable window to wall area ratio
Overall window opening area should not exceed 40% of overall carpet area. Limiting glazing area avoids excessive heat gains and losses in the space.

Enhanced Natural Ventilation



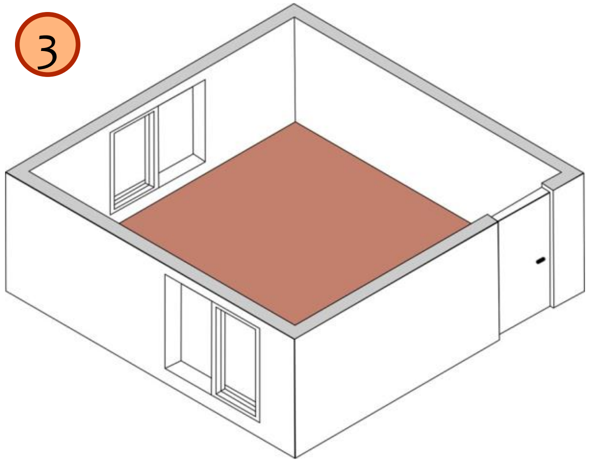
Single Sided Ventilation

Level A



Single Sided but distributed Ventilation

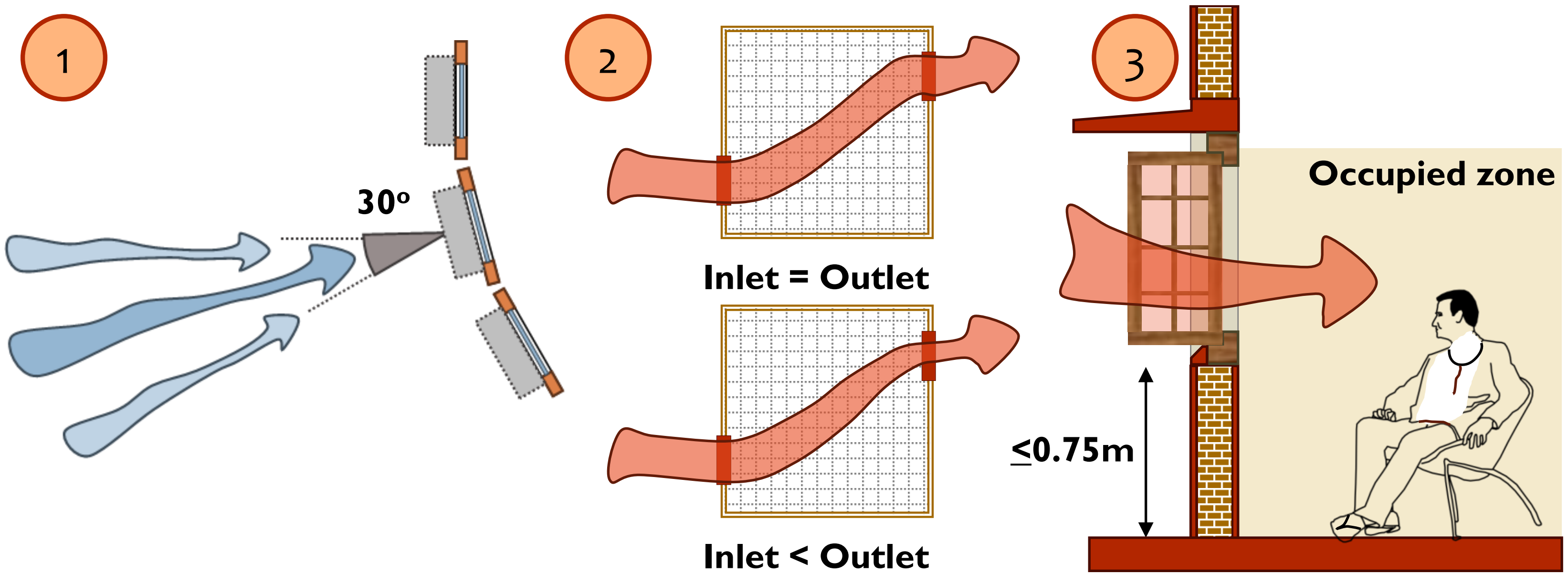
Level A+



Two (or more) - sided Ventilation

Level A++

Enhanced Natural Ventilation

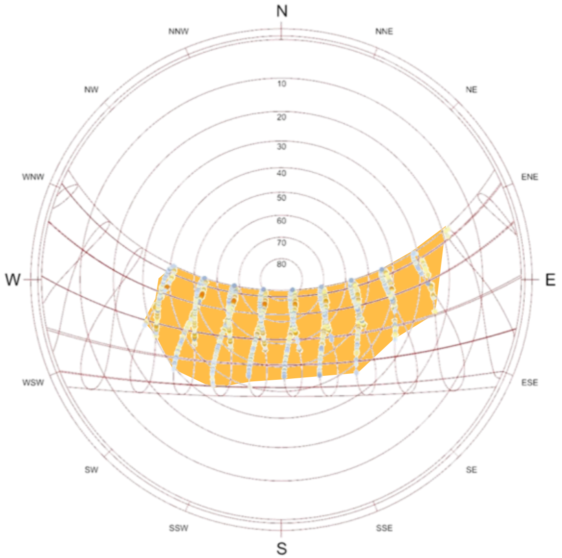


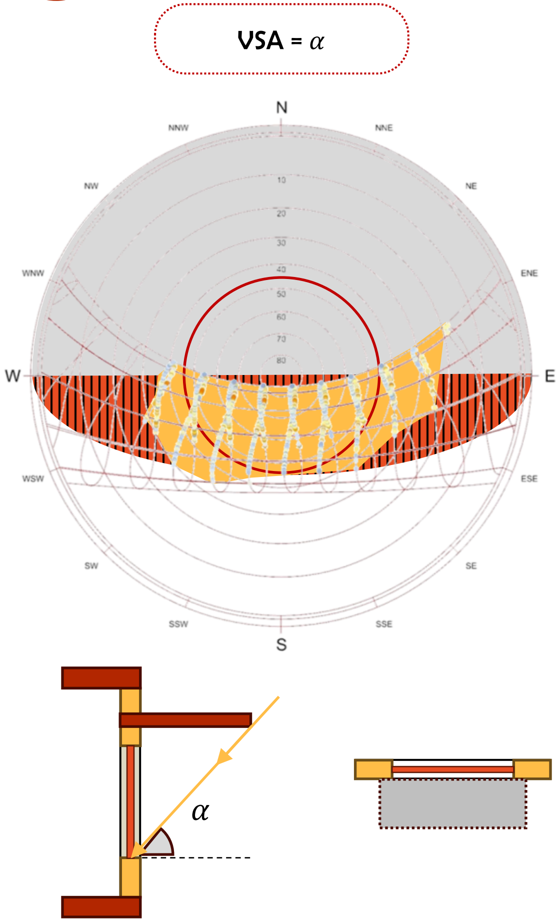
Window orientation
Windows facing the windward side function as air inlets. Orient inlet windows within 30º of the prevalent wind direction to maximize the effectiveness of natural ventilation.

Window size distribution
Inlet windows shall be equal to or larger than the outlet windows to enhance air movement within the indoor space.

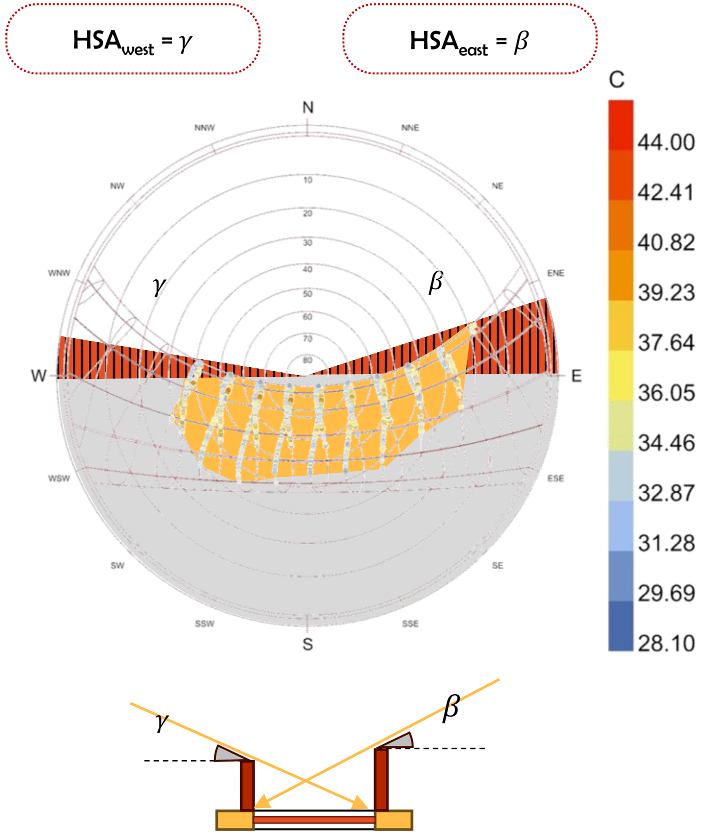
Window cill height
Window cill height at 0.75 m is ideal for the seated position. Judicious planning of window heights enables air movement in the occupied zone.

Window Shading





Stereographic chart showing overhang for south facing facade

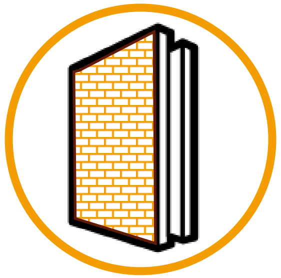


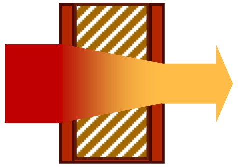
Stereographic chart showing side fins for north facing facade

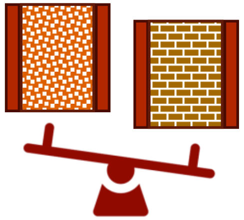
Designing for shading –
When to shade?

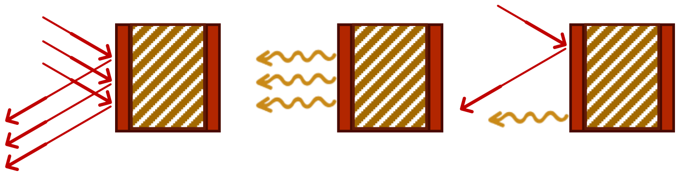
Design for shades whenever ambient temperature exceeds 28 °C and global horizontal radiation exceeds 315 kWh/m².

Prescriptive Compliance







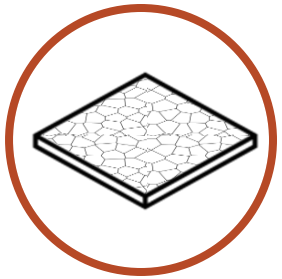


U-factor in W/m²K	Light-weight assembly	Medium/Heavy-weight assembly	
Density (kg/m³)	≥800	<800	
Level A	0.80	1.00	or lower
Level A+	0.60	0.80	or lower
Level A++	0.40	0.45	or lower

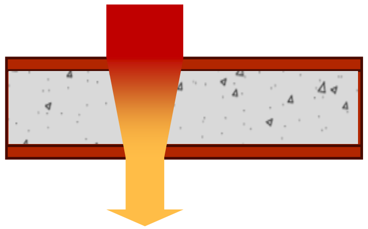
Reflectance	0.60 or higher
Emittance	0.75 or higher
SRI	29 or higher

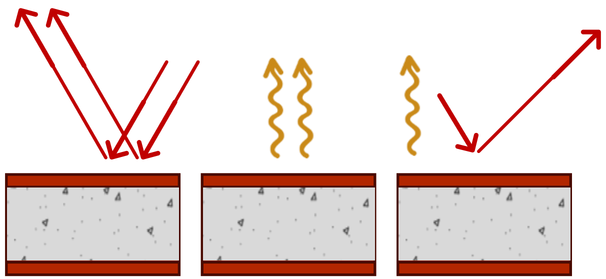
Note: Level A++ is a mandatory if the residential building is mechanically air-conditioned.

Prescriptive Compliance



Roof assembly





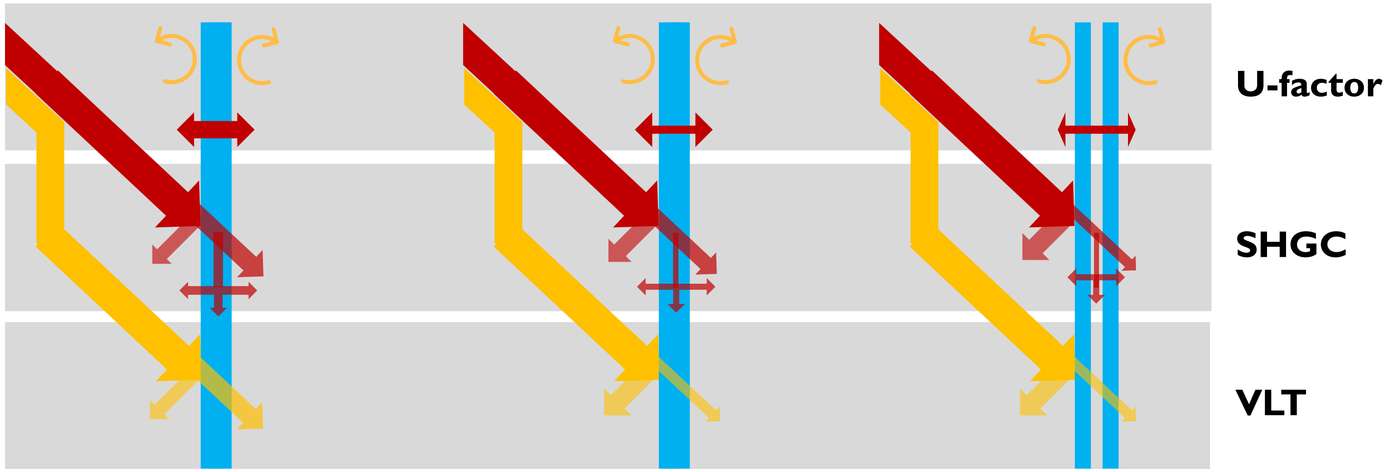
U-factor in W/m²K	
Level A	0.75 or lower
Level A+	0.45 or lower
Level A++	0.25 or lower

Reflectance Emittance SRI	
Reflectance	0.70 or higher
Emittance	0.75 or higher
SRI	78 or higher

Note: Level A++ is a mandatory if the residential building is mechanically air-conditioned.

Prescriptive Compliance

Glazing assembly

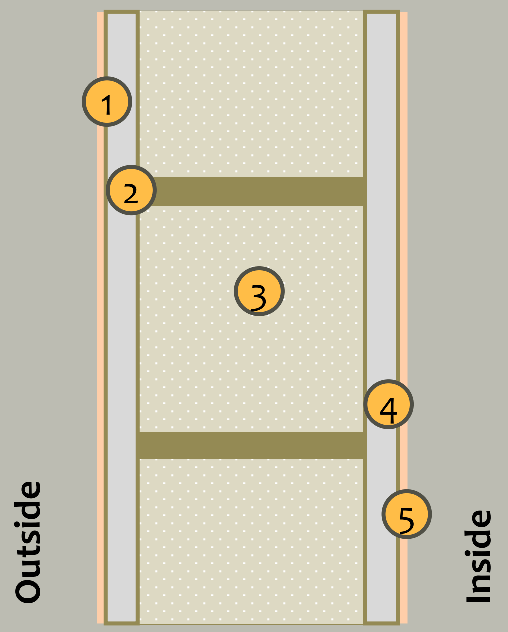


	Level A	Level A+	Level A++
U-factor	5.7 or lower	4.8 or lower	2.8 or lower
SHGC	0.6 or lower	0.4 or lower	
VLT	0.3 or higher		

Note: Level A++ is a mandatory if the residential building is mechanically air-conditioned.

Bundle Approach

Wall assembly
Low Density



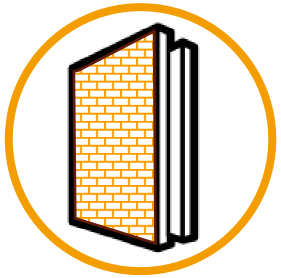
AAC Block Wall

1. Exterior paint
2. External cement plaster (GI chicken wire mesh over block-work and structure joints)
3. AAC block work
4. Internal cement plaster
5. Interior paint

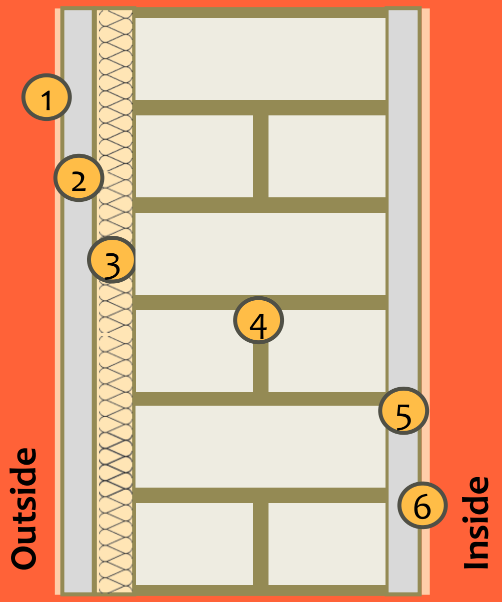
AAC Block work 200 mm	
230 mm thick	0.78 W/m²K

AAC Block work 300 mm	
330 mm thick	0.55 W/m²K

Bundle Approach



Wall assembly
Med Density

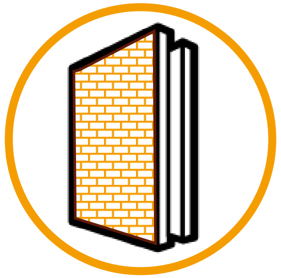


Fly ash brick wall with external insulation

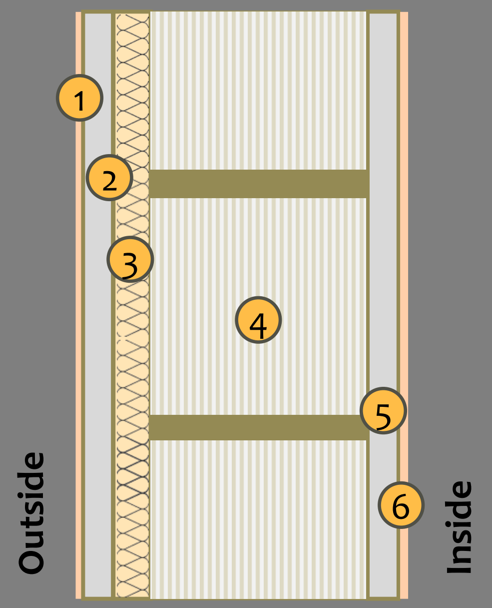
1. Exterior paint
2. Cement plaster/base Coat (over reinforcing mesh)
3. Rigid insulation board applied with adhesive and held in place with PVC fasteners
4. Fly-ash block work
5. Internal plaster
6. Interior paint

Fly ash brick 230 mm	
Expanded Polystyrene 25 mm	
285 mm thick	**0.89 W/m²K**
Fly ash brick 230 mm	
XPS/PUF 25 mm	
285 mm thick	**~0.75 W/m²K**
Fly ash brick 230 mm	
XPS/PUF 50 mm	
315 mm thick	**~0.45 W/m²K**

Bundle Approach



Wall assembly
High Density



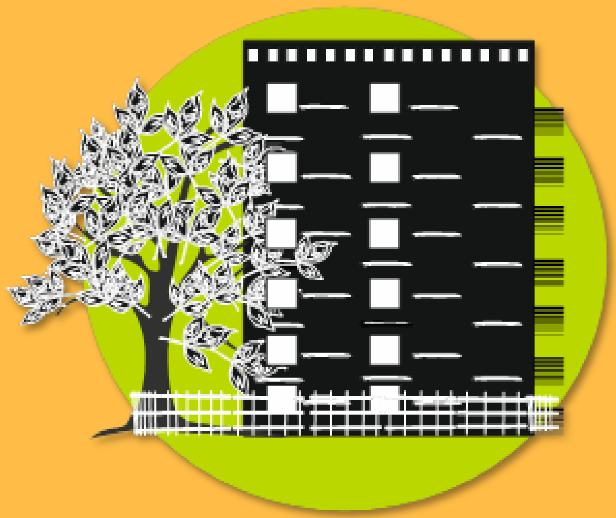
Solid concrete block with external insulation

1. Exterior paint
2. Cement plaster/base coat (over reinforcing mesh)
3. Rigid insulation board applied with water based adhesive and held in place with PVC fasteners
4. Solid concrete block work
5. Internal plaster
6. Interior paint

Solid concrete block 200 mm	
Extruded Polystyrene 25 mm	
255 mm thick	0.81 W/m²K

Solid concrete block 200 mm	
Polyurethane Foam 25 mm	
255 mm thick	0.77 W/m²K

Solid concrete block 200 mm	
XPS/PUF 50 mm	
285 mm thick	~0.45 W/m²K

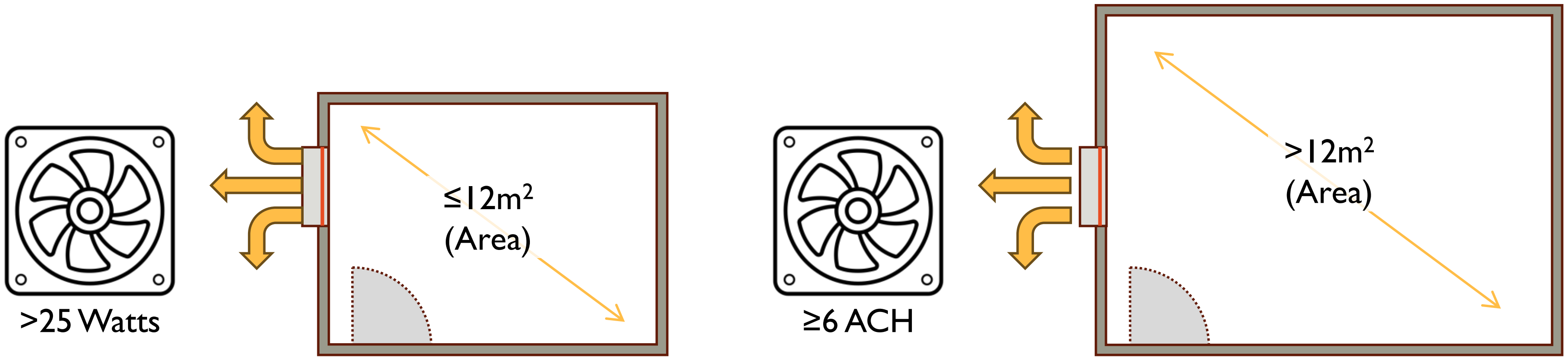


6

Low-energy Systems

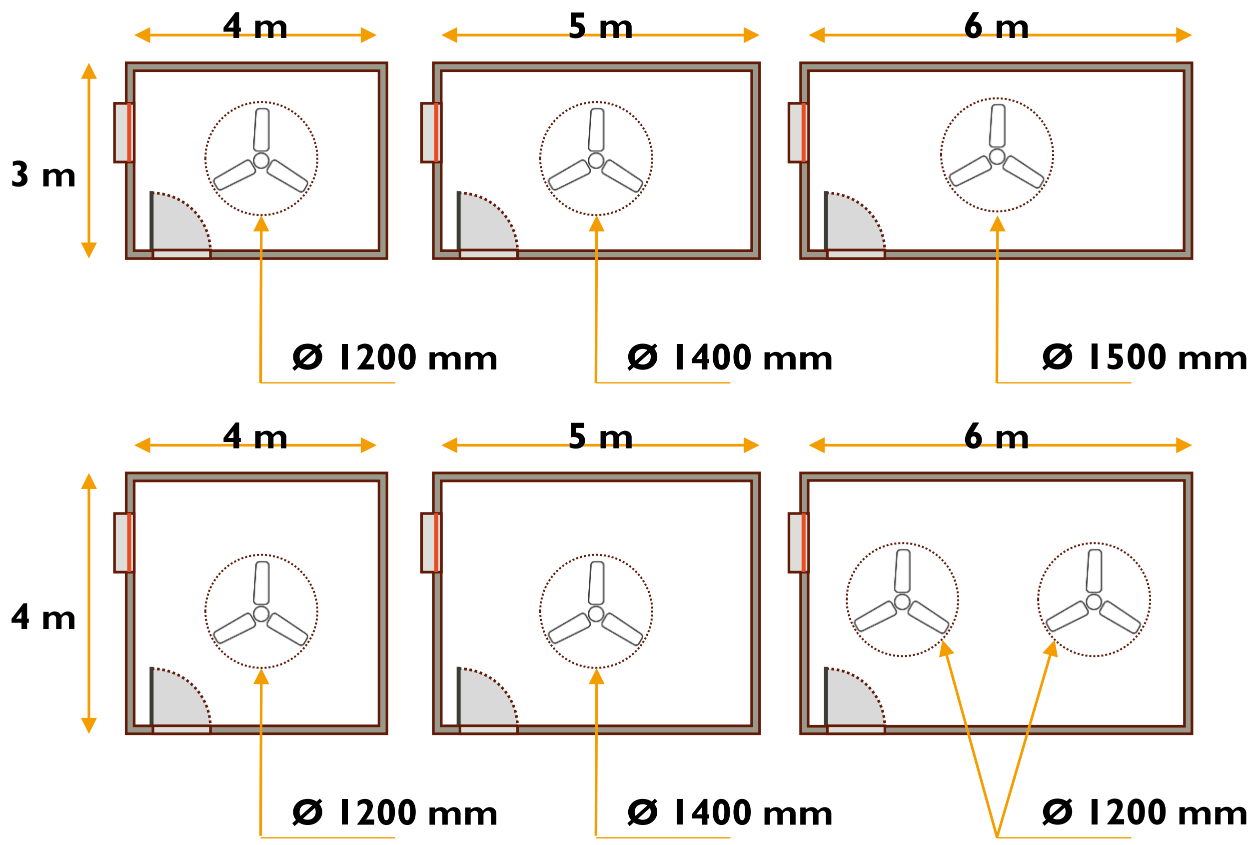
Low-energy Systems

Minimum exhaust requirements: Kitchen, Bath and Lavatory

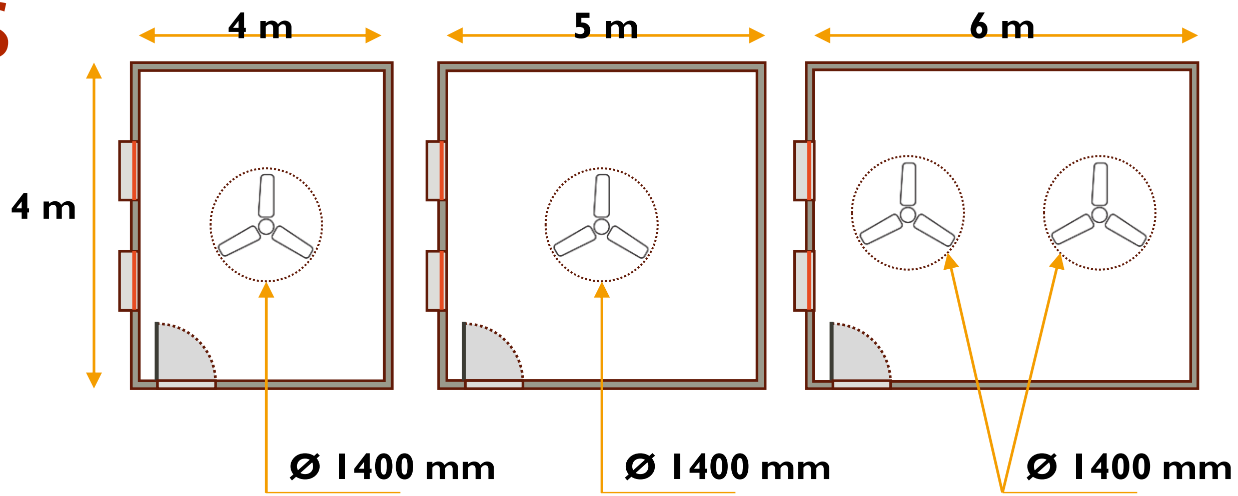


All kitchen, bath and lavatory spaces must maintain minimum ventilation to maintain health and hygiene. These spaces shall have provision to directly exhaust air outside.

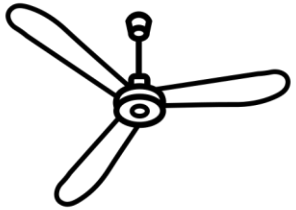
Ceiling Fans



Ceiling Fans



Ceiling Fan



Sweep size (mm)	Min. Service value (CMM/Watt)
> 1200	4.1
<= 1200	5.0

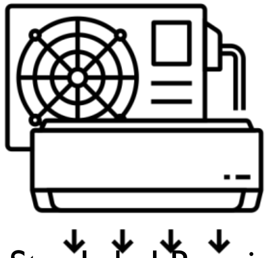
Sweep size (mm)	Min. Service value (CMM/Watt)
> 1200	4.6
<= 1200	5.5

Sweep size (mm)	Min. Service value (CMM/Watt)
> 1200	5.1
<= 1200	6.0

Star Label Requirements for Ceiling Fan. (Validity until December 31, 2024)

Minimum Efficiency of Mechanical Comfort Systems

Split-type Air Conditioner (Variable Speed)

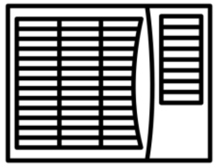


Cooling Watts	ISEER
<10,465	5.0

Default temperature setting of 24°C

Star Label Requirements for 5 Star Air Cooled Chiller (Validity until December 31, 2023)

Unitary-type Air Conditioner (Variable Speed)



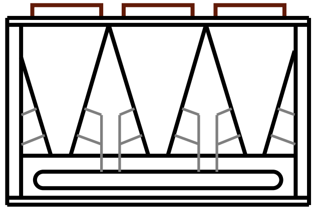
Cooling Watts	ISEER
<10,465	3.5

Default temperature setting of 24°C

Star Label Requirements for 5 Star Air Cooled Chiller (Validity until December 31, 2023)

Minimum Efficiency of Mechanical Comfort Systems

Air Cooled Chiller

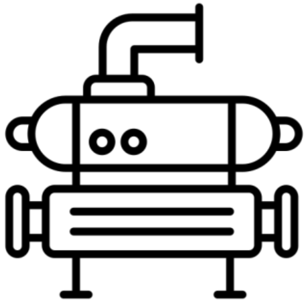


Cooling kW	Min COP*	ISEER
<260	2.4	4.4
>=260	2.6	4.7

Star Label Requirements for 5 Star Air Cooled Chiller (Validity until December 31, 2025)

*Minimum COP for Air Cooled Condenser (for 100% load)

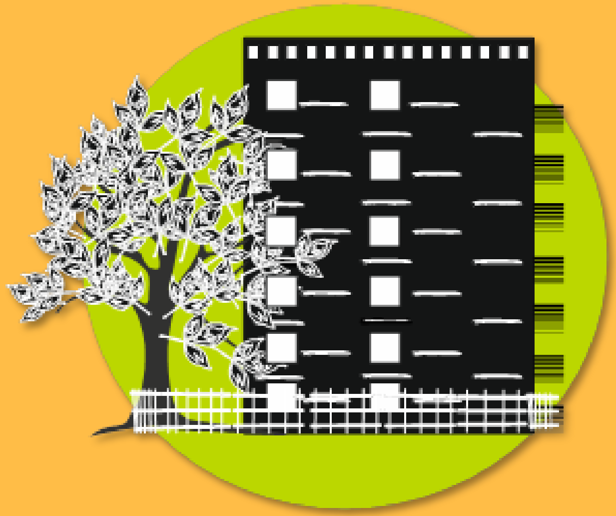
Water Cooled Chiller



Cooling kW	Min COP*	ISEER
<260	4.2	6.6
<530	4.7	7.4
<1050	5.0	8.2
<1580	5.2	8.7
>=1580	5.6	9.0

Star Label Requirements for 5 Star Water Cooled Chiller (Validity until December 31, 2025)

*Minimum COP for Water Cooled Condenser (for 100% load)



7 Lighting Provisions

8 Special Provisions for Large Residential Complexes

Light provisions & Special Provisions for Large Residential Complexes

Visual Comfort - Shielded fixtures minimum light (lux) requirements, & CRI

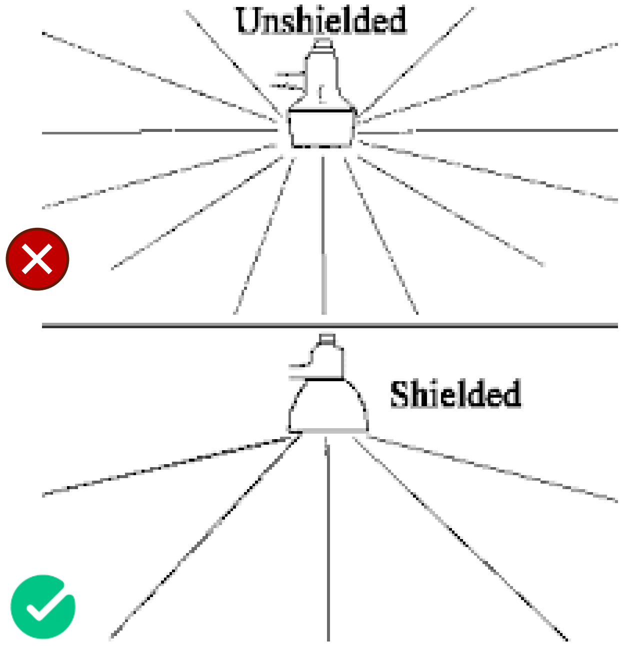


Image Source: Lighting Regulations (Albany County)

Area description	Lux level
Circulation Areas (Lifts, Corridors, Passageways, Stairs)	100
Bathroom/Lavatory	150
Kitchen	500
General lighting	100

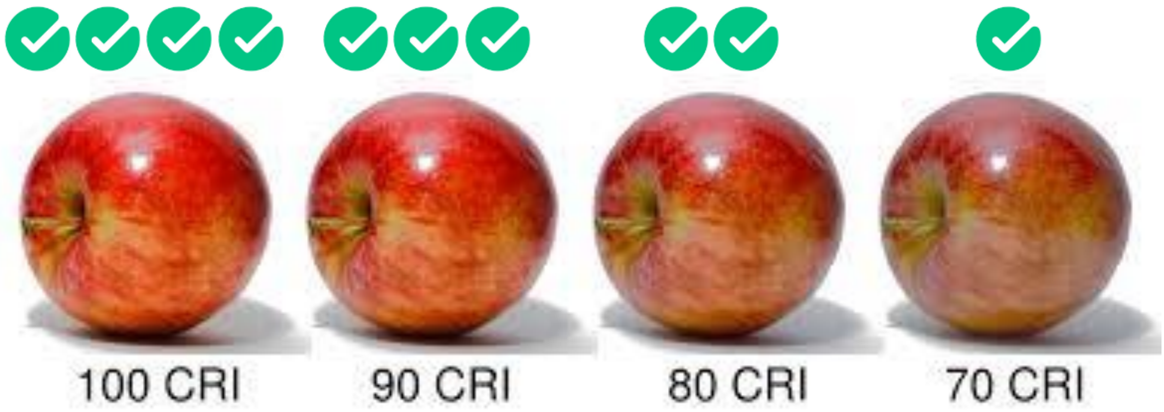
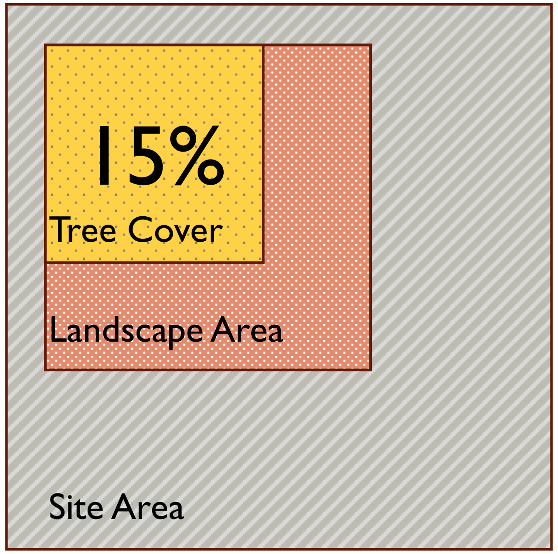
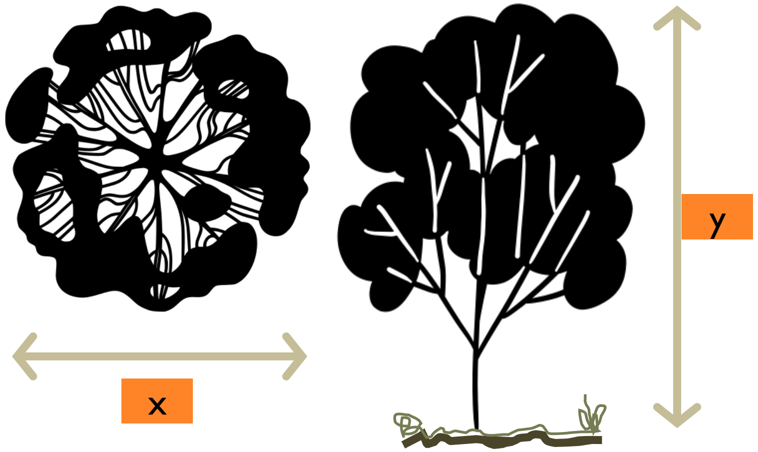


Image Source: **Color rendering index in lighting**

UHIE Mitigation - Minimum Tree Cover





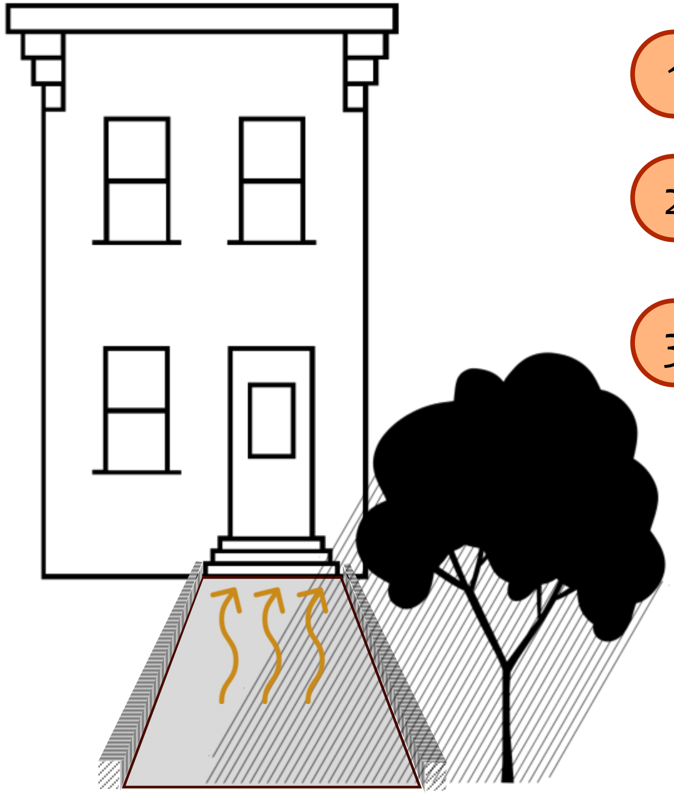
Trees moderate the microclimate by reflecting radiation, evapotranspiration and by providing shade. This leads to reduction in ambient temperatures and overall improvement in thermal comfort.

Tree canopy area requirements

Maintaining a minimum tree canopy area (x) can mitigate urban heat islands. For fulfilling tree canopy area requirements, the landscape design must consider native tree species that mature to a height (y) of 6 ft (or 2m) or greater. Trees with high foliage density should be preferred as they provide shade. Some native tree species are identified in B3-1.

⚠ While a higher tree canopy is desirable, it may lead to high humidity that could adversely impact thermal comfort outcomes. Similarly, while high foliage density is desirable, its impact on the built environment during winter months must be taken into account. Due care must be practiced while selecting tree species.

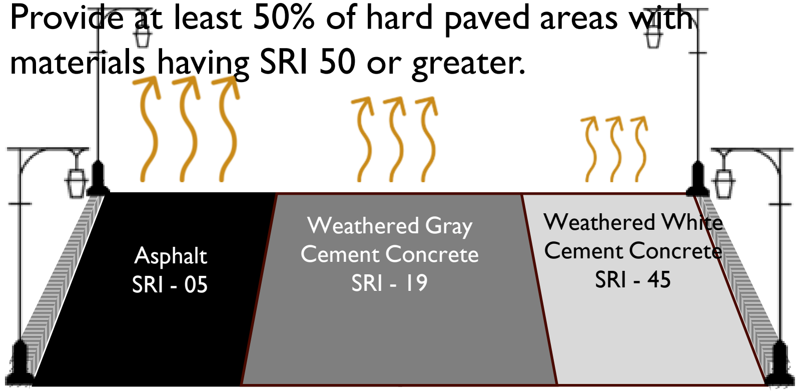
UHIE Mitigation - Reflective paving and road surfaces



1 **Reduce hard paved areas**
Replace hard paved areas with landscape as much as possible.

2 **Shade paved areas**
Plan paved areas such that they are shaded by buildings or vegetation for most parts of the day.
Cover paved areas with temporary structures.

3 **Use reflective and emitting surfaces for pavements**
Provide at least 50% of hard paved areas with materials having SRI 50 or greater.



Thank You!