



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA



Ministry of Housing and Urban Affairs
Government of India



giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH



Thermal Comfort Performance based Design Standard for Affordable Housing in India

First Expert Group Consultation
May 06, 2022 | Le Meridien | New Delhi







1

The Team



Ministry of Housing and Urban Affairs
Government of India



Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH



eds

Building Policies, Building Performance Analysis, Sustainable Design Practices, Training



Wuppertal Institut

Research and Development in Building Policies, Development of Technical Standards



hunnarshala
FOUNDATION

Affordable Housing Design and Policy, Research in Traditional Building Techniques

Total Housing Inc.

Affordable Housing Policies & Strategy Formulation, Micro Finance, Urban Renewal

Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing

2

2



Context and background

Outlines the guiding principles and conceptual approach towards standard development.

Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing

3

3

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:

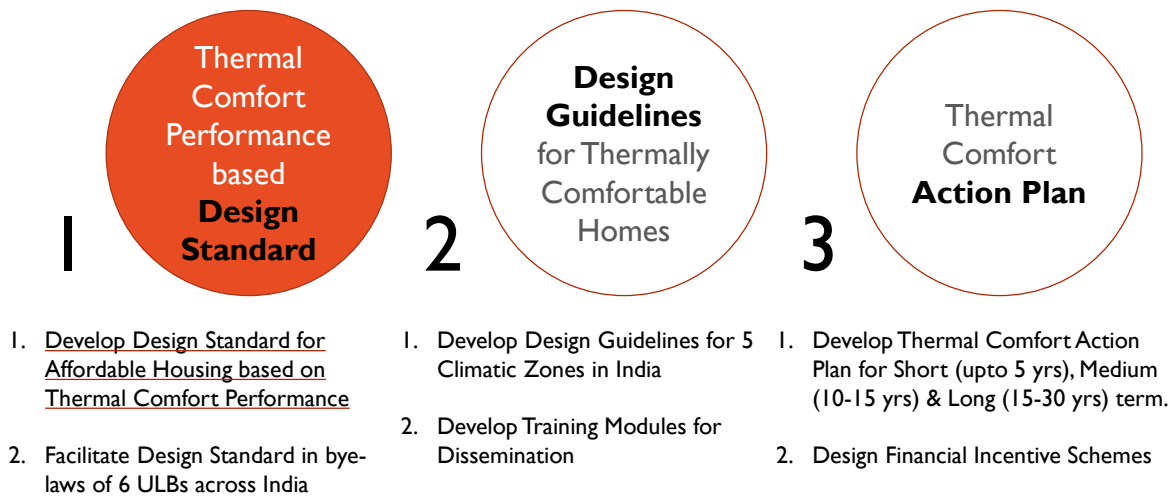
1. Affordable And Quality Housing Is Still A Dream For Many In India
 2. Resilient and affordable housing for all: Lessons on house building from Kochi and Trivandrum, India, Coalition for Urban Transitions

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4

4

Program Overview



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5

5

Workshop Objective

Review and feedback on:

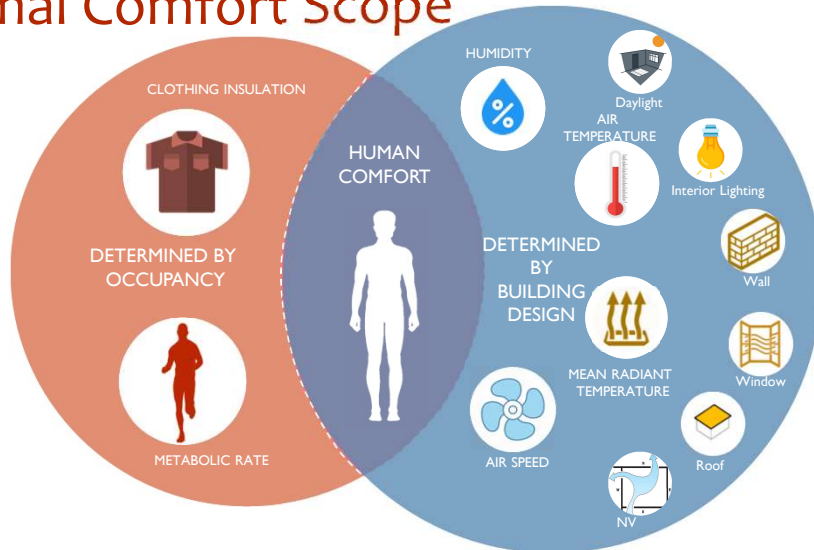
1. Approach for Development of Design Standard for Thermally Comfortable Affordable Housing
2. Affordable Housing Characteristics
 - Affordable Housing Typologies
 - Affordable Housing Material Characteristics
3. Thermal Comfort Standards and Indices

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6

6

Thermal Comfort Scope



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7

7

Scope of the standard

• Typologies

- Standard will focus on Affordable Housing (EWS and LIG Categories).
- Typologies will be sub-categorized as Independent and Multi-family homes.
- Other typologies will be tested for applicability of the standard.



• Building Systems

- Standard will focus on improving thermal comfort performance of un-conditioned, naturally ventilated buildings by integration of passive design strategies.
- Mechanical ventilation measures (Ceiling fan and Exhaust fan) operation will be accommodated.
- Low energy cooling systems (Evaporative cooling, Ground coupled heat transfer, etc.) will be accommodated as for enhanced performance.


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8




8


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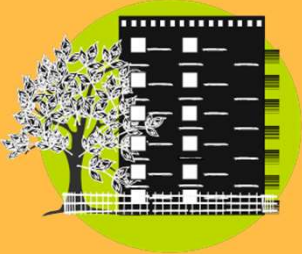


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APPROACH & METHODOLOGY FOR STANDARD
DEVELOPMENT

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Development Approach

Outlines the guiding principles and conceptual approach towards standard development.

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10

Guiding principles for developing standard

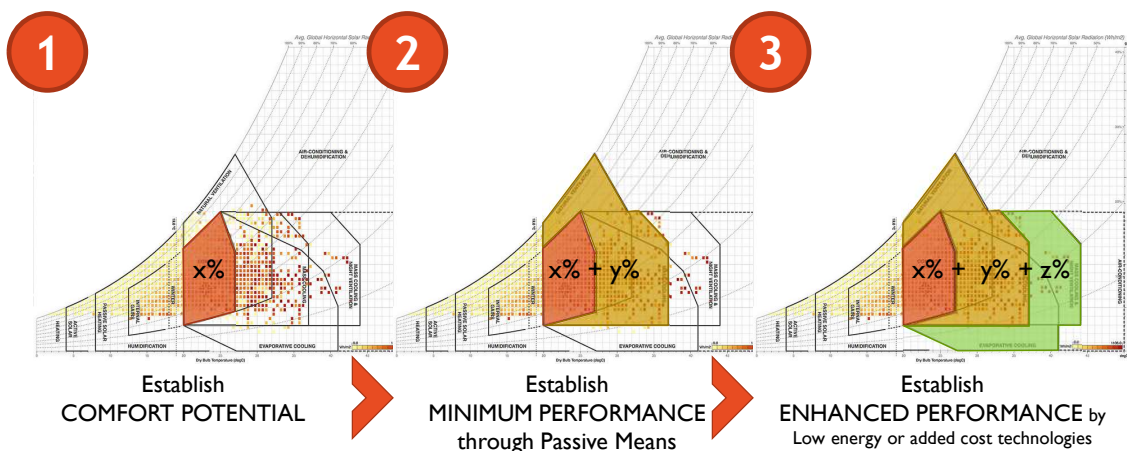
- 1) Target **enhancing thermal comfort by 50 %** (over existing performance)
- 2) Employ **passive design** strategies to enhance comfort (i.e. without mechanical conditioning systems)
- 3) Through standard promote use of,
 - **local building materials** (also low in embodied energy),
 - **low or 'No'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

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11

11

Approach to standard development



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12

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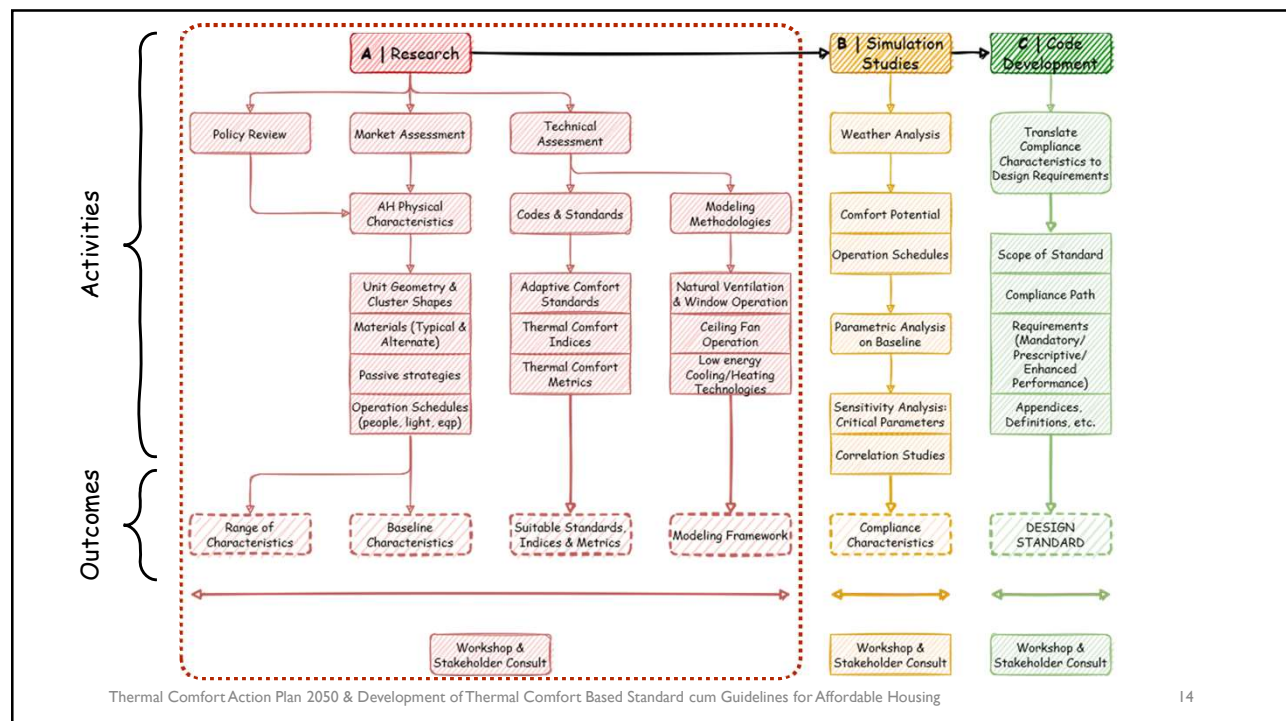
Development Methodology

Outline key steps/tasks in developing standard.

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13

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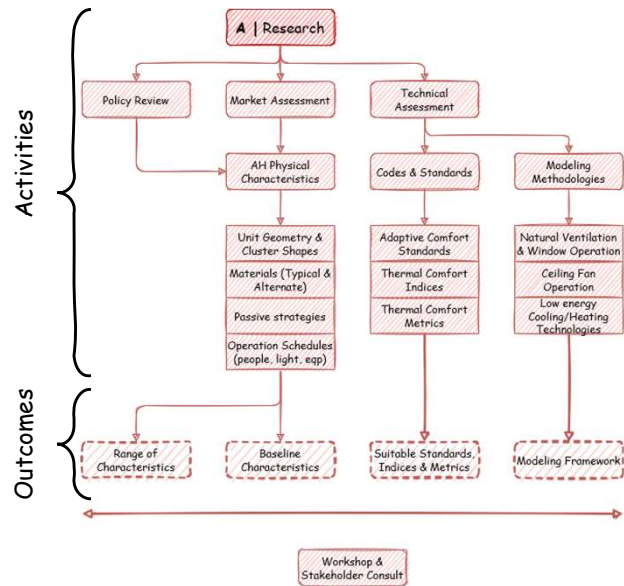


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14

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



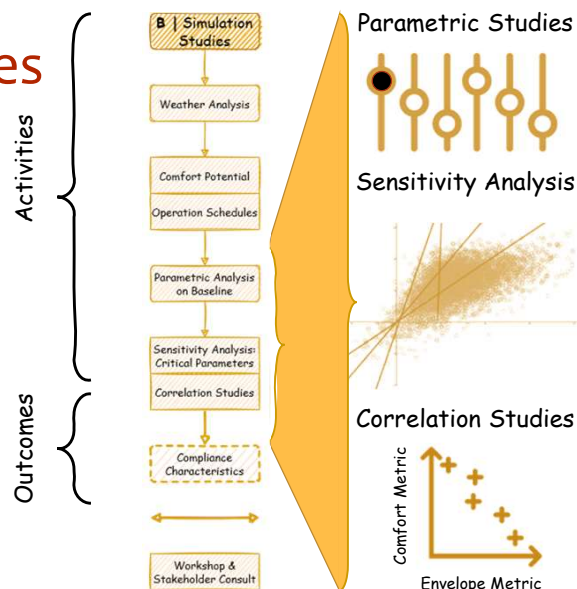
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15

15

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



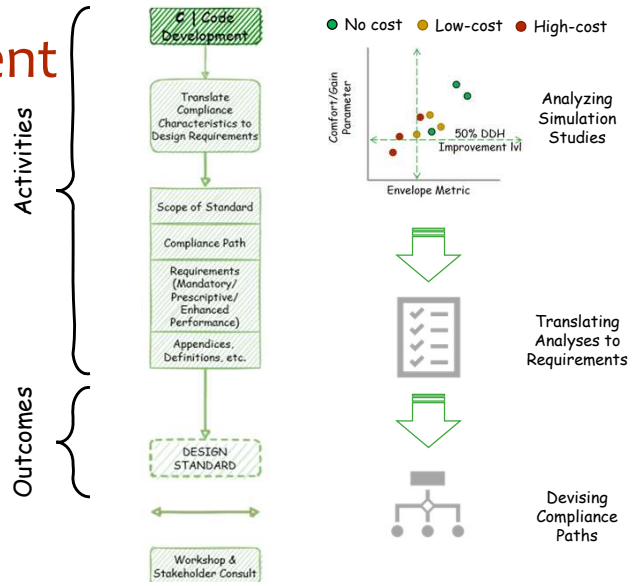
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16

16

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



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17

17

Expected Outcomes

- Standard based on Adaptive Comfort Models
- Standard focused on Envelope Measures for enhancing thermal comfort
- Standard that establishes both Minimum and Enhanced Performance Criteria
- Standard that is,
 - easy to comply with flexibility of compliance options,
 - prescriptive,
 - performance based, and,
 - ready to use compliance bundles/templates
 - easy to interpret, and,
 - easy to verify

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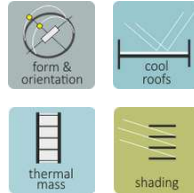
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Expected Outcomes



A Standard based on
Adaptive Comfort
Models



A Standard focused on
Envelope Measures &
Passive Design



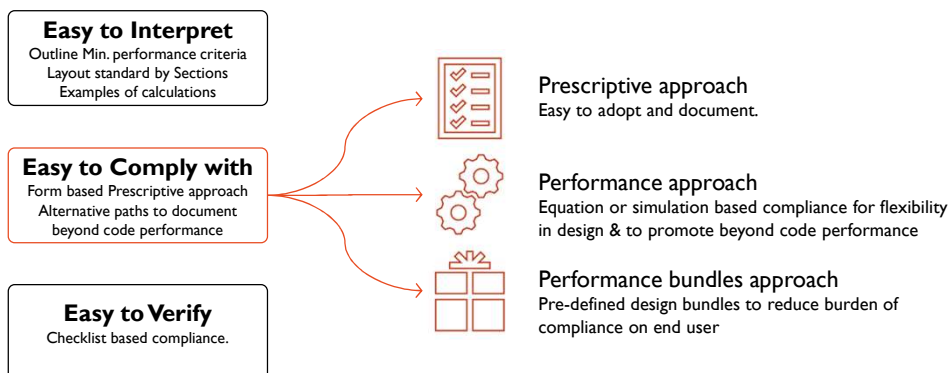
A Standard that establishes
Minimum & Enhanced
Performance Criteria

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19

19


Ease of Compliance – key to uptake & adoption




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20


20




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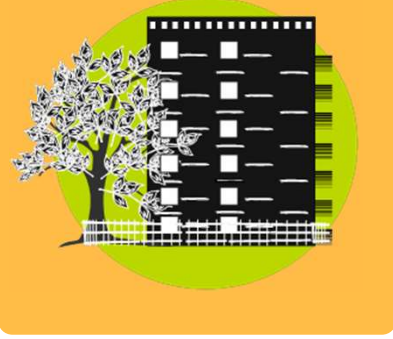
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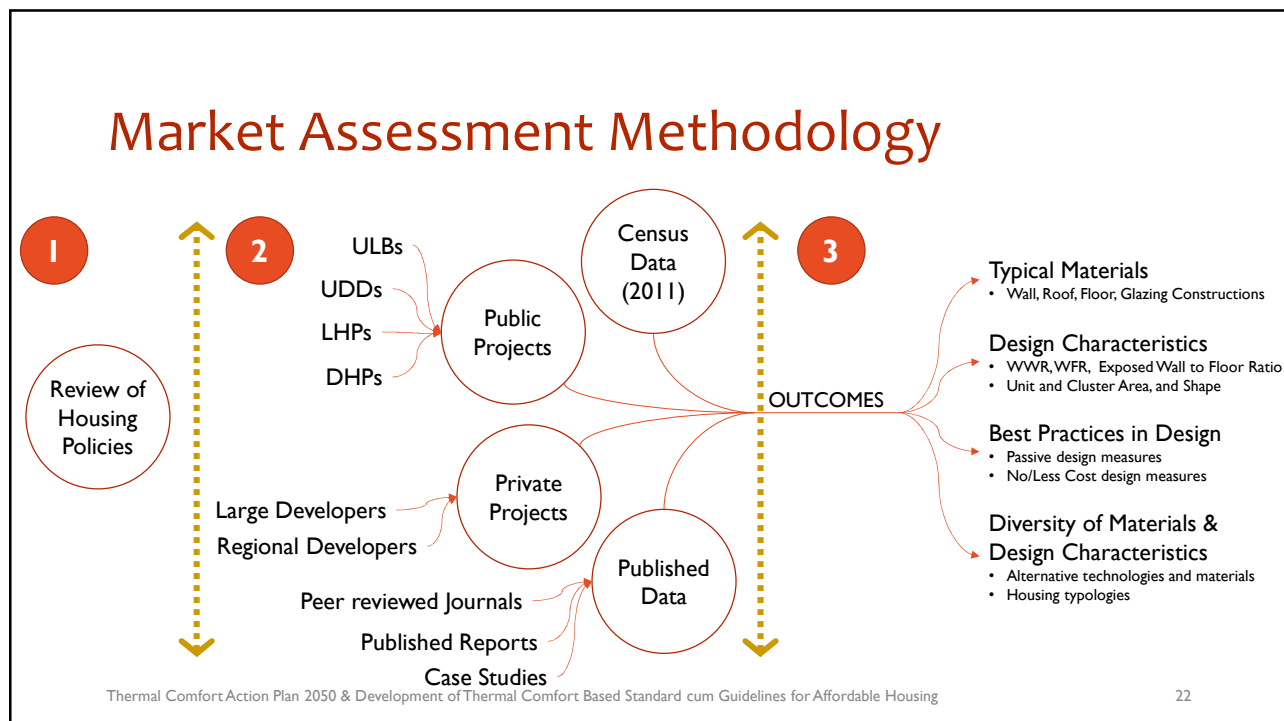
HOUSING SIZE & TYPOLOGY STUDY





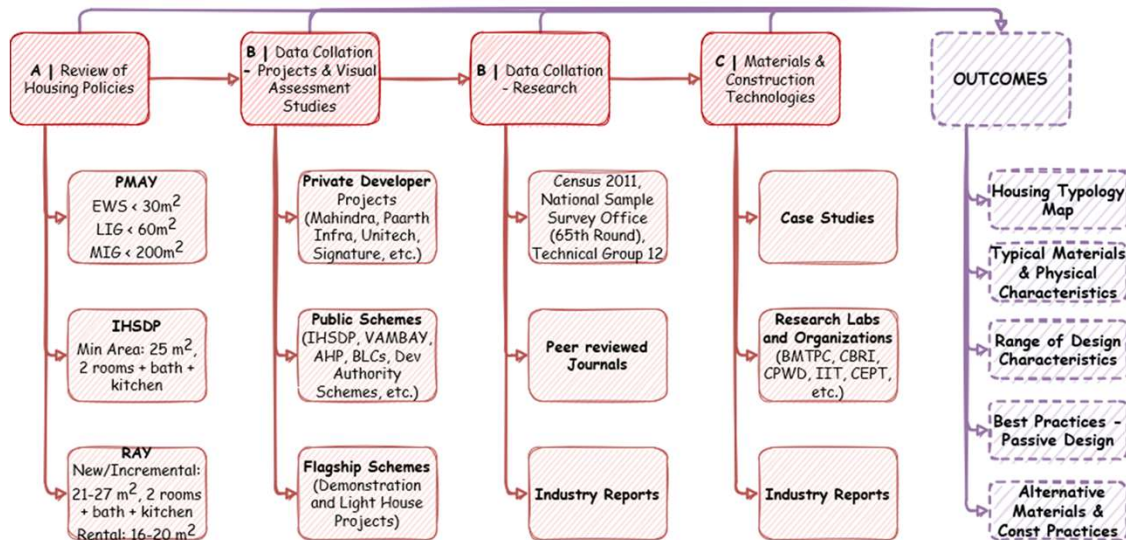


21



22

Market Assessment Methodology



23



Review of Policies & Affordable Housing Projects

Secondary research of Policies, Visual assessment studies and data collection of existing projects to identify typologies.

24

Review of policies identified area and spatial characteristics

PMAY-U Schemes	ISSR	CLSS	AHP	BLC-N, BLC-E
EWS (upto 3 DRs)	Up to 30 sqm	Up to 30 sqm	21-27 sqm	Up to 30 sqm
LIG (upto 4 DRs)	Up to 60 sqm	Up to 60 sqm	-	NA
LIG-A (upto 4 DRs)	-	-	28-40 sq m	NA
LIG-B (upto 4 DRs)	-	-	41-60 sq m	NA
MIG-1 (4+ DRs)	Up to 160 sqm	Up to 160 sqm	NA	NA
MIG-2 (4+ DRs)	Up to 200 sq m	Up to 200 sq m	NA	NA

Policy (PMAY)-Area-Typology Matrix

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25

25

Visual Assessment of homes identified typologies: Single Family Homes



Plotted Development



Row-type

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26

26

Visual Assessment of homes identified typologies: Multifamily Homes



Low Rise Housing



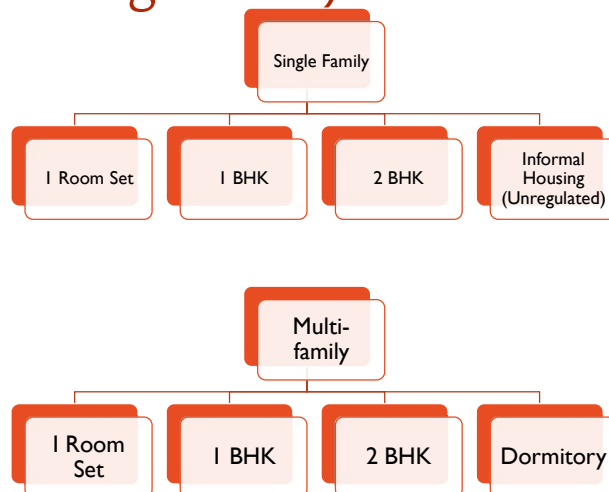
Mid/High Rise Housing

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27

27

Low Cost/Affordable Homes Typology Map (by spatial configuration)

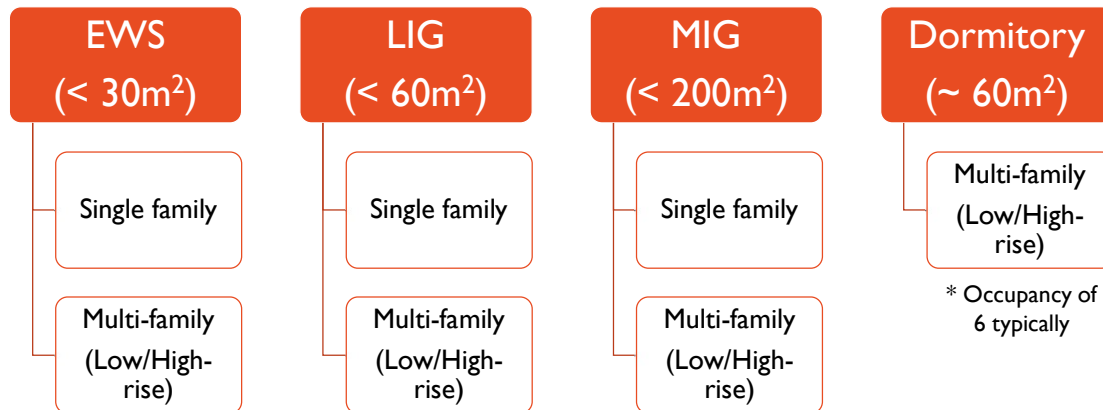


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28

28

Low Cost/Affordable Homes Typology Map (by area)

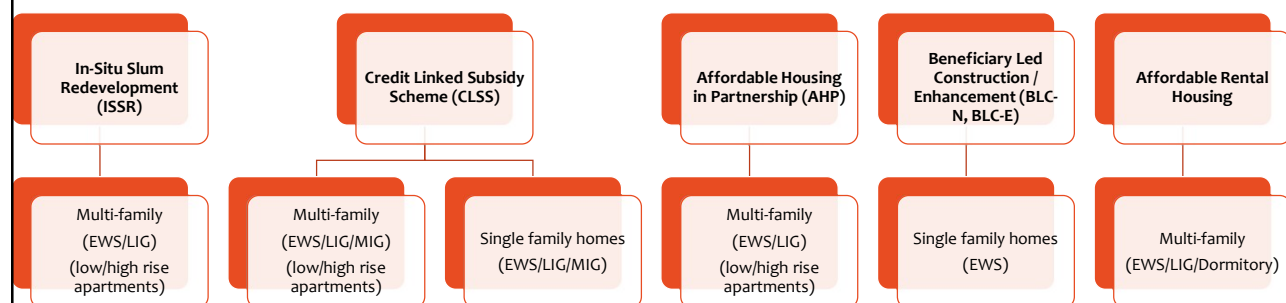


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29

29

Policy (PMAY)-Area-Typology Matrix



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30

30



Housing Characteristics: Representative Projects

Review of projects by private developers, govt. schemes and flagship government programs

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31

31

Data of ~100 affordable housing projects across Pvt Developers and Govt. Agencies compiled

Market Assessment, Affordable Housing Characteristics Data										pysh varma																																																																																																																																																															
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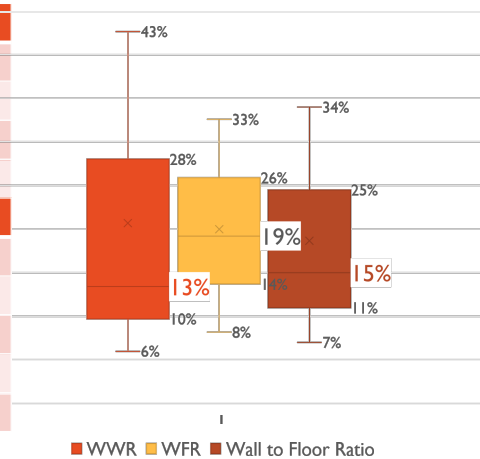
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32

32

Range of Design Characteristics from Compiled Projects

Typology	Carpet Area (m ²)		
	Min	Med	Max
EWS	13.1	25.5	36.0
LIG	27.0	36.8	58.9
MIG	72.0	82.0	97.0
	Min	Med	Max
WWR	6%	13%	43%
WFR _{op}	8%	19%	33%
Wall to Floor	7%	15%	34%
U _{roof} (W/m ² K)	0.47	4.2	5.2
U _{wall} (W/m ² K)	0.45	3.35	10.0



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33

33

Range of Material Characteristics from Compiled Projects

	Min	Other	DHP	LHP
U _{roof} (W/m ² K)	Min	0.47	0.57	
	Med	4.30	3.60	5.20 (Limited Info available)
	Max	5.20	5.20	
U _{wall} (W/m ² K)	Min	0.45	0.57	0.78
	Med	2.60	4.60	4.40
	Max	9.20	6.80	10.00

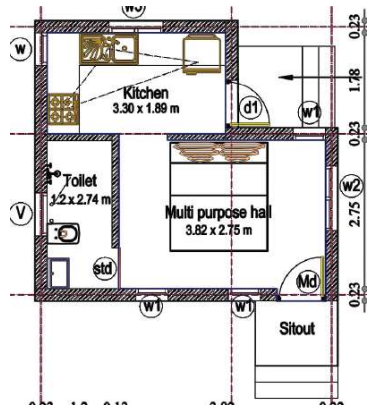
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34

34

Single-family| 1 Room Set| Plotted

Details	
Cluster Size	Plotted
Carpet Area	21.8 m ²
WWR	10%
WFR	27%
Shading Type	Overhang
Area	m ²
Living	10.5
Toilet	3.2
Kitchen	6.2



Details

Unit Plan

View

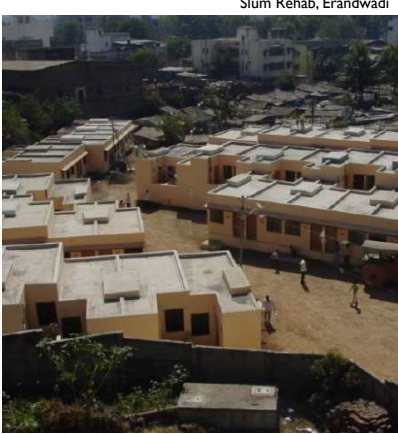
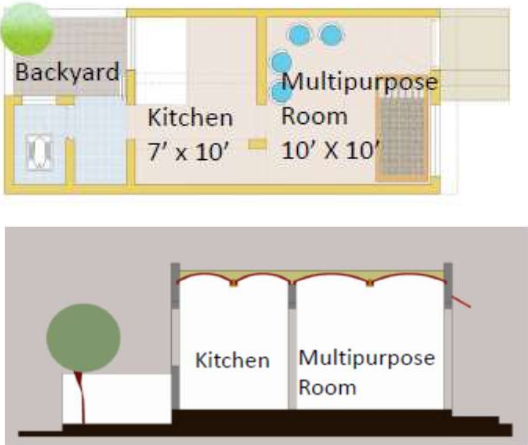
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35

35

Single-family| 1 Room Set| Row Type

Details	
Cluster Size	Row type
Carpet Area	18.6 m ²
WWR	7.5%
WFR	18%
Shading	No
Area	m ²
Living Area	9.3
Toilet	1.4
Bath	1.4
Kitchen	6.5



Details

Unit Plan & Section

View

Source

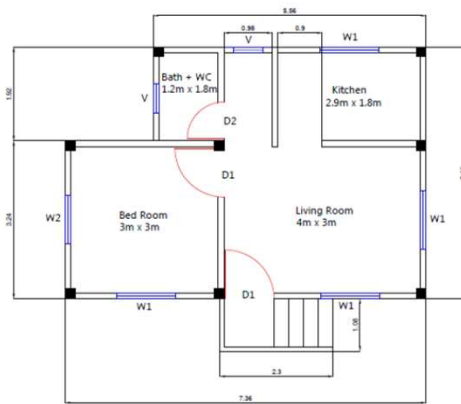
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36

36

Single-family| 1 BHK| Plotted

Details	
Cluster Size	Plotted
Carpet Area	28.5 m ²
WWR	11.5%
WFR	26%
Shading	Overhang
Area	m ²
Living Area	12
Toilet	2.3
Bedroom	9
Kitchen	5.2



Model layout of BLC Municipal Affairs Department, Govt. of Nagaland



Details

Unit Plan

View

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37

37

Single-family| 1 BHK| Row Type

Details	
Cluster Size	Row Type
Carpet Area	37.1 m ²
WWR	7.2%
WFR	24.3%
Shading	Overhang
Orientation	N-S
Area	m ²
Living	12
Toilet	2.2
Kitchen & Din.	11.2
Bedroom	11.7



Private Developer Project, Gujarat



Details

Unit Plan

View

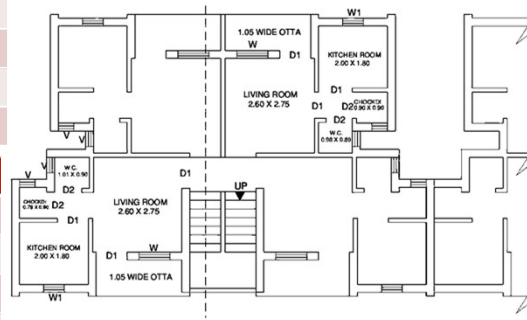
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38

38

Multi-family| 1 Room Set| Low Rise

Details	
Cluster Size	4 units
Carpet Area	15.9 m ²
WWR	9%
WFR	16%
Shading	Overhang
Area	m ²
Living Area	7.9
Toilet	0.9
Bath	0.8
Kitchen	3.6



VAMBAY (Slum Rehab), Surat



Details

Unit & Cluster Plan

View

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39

39

Multi-family| 1 Room Set| Mid Rise

Details		Area	m ²
Cluster Size	10 units	Living Area	10.9
Carpet Area	21.5 m ²	Bath + Toilet	4.2
WWR	6%	Kitchen	5.2
WFR	12%		
Shading	Overhang		
Orientation	NE-SW		



Private Developer, Boisar



Unit Plan

Cluster Plan

View

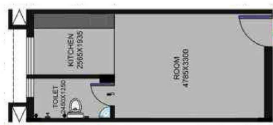
Source

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40

40

Multi-family| 1 Room Set| High Rise



Unit Plan

Details	
Carpet Area	23.6 m ²
WWR	18%
WFR	14%
Area	
Living Room	15.8
Toilet + Bath	3.0
Kitchen	4.8



Cluster Plan



View

Private Developer, Lucknow

[Source](#)

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41

41

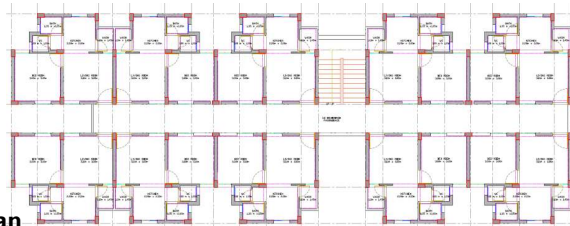
Multi-family| 1 BHK| Low Rise



Unit Plan

Details		Area	
Cluster Size	10 units	Bedroom	9
Carpet Area	28.3 m ²	Living Area	9.3
WWR	9%	Toilet + Bath	2.6
WFR	22.5%	Kitchen	5.1
Orientation	NE-SW		
Shading	Recessed		

Cluster Plan



View

Daman Municipal Council, Daman

[Source](#)

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42

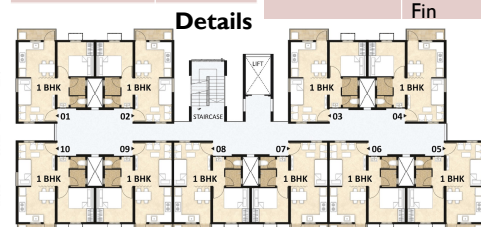
42

Multi-family| 1 BHK| Mid Rise



Unit Plan

Details		Area	m ²
Cluster Size	10 units	Bedroom	8.4
Carpet Area	40 m ²	Living Area	9.2
WWR	16%	Toilet + Bath	4.6
WFR	10.2%	Kitchen	8.4
Orientation	7 – N-S 5 – E-W	Shading	Overhang & Fin



Cluster Plan



View

Mahindra Happinest, Avadi

[Source](#)

43

43

Multi-family| 1 BHK| High Rise



Unit Plan

Area		Details	
Bedroom	10.96	Cluster Size	8 units
Living Area	11.96	Carpet Area	34.51 m ²
Toilet	3.22	WWR	6%
Utility	1.57	WFR	8%
Kitchen	3.90	Orientation	8 – E-W 2 – N-S
		Shading	Overhang



Cluster Plan



View

Light House Project, Lucknow

[Source](#)

44

44

Multi-family| 1 BHK| High Rise



Unit Plan

Details		Area	m ²
Cluster Size	11 units	Bedroom	8.24
Carpet Area	26.02 m ²	Living Area	8.18
WWR	16%	Toilet	2.9
WFR	23.6%	Utility	5.2
Orientation	N-S	Kitchen	6.7
Shading	Overhang		



Cluster Plan



View

[Source](#)

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45

45

Multi-family| 2 BHK| Low Rise

Details	
Cluster Size	4 units
Carpet Area	38.7 m ²
WWR	9.2 %
WFR	13 %
Orientation	E-W
Shading	Overhang
Area	m ²
Bedroom	17.1
Living Area	14.0
Toilet + Bath	4.0
Kitchen	3.7



Cluster Plan

Unit & Cluster Plan



View

[Source](#)

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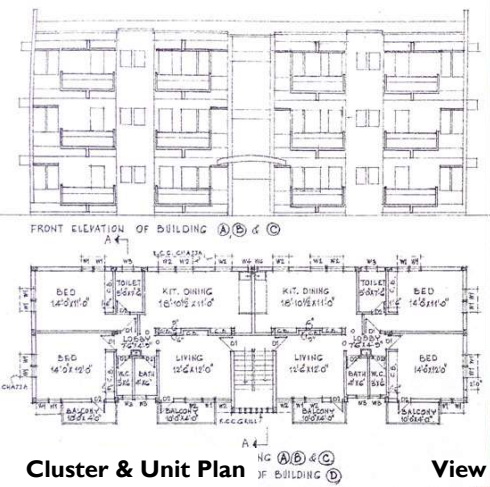
46

46

Multi-family| 2 BHK| Low Rise

Details	
Cluster Size	4 units
Carpet Area	77 m ²
WWR	15.5%
WFR	19.15%
Shading	Overhang

Area	
Bedroom	29.9
Living Area	16.7
Toilet	3.9
Kitchen	19.4



Private Developer, Co-operative Housing Society, Pune

Details

Cluster & Unit Plan

View

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47

47

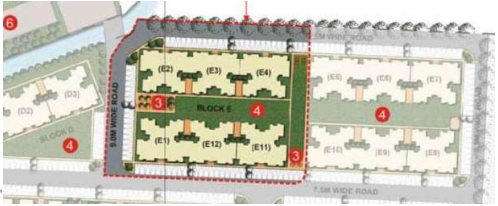
Multi-family| 2 BHK| Mid Rise

Details		Area	
Cluster Size	4 units	Bedroom	28.2
Carpet Area	97 m ²	Living Area	21.5
WWR	11%	Toilet	8.7
WFR	17.3%	Kitchen	6.1
Orientation	E-W		
Shading	Overhang		

Unit Plan



Cluster Plan



UniHomes, Bhopal

View

Source

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48

48

Multi-family| 2 BHK| High Rise

Details	
Cluster Size	4 units
Carpet Area	72 m²
WWR	13%
WFR	18.5%
Orientation	N-S
Shading	Overhang
Area	m²
Bedrooms	23.0
Living Area	29.0
Toilet	6.0
Kitchen	7.0

Unit Plan

Bangalore Development Authority, Kaniminake Phase-3

Cluster Plan and View

[Source](#)

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49

Multi-family| Dormitory| High Rise

Sample Unit Plan

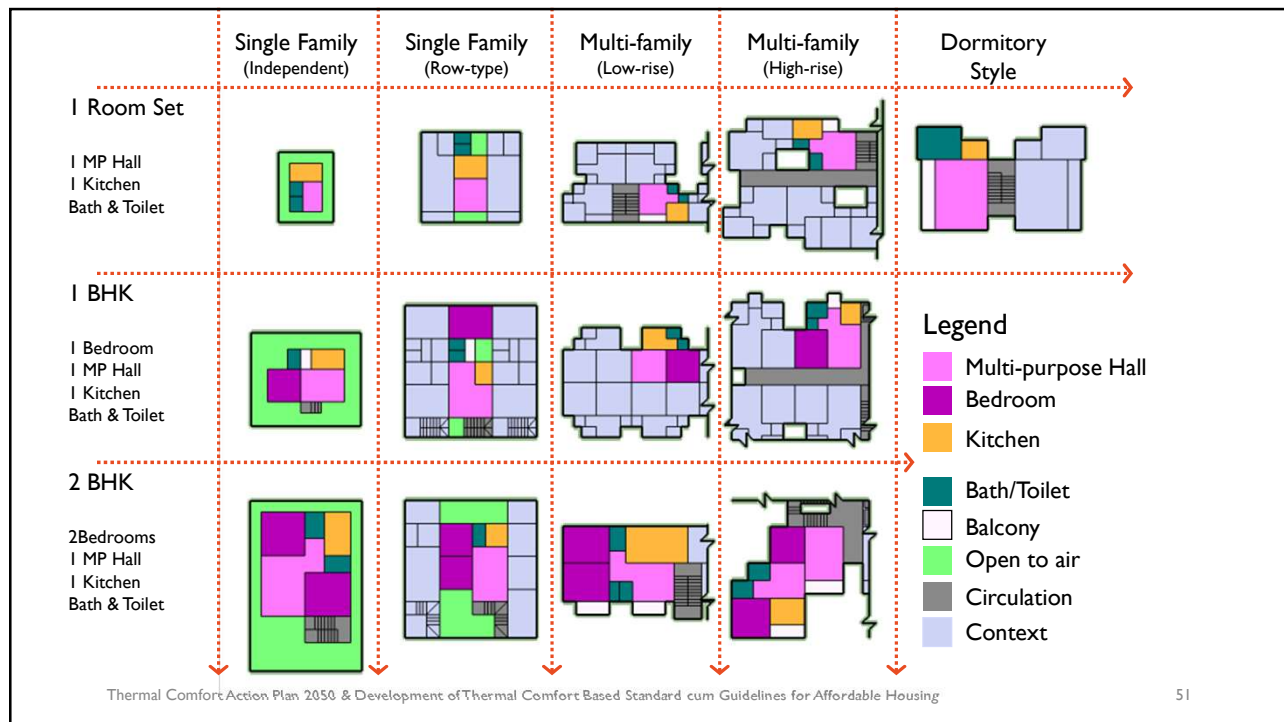
Private Developer, Hinjewadi, Pune

View

[Source](#)


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50



51

51



Affordable Housing Trends & Material Characteristics

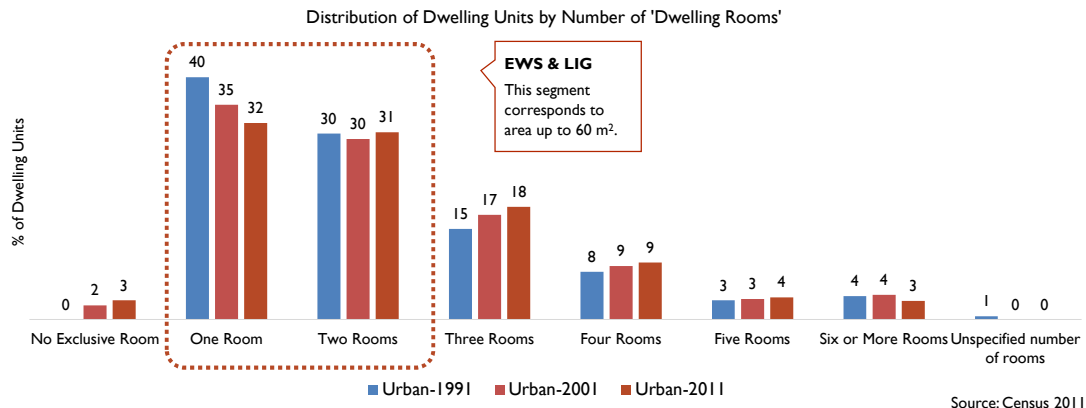
Secondary research of Policies, Census data, peer reviewed journals and industry reports.

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52

52

2/3rd dwellings have less than 3 rooms



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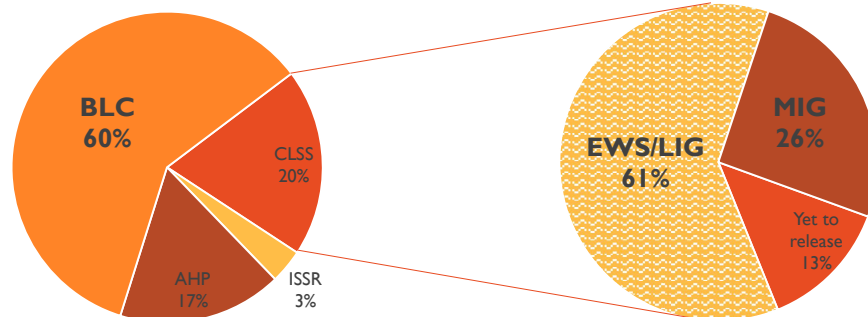
53

53

Standalone homes are key drivers of PMAY

Households Sanctioned under PMAY (U)
122 lakhs

Beneficiaries under CLSS



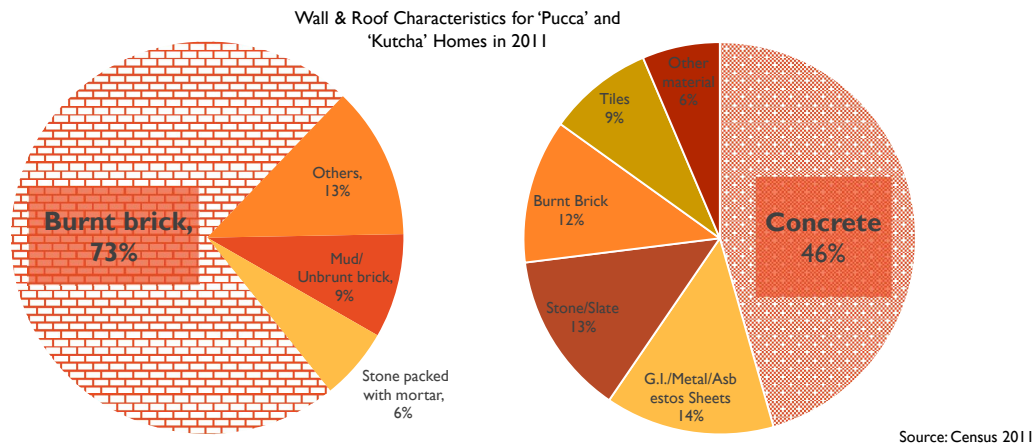
While overall distribution is unknown, there is significant uptake of MIG

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54

54

Brick walls & Concrete Roof characterize 'Pucca' homes



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55

55

Information from peer reviewed research is consistent with Census data

Source	Roof	Wall	Floor	Window	Remarks
Prasad et al.	4-inch-thick concrete slab, waterproofed and finished with clay tiles	Non-load bearing 8-inch-thick brick wall supported with RCC framework	4-inch-thick concrete finished with 1-inch thick terrazzo	single plane glass fitted in 1 inch metal frame (U: 5.1 W/m ² °C, SC=1) (Shaded with 300mm overhang)	building practices in New Delhi for a Middle-Income Group (MIG) household
Tam	6-inch-thick RCC slab	9-inch-thick burnt brick masonry with cement plaster finished with paint over putty & primer	6-inch-thick RCC slab		Low-cost technologies (timber frame windows, rat-trap bond w/o finish, filler slab for roofs and terracotta tiles or cement flooring) can offset 20% costs compared to prevalent construction

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56

56

Information from peer reviewed research is consistent with Census data

Source	Roof	Wall	Floor	Window	Remarks
Trust Fund for Environmentally and Socially Sustainable Development	No Information	Brick wall with plaster on both sides. (U: 2.8 W/m ² .°C)	concrete slab (U: 3.5 W/m ² .°C)	single plane, clear (U: 5.0 W/m ² .°C)	Alternative materials, technologies and practices can enhance comfort and operational energy use.

Other Key Details:

Context: Baseline for this study is based on housing developments in & around Delhi

Cluster layout: G+2 cluster with 4 units per floor.

Infiltration: 2 ACH

Equipment 10 W/m²

Occupancy: 4 (Husband, wife & 2 Children)

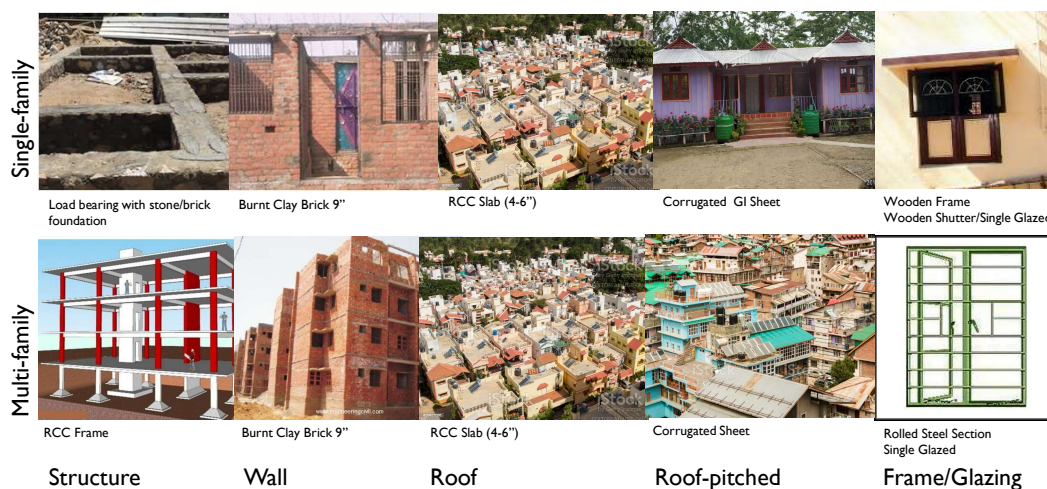
57

Information from peer reviewed research is consistent with Census data

Source	Roof	Wall	Floor	Window	Remarks
Mainstreaming Sustainable Social Housing in India (MaS-SHIP)	No Information	230/250mm thick burnt clay brick masonry in cement-sand mortar (1:6) Cement-Sand Plaster 20mm thick (external)	Ceramic/ vitrified tiles Locally available (pre polished) stone tiles 20-30mm thick Plain Cement	Pressed steel door-window frames (125mmx65mm double rebate or 100mmx50mm single rebate)	RCC framed construction with typical cluster of 4 dwelling units per floor in a low-rise (G+3) typology

58

Typical Material Specifications



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59

59

Typical Material Specifications

	Structure	Envelope	Flooring	Openings	Finishes
Single Family	Load bearing construction with strip footing and RCC plinth beam. Stone, where readily available.	230/250mm thick burnt clay brick masonry in cement-sand mortar (1:6) 150-200 mm thick concrete block masonry in cement mortar (1:6)	Ceramic/ vitrified tiles Locally available (pre polished) stone tiles 20-30mm thick Plain Cement Concrete floor	Wooden shutters on wooden frame. Pressed steel door-window frames (125mmx65mm double rebate or 100mmx50mm single rebate)	Cement-Sand Plaster 20mm thick (external), 15mm thick (internal) White cement based putty Cement Paint external and internal or White wash internal
Multi-family	RCC frame structure as per codal provisions for seismic design, using M20 strength concrete.	Fly Ash bricks are being used as well now.		Pressed steel door-window frames (125mmx65mm double rebate or 100mmx50mm single rebate)	

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60

60



Housing Characteristics: Alternative practices

Review of alternative materials, construction technologies and passive design principles

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61

61



T-Zed Homes	Bengaluru, Temperate
Multi-family (G+3)	2BHK (120 m ²), 3 BHK (250 m ²)
Wall	Concrete Blockwork containing Fly ash and soil stabilized blocks
Floor	Natural stone
Roof	Filler slabs (using recycled railway sleeper bits)
Openings	Shutters of non-forest timber like rubber wood
Passive features	# Vegetation for improving micro-climate & shading buildings # Designed for daylight.

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Malhar Footprints	Bengaluru, Temperate
Multi-family (G+2)	3 BHK (213 m ²)
Wall	CSEB & random rubble masonry
Floor	Local clay tiles (athangudi) & vitrified tiles
Roof	RCC Roof slab ventilated and shaded with GI sheet
Openings	Single glazing, shaded with RCC and Mangalore tile roof overhang
Passive features	# Reduced hard paving, Mud concrete paving # Surface to Volume ratio (0.26 to 0.43) # WWR of 18% to 25% # Shaded Verandah # Skylights over stairwell, # Courtyards for daylight & ventilation


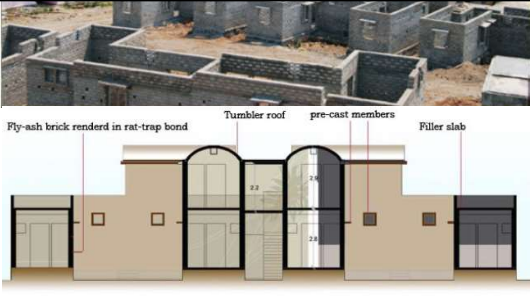
62

			
Realization Community	Tamil Nadu, Warm-Humid	Humidity	Tamil Nadu, Warm-Humid
Multi-family (G+2)	1 BHK, 2 BHK	Multi-family (G+3)	2 BHK (131 m ²), 3 BHK (170 m ²)
Wall	Compressed Stabilized Earth Blocks (CSEB) with lime stabilized earth plaster	Wall	Flyash bricks with Lime cement finish
Floor	Vaulted floor systems having cavities and ventilators	Floor	Vitrified tiles
Roof	CSEB vaulted roofing with insulation	Roof	Styrofoam insulation and reflective tile finish
Openings	Single Glazed windows	Openings	Anodized Aluminium frame for windows
Passive features	# Double height spaces for stack cooling # Earth cooling tunnels # Hygrothermal cooling	Passive features	# Designed for cross ventilation # Vegetation shading East and West walls
Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing		63	

63

			
Slum Rehab	Bhuj, Hot-dry	Smart Ghar III	Rajkot, Hot-dry
Incremental Row-house (G+1)	2 BHK (21-35 m ²)	Multi-family, Stilt + 7	1 BHK (34 m ²)
Wall	Light colored walls	Wall	Cavity wall (South façade), 230mm AAC block
Floor		Opening	Casement windows (shaded)
Roof	Sloping roof with insulation layer, and Flat roof made of shallow domes using earth blocks	Roof	Insulated (40mm Polyurethane foam insulation) and roof finished with china mosaic.
Openings		Passive features	# Mechanically assisted ventilation via shaft # Insulated roof with reflective finish # Windows with external movable shades
Passive features	#		
Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing		64	


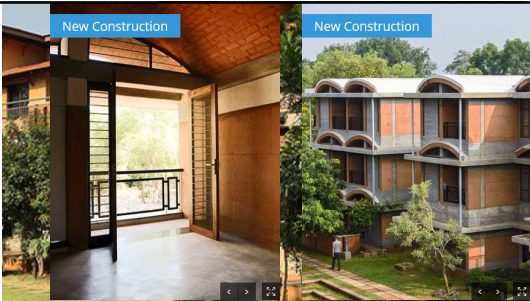
64

			
Demonstration Housing Project	Rae Bareilly, U.P., Composite	IHSDP Phase II	Lonar, Maharashtra, Hot-Dry
Multi-family (G+1)	1 BHK (34 m ²)	Multi-family (G+1)	1 BHK (25 m ²)
Wall	Burnt Clay bricks in Rat Trap Bond	Wall	230 mm Rat trap bond using Flyash Bricks and 15mm plaster on both faces.
Floor	IPS flooring	Roof	Tumbler roofing , that is burnt clay conical tumblers are placed in the arch on the roof.
Roof	Reinforced Brick Concrete Slab for ground floor roof, Filler slab with Earthen Pots for slope roofing, Mangalore tile cladding on sloping roof.	Passive features	# Filler slab, tumbler roofing and rat-trap to improve insulating properties of the envelope. # Cluster planned around courtyards to improve natural ventilation potential.
Openings	Pre cast RCC door frames, Steel window frames and glazed shutters.		
Passive features	# Rat-trap bond wall and filler slab. # Shaded windows # High ceiling for top floor		

Standard cum Guidelines for Affordable Housing

65

65

			
GERES	Leh, Cold	Humanscapes Habitat	Puducherry, Warm-Humid
Single-family	1 BHK (34 m ²)	Multi-family (G+2)	1, 2, 3 & 4 BHK
Wall	Rammed earth or mud/cement bricks	Wall	Poured Earth Concrete (PEC) wall and Waste Cuddapah stone wall
Floor	Insulated floor	Floor	Natural stone and IPS flooring
Roof	Structural system made of wood with a layer of insulation and finished with mud. False roof on the inside filled with natural materials (dried vegetation) and saw dust.	Roof	Brick vaults.
Passive features	# South facing solarium # Double wall with insulation # Insulated floor and roof	Openings	Single glazing, shaded with RCC and Mangalore tile roof overhang
		Passive features	# Light shelf for daylight. # Land & sea breeze for natural ventilation # Shaded windows # High ceiling to aid ventilation. # Designed for adaptive comfort

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66

Passive Strategies by Climate

Measures		Composite	Cold	Warm-Humid	Temperate	Hot-Dry
Building Form (Aspect ratio, Surface Area to Volume ratio)	Design	Aspect Ratios, S-V Ratios for Testing	Aspect Ratios, S-V Ratios for Testing	Aspect Ratios, S-V Ratios for Testing	Aspect Ratios, S-V Ratios for Testing	Aspect Ratios, S-V Ratios for Testing
Building Orientation (Aspect ratio, Spatial Arrangement)	Design	North - South	South facing	Oriented towards prevailing wind.	North-South	North-South
Surface Characteristics - Roof (Absorptivity, Reflectivity)	Material	Roof reflectance, Roof absorptivity, Roof emissivity (Cool Roof, Vegetated roof)	Roof absorptivity, Roof emissivity (Insulated roof – Thatch/Straw agricultural waste)	Roof reflectance, Roof absorptivity, Roof emissivity (Cool Roof, Vegetated roof)	Roof reflectance, Roof absorptivity, Roof emissivity (Cool Roof, Vegetated roof)	Roof reflectance, Roof absorptivity, Roof emissivity (Cool Roof, Vegetated roof)
Surface Characteristics - Wall (Absorptivity, Reflectivity)	Material	Wall absorptivity Surface Roughness (Heat Reflective)	Wall absorptivity Surface Roughness (Trombe Wall)	Wall absorptivity Surface Roughness (Heat Reflective)	Light colored, Heat Reflective	Light colored, Heat Reflective
Surface Characteristics - Thermal Mass (Terrace Garden, Dense Walls)	Material	Wall Assembly combinations (Heavy, Medium & Light weight) (Cavity Wall, Mass Wall, etc)	Wall Assembly combinations (Heavy, Medium & Light weight) (Cavity Wall, Mass Wall, etc)	Wall Assembly combinations (Medium & Light weight) (Cavity Wall, etc)	Wall Assembly combinations (Medium & Light weight) (Cavity Wall, etc)	Wall Assembly combinations (Heavy, Medium & Light weight) (Cavity Wall, Mass Wall, etc)
Ventilation (Window placement, Cluster Arrangement)	Design	Cross Ventilation, Night Venting, Courtyard style cluster	NA	Cross Ventilation, Night Venting, Courtyard style cluster	Cross Ventilation, Night Venting, Courtyard style cluster	High Ventilators, Wind Towers, Courtyard style cluster
Cooling/Heating	Equipment	Evaporative (Downdraught), Ceiling Fan, Air-earth heat exchanger	Air-earth heat exchanger			Evaporative (Downdraught), Ceiling Fan, Air-earth heat exchanger ⁷

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67

Alternative Materials

Wall Materials/Practices	Roof Materials/Practices	Door/Window Materials/Practices
Rat-trap bond walls in burnt clay bricks	Filler slab roof	Natural Fibre Composite door shutters
Fly ash bricks	Precast brick panel roof	Precast RCC door-window frames
Concrete blocks	Precast Plank Joist roof	
Stone filler blocks	Jack Arch roof	
EPS panels	EPS panels	
Glass fiber reinforced concrete (GFRC)	Glass fiber reinforced concrete (GFRC)	
AAC blocks		
Monolithic concrete technology		

Source: Mainstreaming Sustainable Social Housing in India (MaS-SHIP)

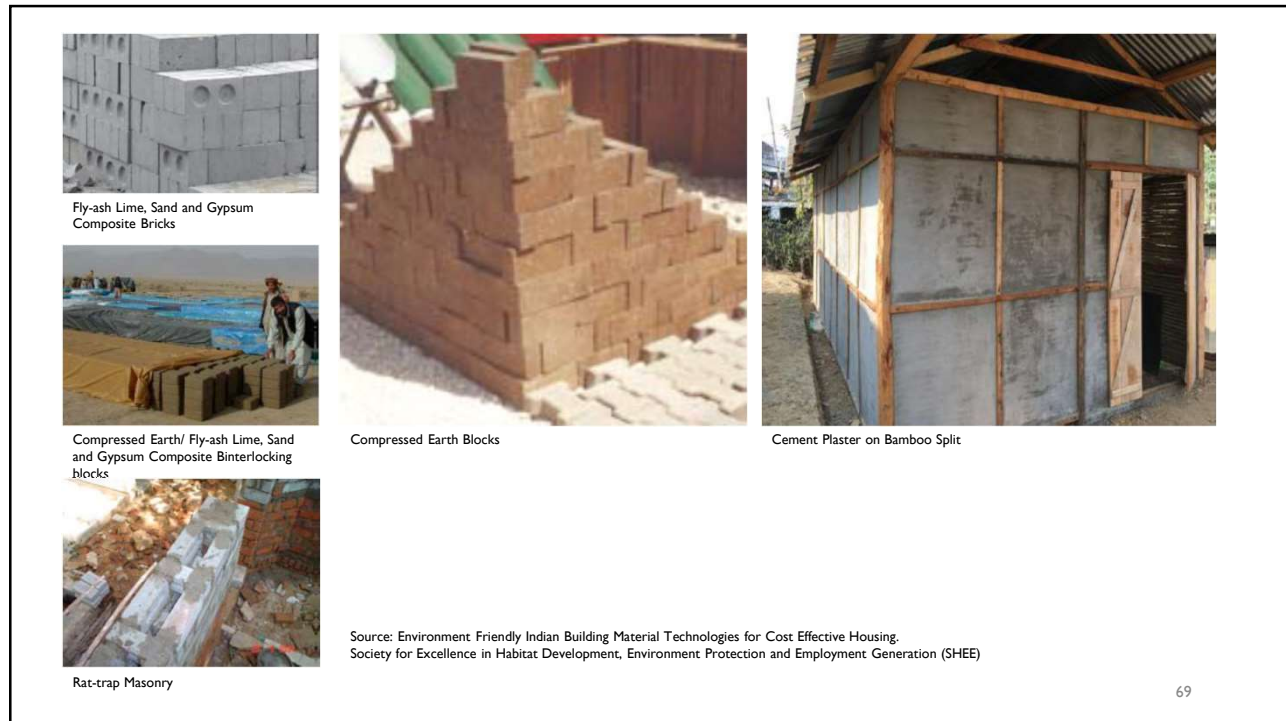
Wall Materials/Practices	Roof Materials/Practices	Door /Window Materials/Practices
Compressed Stabilized Earth Block	Reflective roof tiles	RCC door frames and lintels
Fly-ash brick, Structural Insulated Panel (SIP)	Filler slab	Wood/plastic composites
Aerated Autoclaved Concrete (AAC) block		
Cellular Lightweight Concrete (CLC) block		

Source: Trust Fund for Environmentally and Socially Sustainable Development (TFESD)

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68

68



69



70

Wall Types & Technologies

Alternative Wall Materials (15 +)

Aerated Autoclaved Concrete (AAC) block	Fly-ash Lime Gypsum (FALG) brick
Clay Fly Ash Burnt Bricks	Hemp blocks (Hemp or Agri-waste with lime binder)
Concrete Brick/Block (Hollow/Solid)	Marble Slurry Bricks
Corrugated Sheet (G.I./metal/asbestos/bamboo mat)	Rice Husk Block
Cellular Lightweight Concrete (CLC) block.	Stone
Compressed Stabilized Earth Block (CSEB)	Stone filler blocks
Ferrocement Panel	Structural Insulated Panel (SIP)
Fly-ash brick	

Alternative Walling Techniques (15+)

Cavity wall	Light Gauge Sheet Framed Structures (LGSF) System
Cement Plaster on Bamboo Split	Monolithic Concrete Construction System using aluminum/plastic-aluminum formwork
Compressed Earth/ Fly-ash Lime, Sand and Gypsum Composite	Monolithic Construction with Structural Stay-In-Place CR Steel
Interlocking blocks	Specially Designed Formwork System (Coffor)
Expanded Polystyrene Core Panel System	Poured Earth Concrete
Exterior Insulation and Finishing System	Rat-trap bond
Factory Made Fast Track Modular System	Stay in place EPS double walled panel system
Fibre reinforced cement sheets on either side of light weight concrete core (Aerocon Panels)	
Glass Fiber Reinforced Gypsum (GFRG) Panel Building System	

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71

71

Roof Types & Technologies | Windows & Doors

Alternative Roof Materials (6+)

Brick	Ferrocement
Concrete (Cast in-situ, Pre-cast, Pre Stressed)	Micro concrete
Corrugated Sheet (G.I./metal/asbestos/bamboo mat)	Stone

Alternative Roof Technologies/Techniques (13+)

Cellular light weight concrete slabs	Madras roofing technique
Ferrocement Roofing Channel	Micro concrete roofing tiles
Filler slab roof	Precast brick panel roof
Glass Fiber Reinforced Gypsum (GFRG) panel building system	Precast concrete panels
Jack Arch roof	Precast plank joist roof
Light Gauge Sheet Framed Structures (LGSF) system	Precast solid slab
	Prestressed concrete ribbed/cored slabs

Doors, Window & Frames

Ferrocement frames	Single Glazed Window (5/6mm)	Natural Fibre Composite door shutters
Pressed steel door and window frames		
RCC door frames and lintels		
UPVC Window frames		
Wood/plastic composites		

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72

72



Bamboo Mat Corrugated Roofing sheet



Reinforced Brick Panel and Joists



Ferrocement Roofing Channels



Filler Slab



RCC Plank and Joists



Micro-concrete Roof Tiles

Source: Environment Friendly Indian Building Material Technologies for Cost Effective Housing.
Society for Excellence in Habitat Development, Environment Protection and Employment Generation (SHEE)

73

Range of Material Characteristics

Item	Units	Range – Low	Range – High
Wall – U value	W/m ² .°K	0.6 (Foam cement block)	5.1 (Fire brick)
Wall – Density	kg/m ³	580 (Foam cement block)	2400 (Limestone)
Wall – Specific Heat	J/kg.°K	540 (Foam cement block)	1000 (Fire brick)
Wall - Reflectance	Fraction between (0 - 1)	0.3	0.6
Roof – U value	W/m ² .°K	0.2 (Foam concrete)	6.3 (RCC)
Roof – Density	kg/m ³	700 (Foam concrete)	2500 (RCC)
Roof – Specific Heat	J/kg.°K	850 (RCC)	1100 (Foam concrete)
Roof – Reflectance	Fraction between (0 - 1)	0.3	0.8
Glazing – U value	W/m ² .°K	4.9	6.3
Glazing – SHGC	Fraction between (0 - 1)	0.5	0.9
Glazing – VLT	Fraction between (0 - 1)	0.65	0.85

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74

74

Range of design characteristics

Item	Units	Range – Low	Range – High
Window Wall Ratio	%	5	50
Wall(Exposed) Floor Ratio	%	65	>100
Window (Operable Area) Floor Ratio	%	7	35
Shading (Projection Factor)	Fraction between (0 - 1)	No Shading (PF=0) Combination of Shading Devices • Overhang only • Fin only • Overhang and Fin	PF=1

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75

75



Cost of Affordable Housing

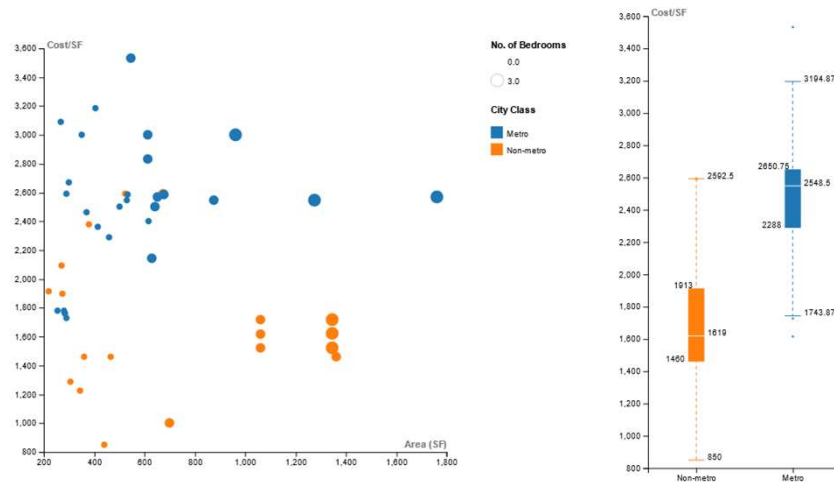
Analysis of cost data from projects by private developers and government agencies

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76

76

Cost for Affordable Housing is Higher in Metros



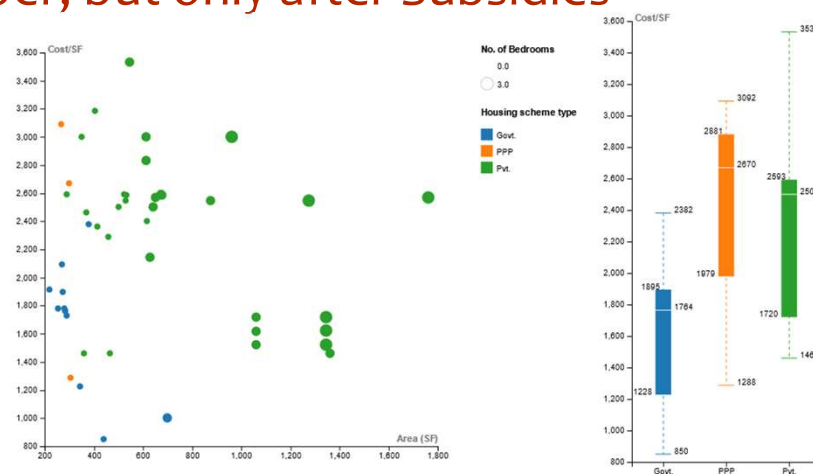
Analysis based on a sample set of 50 Housing projects spread across India

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77

77

Government sponsored Affordable Housing is cheaper, but only after Subsidies




Analysis based on a sample set of 50 Housing projects spread across India


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78


78



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA





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Thermal Comfort Performance based Design Standard for Affordable Housing in India

BUILDING STANDARDS & CODES FOR THERMAL COMFORT







79

Key Objectives

- 1) Ascertain the code and standards framework in India vis-à-vis thermal comfort
- 2) Identify global standards and codes for achieving thermal comfort
- 3) Review indices and metrics for evaluating thermal comfort in residential context

80

Expected Outcomes

- Shortlist of suitable standards and codes with reference to development of design standard for thermal comfort in affordable housing in India
- Highlight Best practices across global codes
- Comparative assessment of standards, thermal comfort indices and thermal comfort metrics

81



Standards, Codes and Rating Systems: Indian Context

Analysis of Thermal Comfort requirements in context of Standards, Codes and Rating Systems prevalent in India.

82

Indian Context – Standards and Codes



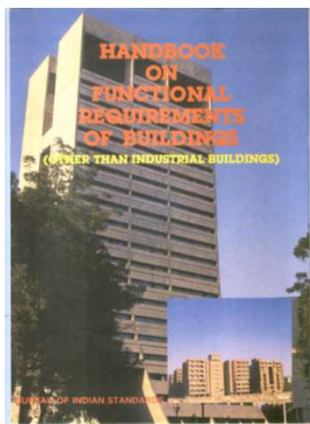
- IS 2440: Guide for **daylighting** of buildings
- IS 3362: Code of practice for **natural ventilation** of residential buildings
- IS 3792: Guide for **heat insulation** of non-industrial buildings
- IS 8888: Guide for requirements of **low-income housing**, Part I: Urban areas
- IS 13727: Guide for requirements of **cluster planning for housing**
- IS SP 41: Handbook on **Functional Requirements of Buildings**
- IS SP 7: **National Building Code of India**
- **Eco-Niwas Samhita**
- ISHRAE Standard-1000I: **Indoor Environmental Quality Standard**

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83

83

Key Highlights: SP 41



Part I: Climatology

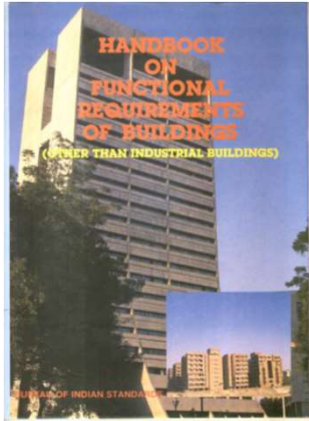
- Clause 2.3: **Indices of Thermal Comfort**
 - Handbook identifies 2 indices of thermal comfort for hot environments:
 - **Effective Temperature** (acceptable for low to moderate heat stress)
 - **Tropical Summer Index (TSI)** (simple to compute and based on relevant climatic conditions, living habits and clothing patterns in the country)
 - Among environmental factors, **globe temperature** and **air temperature** have the **best correlation** with thermal sensation.

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84

84

Key Highlights: SP 41



Part I: Climatology

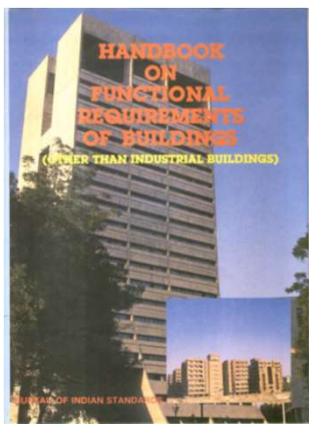
- Clause 4.2: Limits of Thermal Comfort
 - For summer comfort, precise control of indoor temperature is not necessary.
 - Observations indicate increasing air motion from 0.5 to 1.5 m/s is equivalent to decreasing air temperature by 3°C.

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87

87

Key Highlights: SP 41



Part I: Climatology

- Clause 4.4.1.3: Evaporative Cooling
 - Exhaust fan-type coolers perform better compared to blower-type
 - Based on experimental studies at CBRI, design parameters have been optimized.

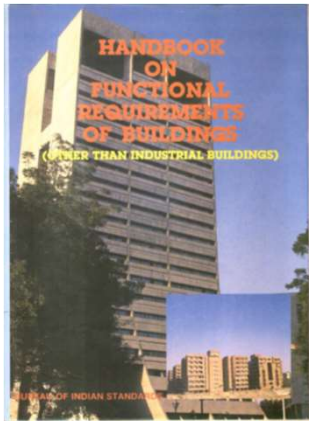
Diameter	Revolution per minute	Power Consumption	Noise Level	Air Volume	Suitable Application
mm		Watts	dB	m ³ /h	
300	1,400	90	56	1,900	Residential
400	900	90	52	2,460	Residential
400	1,400	160	62	4,000	Residential
450	900	145	56	4,340	Residential

Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing

88

88

Key Highlights: SP 41



Part 2: Heat Insulation

- Clause 3.1: Thermal Performance Requirements
 - Envelope Performance requirements for 3 climate zones has been expressed as Thermal Transmittance (U), Thermal Performance Index (TPI), Thermal Time Constant (T) and Thermal Damping (D).
 - Thermal Transmittance (U) and Thermal Time Constant (T) are performance indicators applicable under steady state conditions.

Building Component	Hot-Dry and Hot-Humid Zones				Warm-Humid Zone			
	U (max) (W/m ² K)	TPI (max)	T (min) (h)	D (min)	U (max) (W/m ² K)	TPI (max)	T (min) (h)	D (min)
Roof	2.33	100	20	75	2.33	125	20	75
Exposed Wall	2.56	125	16	60	2.91	175	16	60

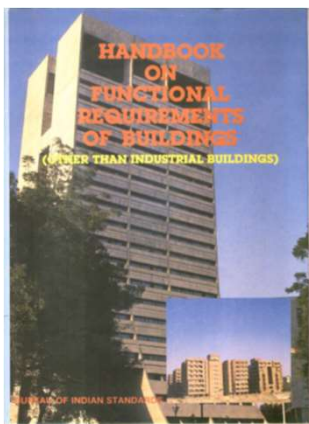
Note:
 Thermal Performance Index (TPI) is indicative of heat gain on peak day through building section. Uses 30°C as base temperature.
 Thermal Time Constant (T) is the ratio of heat stored to thermal transmittance of the structure expressed in hours.
 Thermal Damping (D) is expressed as percentage and is an indicator of reduction in temperature swing on peak cooling day.

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89

89

Key Highlights: SP 41



Part 2: Heat Insulation

- Clause 4.1.3.7: Criteria for Thermal Performance Rating
 - In tropical climate, thermal performance is function of solar temperature, which in turn is influenced by climate data, surface color and orientation.
 - For unconditioned buildings, Peak Degree Hours (PDH)* are the underlying basis for rating of thermal performance of building. For AC buildings Peak Heat Gain Factor (PHGF) is used.
- * Temperature above 30°C

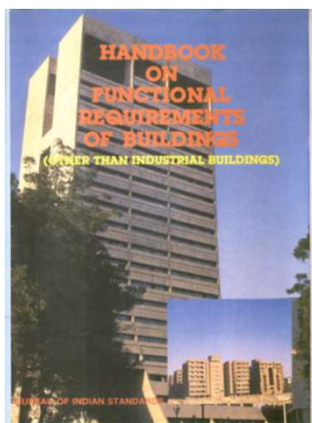
Thermal Performance Index				Class	Quality of Performance
Unconditioned		Air-Conditioned			
	<=75		<=50	A	Good
>75	<=125	>50	<=100	B	Fair
>125	<=175	>100	<=150	C	Poor
>175	<=225	>150	<=200	D	Very Poor
>225		>200		E	Extremely Poor

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90

90

Key Highlights: SP 41



Part 2: Heat Insulation

- Clause 8.3: Selection of shading device & 8.4: Selection of building components
 - **Shade factor** of windows for hot-dry and hot-humid climates must be less than 0.5.
 - References Thermal Performance Index thresholds
- Clause 9.1: **Building Index** (Thermal Performance Metric coupled with Comfort)
 - Building Index is the ratio of peak heat gain averaged over the enclosure's surface area to an acceptable heat gain limit.
 - 46 W/m^2 is threshold for acceptable limit of heat gain. Relaxation to 50 W/m^2 with fan operation.

Building Index	Indoor Air Temperature (in °C)	Comfort Conditions with Fan
0-50	32	Comfortable
51-100	32-36	Slightly Warm
101-150	36-40	Hot

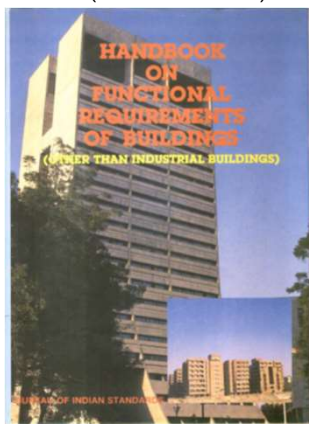
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91

91

Key Highlights: SP 41

Part 2 (Heat Insulation), Clause 7: Recommended building characteristics for various climates



	Hot-Dry	Hot-Humid	Warm-Humid	Cold
External Walls	# Constructed of bricks or similar locally available materials. # Thickness of external wall $\geq 22.5 \text{ cm}$. # Cavity walls, hollow block, insulation etc.	# 11.25 cm brick, hollow blocks 10 cm, Light weight conc blocks 10 cm, # Lightweight roof. Protection against heavy rainfall.	# 11.25 cm brick, hollow blocks 10 cm, with 2.5 cm of insulation on the inner side.	# 11.25 cm brick with 2.5 cm of insulation on the inner side.
Roof (Flat/Sloping)	# 10 cm RCC or reinforced brick cement (RBC) over which 7.5 cm thick mud phuska or cinder or any other equivalent insulating material laid with waterproofing.	# 15-20% of floor area as fenestration. # Shutters that can be tightly closed during summer days or winter nights. # External and Internal shading. # Heat resistant glasses, double and painted glasses.	# 15-20% of floor area as fenestration. # Windows in the direction of wind. # Windows in horizontal direction with low sill height. # Cross ventilation.	# Cement or GI sheets backed by false ceiling of wood, 2.5 cm wood- wool board or equivalent material.
Glazing	# 15-20% of floor area as fenestration. # Shutters that can be tightly closed during summer days or winter nights. # External and Internal shading. # Heat resistant glasses, double and painted glasses.	# 15-20% of floor area as fenestration. # Windows in the direction of wind. # Windows in horizontal direction with low sill height. # Cross ventilation.	# Up to 25% of floor area as fenestration. # Longer axis facing N-S. # Double glazing to avoid heat losses.	# Up to 25% of floor area as fenestration. # Longer axis facing N-S. # Double glazing to avoid heat losses.

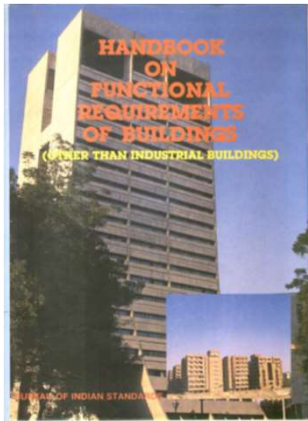
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92

92

Key Highlights: SP 41

Part 2 (Heat Insulation), Clause 7: Recommended building characteristics for various climates



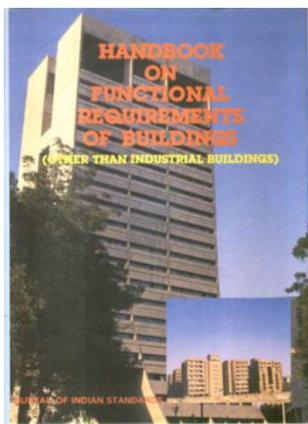
	Hot-Dry	Hot-Humid	Warm-Humid	Cold
Special Needs	# Outdoor sleeping areas for summer nights are essential. # Cooling building by spraying water on roofs, white painted reflective surfaces and shading. # Use of ceiling fans. # Desert coolers, may be used in summer. # Unit type room heaters may be required during winter months.	# Outdoor sleeping areas for summer nights are essential. # White painted reflective surfaces and shading. # Use of ceiling fans is desirable. # Desert coolers are not suitable in these areas.	# Building axis preferably along E-W or NE-SW axis to reduce solar heat gains by walls and improve wind movement. # Good rain-water drainage is essential. # Desert coolers are not suitable in these areas.	# Protect wall and roof surfaces against heavy rain and snowfall. # Use vapour barrier to protect insulation against condensation. # Artificial heating is essential during winter. # Ceiling fans may be used during summer.

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93

93

Key Highlights: SP 41



Part 3: Ventilation

- Clause 4: Minimum standards of ventilation

Space type	Air changes per hour
Bed Rooms/ Living Rooms	3-6
Bath/Toilets	6-12
Kitchen (Domestic)	3-6

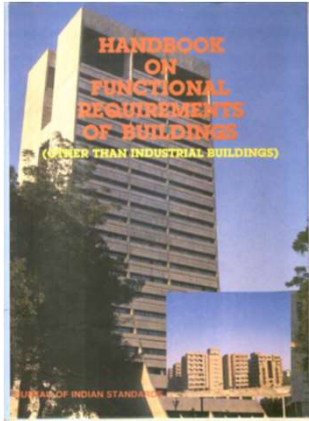
- Clause 5.3.1: Design guidelines for comfort ventilation
 - Orient building to take advantage of prevailing winds. Orient building b/w 0 and 30° of prevailing winds.
 - Openings at lower level on windward side and higher level on leeward side.
 - Maintain cill height at 85% of critical height (say head level).
 - Maintain inlet and outlet area of nearly equal area.
 - Maintain area of openings b/w 20 and 30% of floor area
 - Minimize shielding effect (of obstructions) by keeping distance b/w 2 rows equal to 8 and 10 times the height for semi-detached and row type homes respectively.

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94

94

Key Highlights: SP 41



Part 4: Lighting

- Recommended illumination levels in lux and daylight factor for residential use are defined.

Space type	Illumination (Lux)	Daylight Factor (percent)
Kitchen	200	2.5
Bathroom	100	
Stairs	100	
Living Room		0.625
Homework/sustained reading	300	
Reading casual	150	
Study Room		1.9
Circulation		0.313

Note:

Wherever applicable, Illumination and Daylight Factor values must be ensured at horizontal work plane, room centre and other specific locations.

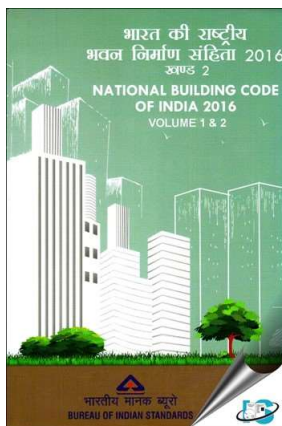
1% DF=80 lux

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95

95

Key Highlights: NBC 2016



Vol 2: Part 8: Section I: Lighting and natural ventilation

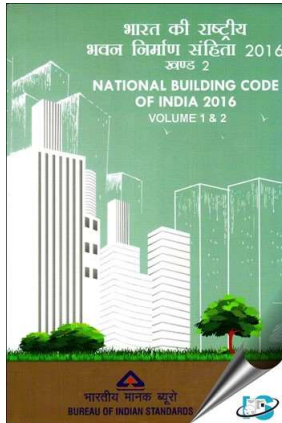
- Clause 5.2.3.1: Indices of thermal comfort
 - Effective Temperature (ET), Tropical Summer Index (TSI) and Adaptive Thermal Comfort
- Clause 5.4.3: Design guidelines for natural ventilation
 - 29 strategies outlined to improve natural ventilation.

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96

96

Key Highlights: NBC 2016



Vol 2: Part 8: Section 3: AC, heating and mechanical ventilation

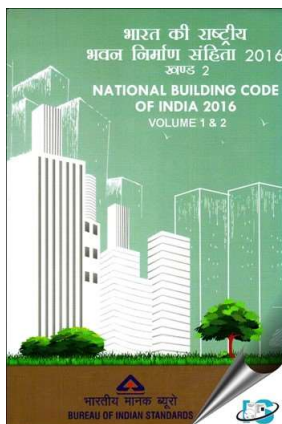
- Clause 6.2: Design of Indoor Conditions as per Adaptive Thermal Comfort Model.
 - Operative temperature is a suitable index to measure thermal comfort in the building having low indoor air velocities (≤ 0.5 m/sec).
 - Effective temperature is the recommended index for indoor air velocities exceeding 0.5 m/sec.

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97

97

Key Highlights: NBC 2016



Vol 2: Part 8: Section 3: AC, heating and mechanical ventilation

- Clause 6.2: Design of Indoor Conditions as per Adaptive Thermal Comfort Model.

Adaptive Comfort approach recognizes

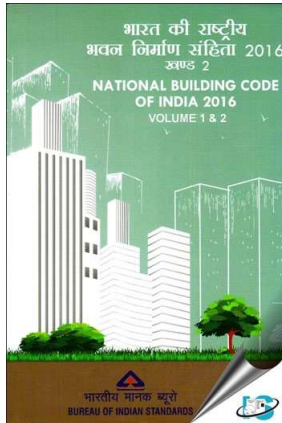
- People's thermal comfort needs depend on their past and present context, that vary with outdoor environment
- People living year-round in AC spaces are likely to develop high expectations for cool temperatures
- People in naturally ventilated buildings with access to controls can adapt & have tolerance to wider range of temperatures

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98

98

Key Highlights: NBC 2016



Vol 2: Part 8: Section 3: AC, heating and mechanical ventilation

- Clause 6.2: Design of Indoor Conditions as per Adaptive Thermal Comfort Model.
 - Adaptive Thermal Comfort Model for NV Building
 - Equation based on 30-day outdoor running mean temperature.
 - Equation does not apply when running mean temperature is below 15 °C.
 - For neutral temperature,

$$T_{neutral} = 0.54 \times T_{out} + 12.83$$
, where
 - $T_{neutral}$ is the indoor operative temperature for neutral sensation
 - T_{out} is the 30-day outdoor running mean temperature
 - Comfort band for 90% acceptability

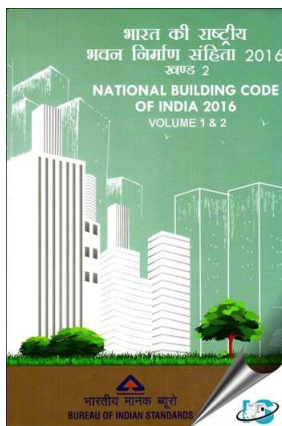
$$T_{neutral} \pm 2.38$$

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99

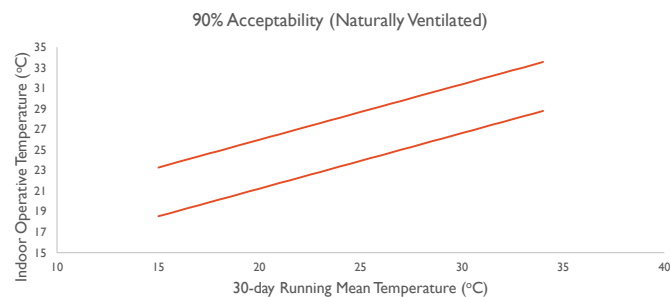
99

Key Highlights: NBC 2016



Vol 2: Part 8: Section 3: AC, heating and mechanical ventilation

- Clause 6.2: Design of Indoor Conditions as per Adaptive Thermal Comfort Model.



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100

100

Key Highlights: IS 8888 (Part 1): 1993, Requirements of Low-Income Housing – Guide



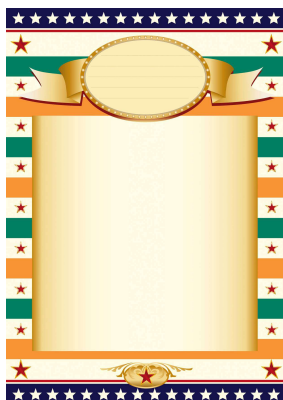
- Applicable to dwelling units of **maximum plinth area of 40 m²**
- Minimum plot size, ground coverage, FSI & size of room are outlined for metro & non-metro cities
- **Lighting and Ventilation guidelines:** Windows and ventilators shall meet
 - 1/10th of the floor area in Hot-Dry climate
 - 1/6th of the floor area for Wet-Hot climate
- Guide **discourages plotted development** (except in case of incremental housing) & **recommends row housing and group housing on cluster planning approach**

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101

101

Key Highlights: IS 13727: 1993, Requirements of Cluster Planning for Housing – Guide



- The Guide “**rediscovers the virtues of low-rise, high-density development in the context of affordability and incremental growth**”
- Highlights ‘**Cluster Planning**’ as a powerful urban design tool
- Acknowledges conventional byelaw provisions hinder efficient planning.
- Standard prescribes **clusters of 20 homes** (and not more)
- Standard prescribes cluster openings (or courtyard)
 - **minimum courtyard width 6m or 3/4th height**
 - **maximum courtyard width and breadth 13 m**
 - **area of cluster court shall not be less than 36m²**
- Clusters are typically designed around courtyards

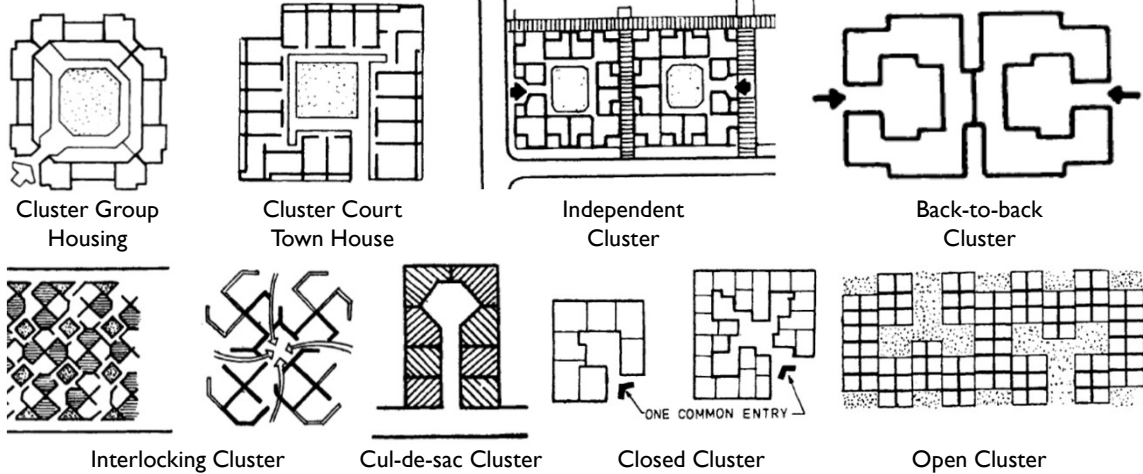
Indicative of low-rise (G+3) development

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102

102

Key Highlights: IS 13727: 1993, Requirements of Cluster Planning for Housing – Guide



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103

103

Key Highlights: ECO-NIWAS Samhita



- Applicable to residential buildings developed on **minimum plot area of 500 m²**
- Code acknowledges building envelope as central to
 - maintaining thermal comfort,
 - improving energy efficiency, and,
 - reducing life cycle environmental impact

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104

104

Key Highlights: ECO-NIWAS Samhita



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

Referenced from NBC 2016

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

Visible Light Transmittance (VLT)

Referenced from NBC 2016

Window-to-wall ratio (WWR)	Minimum VLT
0–0.30	0.27
0.31–0.40	0.20
0.41–0.50	0.16
0.51–0.60	0.13
0.61–0.70	0.11

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105

105

Key Highlights: ECO-NIWAS Samhita



- Code advises
 - $WWR \leq 0.15$ (or at least limit to 0.40), and,
 - $VLT \geq 0.4$
- Envelope Performance
 - Maximum Thermal Transmittance of Roof: $1.2 \text{ W/m}^2\cdot\text{K}$
 - Residential Envelope Transmittance Value (except roof) limit 15 W/m^2
 - RETV is not applicable for Cold climate
 - Maximum Thermal transmittance for Cold climate (all surfaces except roof): $1.8 \text{ W/m}^2\cdot\text{K}$
- References NBC 2016 for guidelines for enhancing natural ventilation

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106

106

Key Highlights: SVAGRIHA



- Applicable to,
 - stand-alone buildings
 - developments with built up area up to 2,500 m²
- CR#2
 - Integrate at least 2 passive design measures
- CR#3:
 - Maximum allowable WWR 60%
 - Meet/exceed daylight area of 25% (As/ECBC 2007 and references Daylight Factors from SP41)
 - Minimum insolation reduction (over base case)

Points	Composite/Warm & Humid/Hot & Dry	Moderate*
1	30%	10%
2	45%	20%
3	60%	30%

* Moderate refers to Temperate climate.

107

Key Highlights: SVAGRIHA



- CR#5
 - Maximum allowable Thermal Load (in W/m²). Includes external and internal gain sources.

Climate Zone	City	> W/m ² (1 point)	> W/m ² (2 points)
Moderate	Bengaluru	135	115
Hot-Dry	Jodhpur	135	110
Composite	Allahabad	165	125
Composite	New Delhi	135	115
Composite	Chandigarh	135	110
Composite	Hyderabad	125	110
Warm-Humid	Chennai	135	110
Warm-Humid	Pune	125	100
Warm-Humid	Kolkata	125	100
Warm-Humid	Mumbai	115	95

108

Key Highlights: GRIHA for Affordable Housing



- Applicable to developments approved as per PMAY guidelines
- CR#I
 - At least **2 passive design** and low-impact site planning strategies
 - Demonstrate use of active, **low-energy cooling/heating systems**

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109

109

Key Highlights: GRIHA for Affordable Housing



- List of potential passive design measures

Strategy	Climate Zone	Strategy	Climate Zone
Wind tower	Co, HD, WH	Solarium/Sun space	Cold
Courtyard	Co, HD, Mo, WH	Openings (for gain)	Cold
Roof Pond (Evap cooling)	Co, HD	Air-lock	Cold
Reduced solar access	Co, HD	Glass covered atrium	Cold
Orientation (for X Vent)	Co, Mo, WH	Orientation (heat gain)	Cold
Thermal Mass	Co, Cold, Mo, HD, WH	Rock bed	Cold
Vegetation Cover	Co, HD, Mo	Light colored external	Co, HD, Mo, WH
Response to Topography	Cold, Co, Mo, HD	High ceiling/Ventilated roof	Co, WH
Light Shelf	Co, Cold, Mo, HD, WH	Shaded window	HD, Mo, WH
Buffer Spaces	Co, HD, Mo, WH	Shaded verandah	Co, HD, WH
Cool Roof	Co, Cold, Mo, HD, WH	Solar chimney	HD, WH
Trombe Wall	Cold	Passive evap cooling struct	Co, HD
Direct Solar Gain	Cold		

Cold: Cold | **Co:** Composite | **HD:** Hot Dry | **Mo:** Moderate (or Temperate) | **WH:** Warm Humid

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110

110

Key Highlights: GRIHA for Affordable Housing



- CR#2
 - Mitigate Urban Heat Island Effect (UHIE): SRI > 0.5
- CR#6
 - Thresholds for allowable peak envelope gain

Climate Zone	Peak Envelope Heat Gain Factor (W/m ²) (2 points)
Composite	55
Hot-Dry	50
Warm-Humid	40
Moderate	30

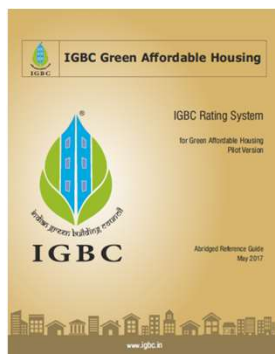
- CR#8
 - Minimum 25% area meeting the UDI requirements for at least 90% of daylight time

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111

111

Key Highlights: IGBC Affordable Housing



- Applicable to housing projects with at least 70% dwelling units with maximum carpet area of 60m².

Climate Zone	Maximum 'U'-Value of the overall assembly (W/m ² K)		
	Wall	Roof	Glazing
Composite	2.5	1.2	5.7
Hot and Dry	2.5	1.2	5.7
Warm and Humid	2.5	1.8	5.7
Moderate	1.1	1.2	5.7
Cold	2.5	1.2	-

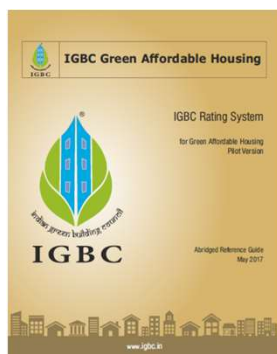
Climate Zone	Maximum SHGC Value	
	WWR < 20%	WWR < 20%
Composite	0.50	0.42
Hot and Dry	0.50	0.42
Warm and Humid	0.50	0.42
Moderate	0.60	0.48
Cold	0.80	0.80

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112

112

Key Highlights: IGBC Affordable Housing



- Daylight Compliance Approach
 - Option I
 - Simulation based approach demonstrating 110 lux for more than 50% of regularly occupied spaces with clear sky condition on Sep 21, 12 PM at 2'6" height.
 - Option I
 - Meet or exceed glazing factor requirements for regularly occupied spaces.
 - Constant for vertical and horizontal window surface are 0.2 and 1.0 respectively
 - Exclude windows that are obstructed from daylight calculations

$$\text{Glazing Factor} = \frac{(\text{Window Area} \times \text{Visible Transmittance} \times \text{Constant} \times 100)}{\text{Floor Area}}$$

Type of Regularly Occupied Space	Minimum Glazing Factor (GF)
Living/Bed Room	1
Multi-purpose Room	1
Kitchen	2

Note: For other regularly occupied spaces which are not listed in the table above, a minimum glazing factor of 1 should be achieved.

113

Key Highlights: IGBC Affordable Housing



- Ventilation requirements are specified as
 - Net openable area as a percentage of floor area
 - Minimum exhaust requirement

Space type	Net openable area as percentage of total carpet area [100 X Openable Area/Total Carpet Area]	
Living Room	10%	
Kitchen	8%	
Bathrooms	4%	

Space Type	Floor Area	Minimum Airflow
Bathroom	≤ 4.64 m ² (50 ft ²)	50 cfm
Kitchen	≤ 9.3 m ² (100 ft ²)	100 cfm

114



Standards and Codes : Global Context

Analysis of Thermal Comfort requirements in context of global Standards and Codes.

Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing 115

115

Global Context – Standards and Codes




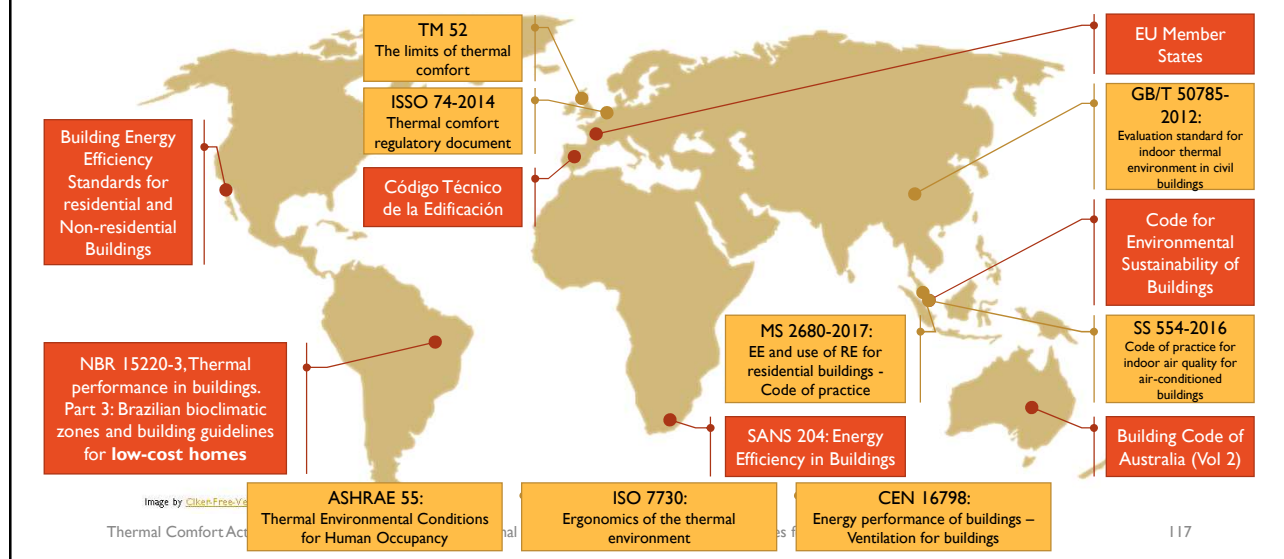
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- **Building Codes:**
 - Australia: Building Code of Australia (Vol 2)
 - Singapore: Code for Environmental Sustainability of Buildings
 - South Africa: SANS 204: Energy Efficiency in Buildings
 - Spain: Código Técnico de la Edificación
 - US (California): Building Energy Efficiency Standards for residential and Non-residential Buildings
 - Brazil: NBR 15220-3: Thermal performance in buildings. Part 3: Brazilian bioclimatic zones and building guidelines for low-cost houses
 - EU Member states
 - Malaysia: MS 2680-2017: Energy efficiency and use of renewable energy for residential buildings - Code of practice
- **Thermal Comfort Standards**
 - ASHRAE 55: Thermal Environmental Conditions for Human Occupancy
 - ISO 7730: Ergonomics of the Thermal Environment
 - CEN 16798: Energy Performance of Buildings – Ventilation for Buildings
 - ISO 74: Thermal Comfort Regulatory Document
 - CIBSE TM 52: The Limits of Thermal Comfort
 - GB/T 50785: Evaluation Standard for Indoor Thermal Environment in Civil Buildings

Thermal Comfort Action Plan 2050 & Development of Thermal Comfort Based Standard cum Guidelines for Affordable Housing 116

116

Global Context – Standards and Codes



117

	ASHRAE 55	EN 16798-1	ISO 7730	NBC	GB/T 50785	SS 553	ISHARE 10001
Revised in	2020	2019	2015	2016	2012	2016	2019
Standard is developed specifically for Residential application	0	1	1	0	0	-1	0
-1: Specifically excludes residential buildings. 0: Not specifically designed for residential buildings. 1: Specifically designed for residential buildings.							
Standard applies to Naturally Ventilated buildings.	1	0	-1	0	0	-1	0
-1: Does not account for natural ventilation 0: Accounts for natural ventilation 1: Accounts for natural ventilation & occupant-control (windows)							
Standard applies to Mixed-mode operation in buildings.	-1	1	-1	1	1	-1	1
-1: Does not account for mixed-mode operation in buildings. 0: 1: Accounts for mixed-mode operation in buildings.							
Standard applies to Air-conditioned buildings.	1	1	1	1	1	1	1
-1: Does not account for Air-conditioned buildings. 0: 1: Accounts for Air-conditioned buildings.							
Data Source.	0	-1	0	1	0	0	0
-1: SCATs (Europe). 0: RP-884 (Continental Representation) 1: Field Studies in India.							
Comfort Indices - PMV and PPD for Air-conditioned Buildings	1	1	1	-1	1	-1	-1
-1: No 0: 1: Yes							
PMV Limits	(0.5) 0.5	(0.7) 0.7	(0.7) 0.7	NA NA	(1.0) 1.0	NA NA	NA NA
PPD Limits	10%	15%	15%	NA	25%	NA	NA
Note (PMV/PPD Limits): (1) The most lenient class/acceptability limit has been used to map PMV/PPD, except, (a) Category IV for EN 16798 has not been included as it is meant for short occupancy periods only, and (b) Category III of GB/T has no limits so Category II has been used for defining limits. (2) ISHRAE 10001 does not specify criteria for the overall thermal comfort index value.							
Comfort Indices - Operative temperature (Adaptive Comfort) for Mixed-mode operation or naturally ventilated building.	10.0	33.5	10.0	30.0	?	?	?
-1: Does not account for Hot summer/cold winter, hot summer/warm winter, mild zone, for Category II of GB/T 50785 has been used. ? indicates information not available. 'NA' indicates metric/indicator Not Applicable.							

118

Envelope and ventilation requirements as proxy for Comfort

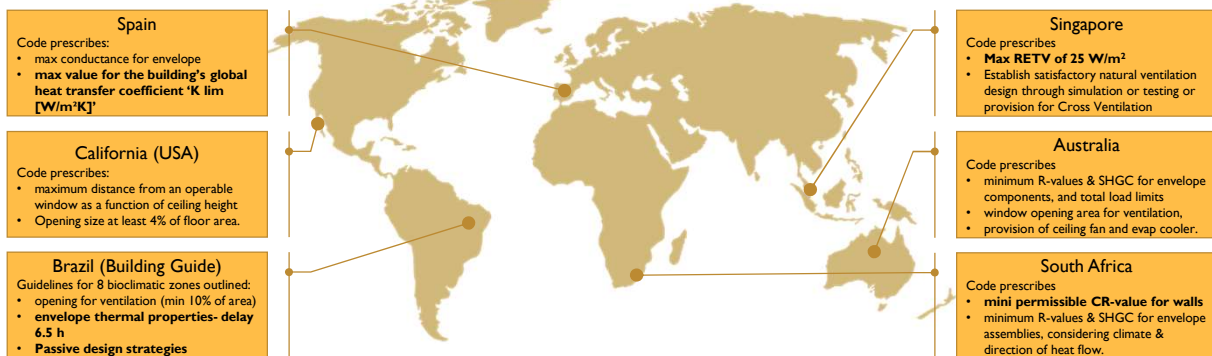


Image by [Ciller-Free-Vector-Images](#) from [Pixabay](#)

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119

119

Comfort evaluated as threshold/differential

Temperature Threshold & Differential	Sweden Recommended Minimum operative temperatures $\leq 18^{\circ}\text{C}$ (relaxed to 20°C for old people) & difference b/w rooms $< 5^{\circ}\text{C}$.
Temperature Threshold + Allowance	Denmark Indoor temperatures, (1) Not more than 100 hours above 26°C and (2) Not more than 25 hours above 27°C .
Heat Gain Threshold	Poland Equation to limit surface area of windows prescribed. Upper limit for solar gains in Summer specified at 0.35.
Temperature Differential	Brussels Region Maximum difference between internal and external temperature should be between 5°C and 7°C (in summer).
Temperature Threshold	France TIC-the max. operative temperature should not exceed TIC_{ref} for more than 5 consecutive days. In NV zones TIC_{ref} is based on OT.
Transmittance and Thermal Mass	Italy Wall: $\text{YIE} < 0.12 \text{ W/m}^2\text{K}$ OR surface thermal mass $> 230 \text{ kg/m}^2$ Floor/Roof: $\text{YIE} < 0.20 \text{ W/m}^2\text{K}$ Window: $\text{SF} < 0.5$



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120

120

Requirements specify comfort and envelope

UK
For non-air-conditioned dwellings, CIBSE specifies general indoor comfort temperatures.

- **Living areas** should be at an operative (maximum) temperature of **25°C**.
- **Bedrooms** should be at an operative (maximum) temperature of **23°C**, noting that sleep may be impaired above an operative temperature of 24°C.

As per TM 52:

- **Duration of Overheating:** Hours of exceedance $\leq 3\%$ of Occupied hours
- **Severity of Overheating:** Weighted exceedance ≤ 6
- **Temperature Upper Limit (°C):** $\Delta T > 4^\circ\text{C}$

As per CIBSE Guide A

- Hours of exceedance $\leq 3\%$ of Occupied hours

Germany
"Sonneneintragskennwert", an indicator of max solar gains must be checked for each room to avoid overheating for more than 10% hours. Recommended Indoor Temperature ranges (b/w 25-27 °C), thermal capacity of envelope and strategies vary depending upon climatic region (A, B or C). Temperature in apartments and bathrooms should be at least 20 and 22 °C respectively. Landlords are responsible for providing equipment to maintain conditions



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121

121

Best practices across the globe

- **Brazil:** Thermal Performance Standard (ABNT NBR 15220-3) is **based on Bioclimatic principles**.
- **Sweden:** **Minimum guarantee** of satisfactory thermal comfort required by Building Code.
- **UK:** Regulations identify **distinct comfort requirements in sleeping and living rooms**.
- **Italy and South Africa:** **Envelope performance requirements account for thermal capacity**
 - Italy utilizes periodic thermal transmittance (YIE) that accounts for thermal transmittance and decrement factor.
 - South Africa sets CR value for envelope, i.e. product of thermal capacity of wall and its thermal resistance
- **Germany:** Regulations require the **lessor to guarantee an indoor temperature** of at least 19 °C in winter.

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122

122

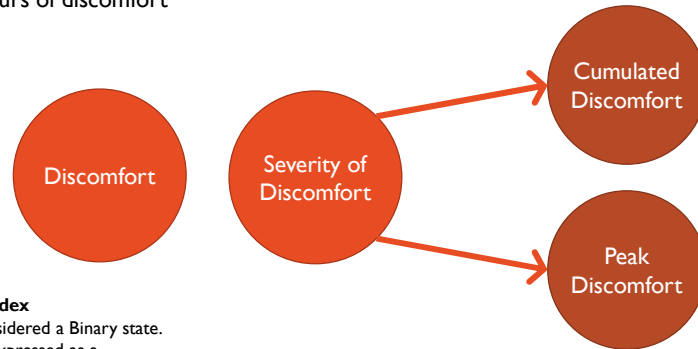
Thermal Comfort Metrics

Hours of Exceedance

Eg: CIBSE TM 52 - 3% of occupied hours of discomfort allowed

Percentage Index

Comfort is considered a Binary state. Discomfort is expressed as a percentage of occupied hours outside a comfort threshold with respect to the total number of occupied hours.



Degree-Hours

Eg: EN 15251 Annex F – Weighting discomfort by the number of degrees above the comfort temperature.

Cumulative Index

Total accumulated discomfort as a sum of uncomfortable periods, typically hours.

Peak Discomfort

Heat stress experienced on peak day or peak periods.

Peak Temp/Peak Gain

Eg: Passive Survivability Credit, LEED Maintain a maximum (90°F/32.2°C) degree (the “Extreme Caution” threshold) heat index temperature during the hot season.¹²³

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123

Thermal Comfort Standards – Suitability of Adaptive Models

	ASHRAE 55	EN 16798-1	ISO 7730	NBC	GB/T 50785	IS 553	IShare 100001
Revised in	2020	2019	2015	2016	2012	2016	2019
Standard is developed specifically for Residential application -1: Specifically excludes residential buildings. 0: Not specifically designed for residential buildings. 1: Specifically designed for residential buildings.	0	1	1	0	0	-1	0
Standard applies to Naturally Ventilated buildings. -1: Does not account for natural ventilation 0: Accounts for natural ventilation 1: Accounts for natural ventilation & occupant-control (windows)	1	0	-1	0	1	1	0
Standard applies to Mixed-mode operation in buildings. -1: Does not account for mixed-mode operation in buildings. 0: 1: Accounts for mixed-mode operation in buildings.	-1	1	-1	1	1	1	1
Standard applies to Air-conditioned buildings. -1: Does not account for Air-conditioned buildings. 0: 1: Accounts for Air-conditioned buildings.	1	1	1	1	1	1	1
Data Source. -1: SCATs (Europe). 0: RP-884 (Continental Representation) 1: Field Studies in India.	0	-1	0	1	1	1	0
Comfort Indices - Operative temperature (Adaptive Comfort) for Mixed-mode operation or naturally ventilated building.	10.0 33.5	10.0 30.0	? ?	15 34	18.0 30.0	? ?	? ?
Note: Temperature range for Hot summer/cold winter, hot summer/warm winter, mild zone, for Category II of GB/T 50785 has been used. ‘?’ indicates information not available. ‘NA’ indicates metric/indicator Not Applicable.							

124

124

NBC Adaptive Model's applicability is more suitable to Indian context

Adaptive Comfort Models	Indoor Operative Temperature in °C (Naturally Ventilated Buildings)																								
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
GB/T 50785									A	A	A	A	A	A	A	A	A	A	A	A	A				
ISO 17772, EN 16798	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A				
ISO 7730	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A							
ASHRAE 55 (80% Acceptability)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
NBC 2016						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Legend A Standard applicability

Note:

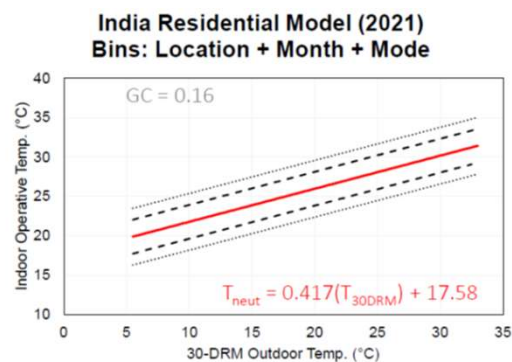
1. Thresholds for both summer and winter season have been considered.
2. Thresholds for residential application used wherever applicable.
3. Some values have been rounded up/down to the nearest integer.
4. For ISO 17772, EN 16798 comfort range has been considered only till Category III.
5. Comfort range for NBC 2016 has been referenced from IMAC model for Naturally Ventilated Buildings (Manu et al., 2016).

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125

125

India Residential Model 2021



Field studies are from Residential context that is representative of all Indian Climate Zones

Study indicates wider range of temperature tolerance, Even more than displayed in NBC

80% Acceptability at $\pm 3.60^\circ\text{C}$
90% Acceptability at $\pm 2.15^\circ\text{C}$

Note: The India Residential Model has been developed under the IGEN-EERB project. This is currently un-published and a work under progress. This information is being presented for the purpose of Expert Consultation **ONLY** and may not be reproduced elsewhere.

126

126



Thermal Comfort Indices & Metrics



Analysis of Thermal Comfort requirements in context of global Standards and Codes.

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127

127

Thermal Comfort Indices

Thermal Comfort Index	Suitability	Limitation
Indoor operative Temperature 	<ul style="list-style-type: none"> Adaptive comfort models evaluate comfort based on Indoor Operative Temperature. Available for evaluating comfort on multiple adaptive models Amenable to computations of cumulative (degree discomfort hour) and point in time (peak discomfort) metrics. 	<ul style="list-style-type: none"> Does not account for personal factors like clothing, metabolic rate. However, field studies on which these adaptive models are based, account for personal factors as adaptation. Unsuitable for air velocities higher than 0.5 m/sec
Tropical Summer Index 	<ul style="list-style-type: none"> Compared to other indices (CET, ITS, WBGT, ECI, HIS, etc.), TSI has the highest correlation with Thermal Sensation Votes. Based on field trials conducted in India in unconditioned setting. Accommodates Relative Humidity and capable of accounting radiant asymmetry. Amenable to computations of cumulative (degree discomfort hour) and point in time (peak discomfort) metrics. 	<ul style="list-style-type: none"> Field trials limited to a particular season, location and respondent group. Does not account for personal factors like clothing, metabolic rate. However, field studies on which this index is based, account for personal factors as adaptation..

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128

128

Thermal Comfort Indices & Associated Metrics

Thermal Comfort Index	Units	Peak Exceedance	Exceedance Hours	Exceedance Degree Hours
Operative Temperature (OT)	°C	Max and Min indoor OT recorded.	A value of indoor OT outside comfort band (established hourly using equations for adaptive comfort models) is considered uncomfortable.	The deviation in Indoor OT for the respective exceedance hour cumulated over the period of a year.
Standard Effective Temperature (SET)	°C	Max and Min SET recorded.	A value of SET outside comfort band (established for each hour) is considered uncomfortable. SET Comfort band as/LEED ranges between 12.2 – 30 °C.	The deviation in SET for the respective exceedance hour cumulated over the period of a year.
Tropical Summer Index (TSI)	°C	Max and Min TSI recorded.	A value of TSI outside comfort band (established for each hour) is considered uncomfortable. TSI Comfort band as/NBC ranges between 19 – 34 °C.	The deviation in TSI for the respective exceedance hour cumulated over the period of a year.

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129

129

Thermal Comfort Metrics

Thermal Comfort Index	Unit	Metrics		
		Peak Exceedance	Exceedance Hours	Exceedance degree hours
Operative Temperature (OT)	°C	Max and Min indoor OT recorded	Number of occupied hours Indoor OT is outside comfort band	Deviation in Indoor OT for the respective exceedance hour cumulated over a year
Tropical Summer Index (TSI)	°C	Max and Min TSI recorded.	Number of occupied hours TSI is outside comfort band TSI Comfort band as/NBC ranges between 19 – 34 °C.	Deviation in TSI for the respective exceedance hour cumulated over year

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130

130

Definition of Indices

Operative temperature

“the uniform temperature of an imaginary black enclosure, and the air within it, in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment”

ASHRAE 55

Tropical Summer Index

“It is defined as the air/globe temperature of still air at 50% RH which produces the same overall thermal sensation as the environment under investigation.”

Sharma et al.

131

Thermal Comfort Indices & Associated Metrics

Thermal Comfort Index	Units	Peak Exceedance	Exceedance Hours	Exceedance Degree Hours
Operative Temperature (OT)	°C	Max and Min indoor OT recorded.	A value of indoor OT outside comfort band (established hourly using equations for adaptive comfort models) is considered uncomfortable.	The deviation in Indoor OT for the respective exceedance hour cumulated over the period of a year.
Standard Effective Temperature (SET)	°C	Max and Min SET recorded.	A value of SET outside comfort band (established for each hour) is considered uncomfortable. SET Comfort band as/LEED ranges between 12.2 – 30 °C.	The deviation in SET for the respective exceedance hour cumulated over the period of a year.
Tropical Summer Index (TSI)	°C	Max and Min TSI recorded.	A value of TSI outside comfort band (established for each hour) is considered uncomfortable. TSI Comfort band as/NBC ranges between 19 – 34 °C.	The deviation in TSI for the respective exceedance hour cumulated over the period of a year.

132

Effective Temperature

Effective temperature is defined as the temperature of still, saturated air which has the same general effect upon comfort as the atmosphere under investigation. Combinations of temperature, humidity and wind velocity producing the same thermal sensation in an individual are taken to have the same effective temperature.

NBC 2016

Corrected Effective Temperature

Bedford (1946) proposed the use of globe temperature reading instead of the air temperature reading to make allowance for the radiant heat.

“An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body and its numerical value is that of the temperature of still saturated air which would induce an identical sensation.”

SP 41

Standard Effective Temperature

“the temperature of an imaginary environment at 50% RH, <0.1 m/s (20 fpm) average air speed (V_a), and , in which the total heat loss from the skin of an imaginary occupant with an activity level of 1.0 met and a clothing level of 0.6 clo is the same as that from a person in the actual environment, with actual clothing and activity level.”

ASHRAE 55

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135

135

Tropical Summer Index

“It is defined as the air/globe temperature of still air at 50% RH which produces the same overall thermal sensation as the environment under investigation.”

Sharma et al.

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136

136



Key Outcomes

1. Suitable Adaptive Comfort Models for Residential context in India.
2. Suitable thermal comfort indices and metrics.
3. Gaps and best practices to aid development of Design Standard

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137

137

EN & NBC Address NV, MM & Residential Use

Revised in	ASHRAE 55 2020	EN 16798-1 2019	ISO 7730 2015	NBC 2016	GB/T 50785 2012	IS 553 2016	SHARE 100001 2019
Standard is developed specifically for Residential application -1: Excludes residential buildings. 0: No mention of applicability to residential buildings. 1: Applicable to residential buildings.	0	1	1	0	0	-1	0
Standard applies to Naturally Ventilated buildings. -1: Does not account for natural ventilation 0: Accounts for natural ventilation 1: Accounts for natural ventilation & occupant-control	1	0	-1	0	0	-1	0
Standard applies to Mixed-mode operation in buildings. -1: Does not account for mixed-mode operation. 1: Accounts for mixed-mode operation in buildings.	1	1	-1	1	1	-1	1

EN Std is Applicable to Residential typology & mixed-mode operation

Although NBC does not distinguish typologies, it does not exclude Residential

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138

138

NBC is representative of Indian Physiology & Climate

	ASHRAE 55	EN 16798-1	ISO 7730	NBC	GB/T 50785	BS 553	ISHARE 100001
Revised in	2020	2019	2015	2016	2012	2016	2019
Standard applies to Air-conditioned buildings. -1: No. 1: Yes.	1	1	1	1	1	1	1
Data Source. -1: SCATs (Europe). 0: RP-804 (Continental Representation) 1: Field Studies in India.	0	-1	-1	1	0	0	0
Comfort Indices - Operative temperature (Adaptive Comfort) for Mixed-mode operation or naturally ventilated building.	10.0 33.5	10.0 30.0	? ?	15 34	18.0 30.0	? ?	? ?
<p>Note: Temperature range for NBC references BEE Residential Label program Temperature range for Hot summer/cold winter, hot summer/warm winter, mild zone, for Category II of GB/T 50785 has been used. '?': indicates no information available</p>							

Field Studies are representative of Indian physiology and climate. **References IMAC model.**

NBC accommodates a higher temperature threshold.

Since Adaptive Approach is statistical in nature, the derived equations have a higher degree of reliability in predictions when there are contextual similarities with field studies that derived the equations in the first place. (Ferrari et al.)

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139

139


NBC is most suited to Indian Context

Adaptive Comfort Standard	Suitability	Limitations
ASHRAE Standard 55	Applicable for a wide temperature range (10-33.5°C)	Adaptive Comfort model does not extend to Mixed Mode Buildings
ISO 7730	Specifically accommodates residential building typology	Based on field studies conducted in European Context Adaptive Comfort model does not extend to Mixed Mode Buildings Field studies in Office Use Context.
EN 16798-1	Specifically accommodates residential building typology	Based on field studies conducted in European Context Field studies in Office Use Context.
NBC	Based on field studies in Indian Context Accommodates a higher temperature threshold (34°C) Applicable to Mixed Mode, Naturally Ventilated Buildings	Field studies in Office Use Context.


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140


140



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA





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Thermal Comfort Performance based Design Standard for Affordable Housing in India

**AFFORDABLE HOUSING IMPLEMENTATION:
CHALLENGES, GAPS & WAY FORWARD**







141

Key Objectives

- 1) Review of international affordable housing policies.
- 2) Review of national housing schemes, related policies & regulations.
- 3) Review of state affordable housing policies and implications on thermal comfort.

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142

142

Expected Outcomes

- 1) Identify challenges in Affordable Housing Implementation
- 2) Identify climate specific challenges and integration of Passive design practices.

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143

143



Housing Policies : Global Context

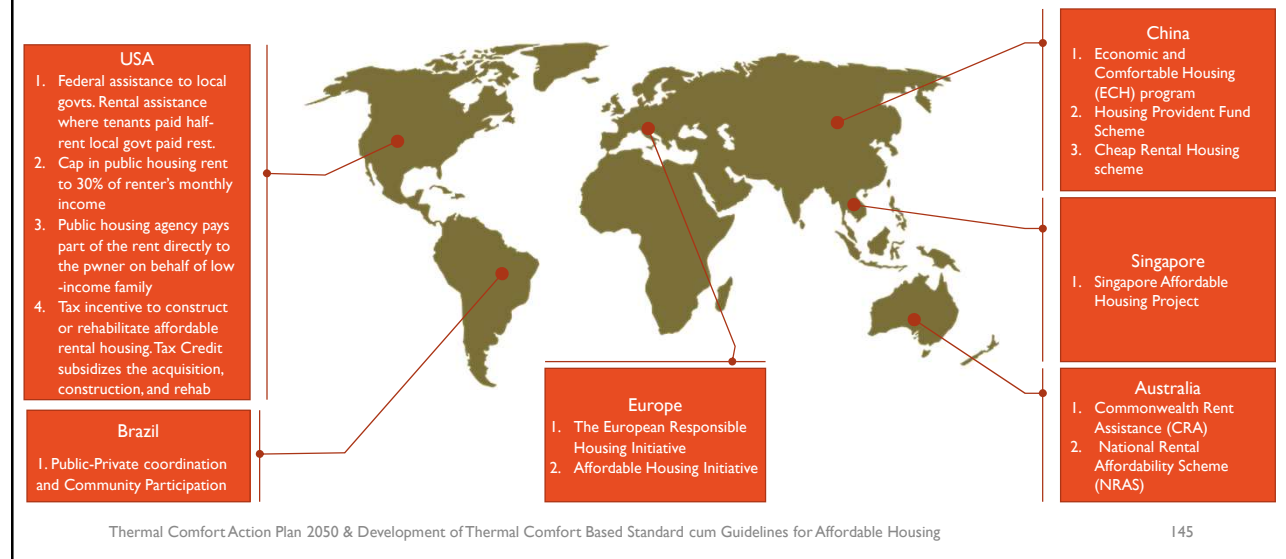
Analysis of Thermal Comfort requirements in context of global Standards and Codes.

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144

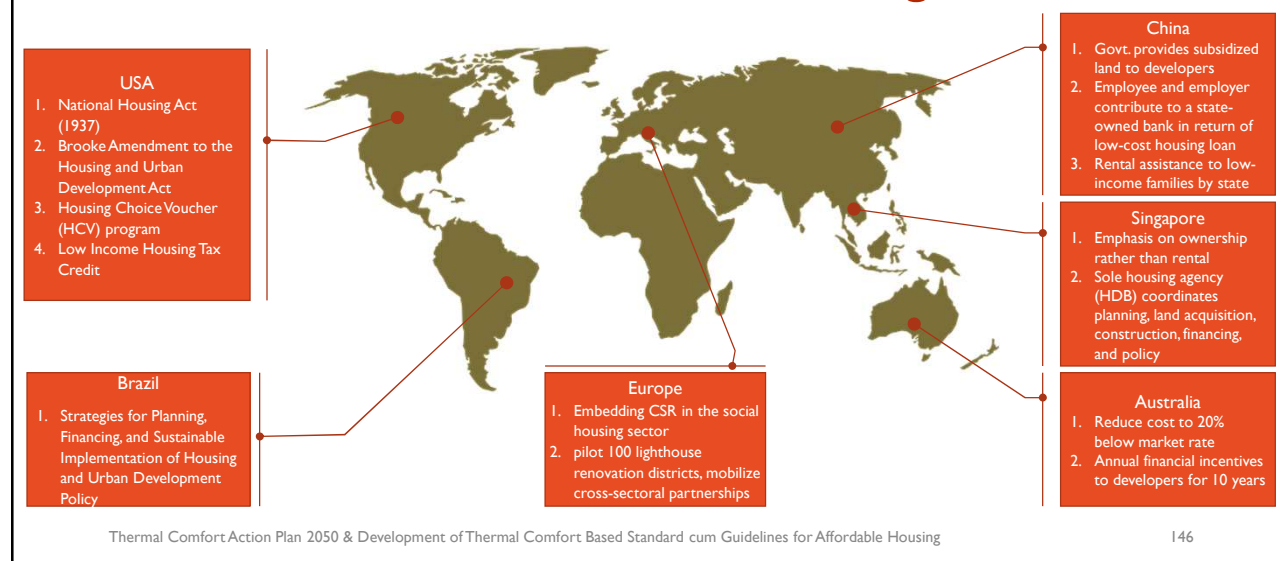
144

Global Context – Affordable Housing Policies



145

Global Context – Affordable Housing Policies



146

Programs for 'Greening' affordable housing



USA: Evergreen Sustainable Development Standard (ESDS)

All publicly funded Affordable housing must meet ESDS. Standard makes indirect reference to Thermal Comfort



USA: Qualified Allocation Plans
State housing finance agencies can allocate greater housing credits (LIHTCs) to projects that incorporate certification to credible third-party green building criteria.

HomeInnovation, Accessed Feb 21, 22



SUNREF - Affordable Green Housing India Programme

Refinance support to eligible PLIs for financing eligible individuals/residential pre-certified projects. (4/5 star rating by GRIHA or Gold/Platinum rating by IGBC)

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147

147



Map Source: Wikipedia

Housing Policies: Indian Context

This section provides an overview of the key policies on affordable housing

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148

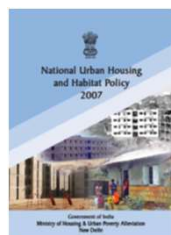
148

National Policy Framework: Key Policies



Jawaharlal Nehru National Urban Renewal Mission (JNNURM), 2005

1. An umbrella programme for thematic sub-schemes like Basic Services for Urban Poor (BSUP), Integrated Housing and Slum Development Programme (IHSDP), Interest Subsidy Scheme for Housing the Urban Poor (ISHUP) and Affordable Housing in Partnership (AHP);
2. Identifies Integrated development of slums (slum rehab and improvement) and provision of affordable housing for EWS, LIG, etc. under the BSUP sub-mission.



National Urban Housing and Habitat Policy (NUHHP), 2007

1. Establishes need for 'Affordable Housing to All' with special emphasis on EWS and LIG sectors.
2. Stresses on 'Regional Planning Approach' which is ecologically sustainable.
3. Lays emphasis on earmarking land for the EWS/LIG in new housing projects.
4. Lays emphasis on Government retaining its role in social housing so that affordable for benefit of EWS and LIG.

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149

149

National Policy Framework: Key Policies

Pradhan Mantri Awas Yojana - Urban (PMAY - U)

1. 'Housing for all' mission to be implemented b/w 2015-22.
2. Mission addresses EWS, LIG & MIG categories.
3. All homes must have basic amenities (toilet, water supply, electricity & kitchen)
4. Preference to vulnerable sections of society.
5. Scheme has 5 components that weave basic services, finance, PPP and migration crisis.
6. Package of Govt. Assistance and Incentives
7. Set up Technology Sub-mission, LHPS, Awareness programs and transparent & robust MIS.

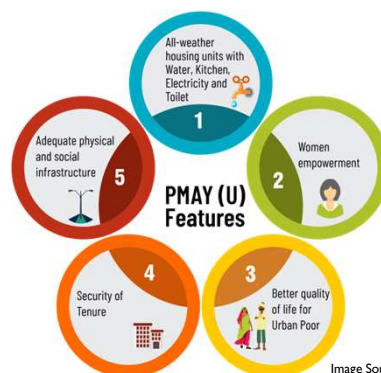


Image Source: PMAY

In-Situ Slum Redevelopment (ISSR)

Credit Linked Subsidy Scheme (CLSS)

Affordable Housing in Partnership (AHP)

Beneficiary Led Construction / Enhancement (BLC-N, BLC-E)

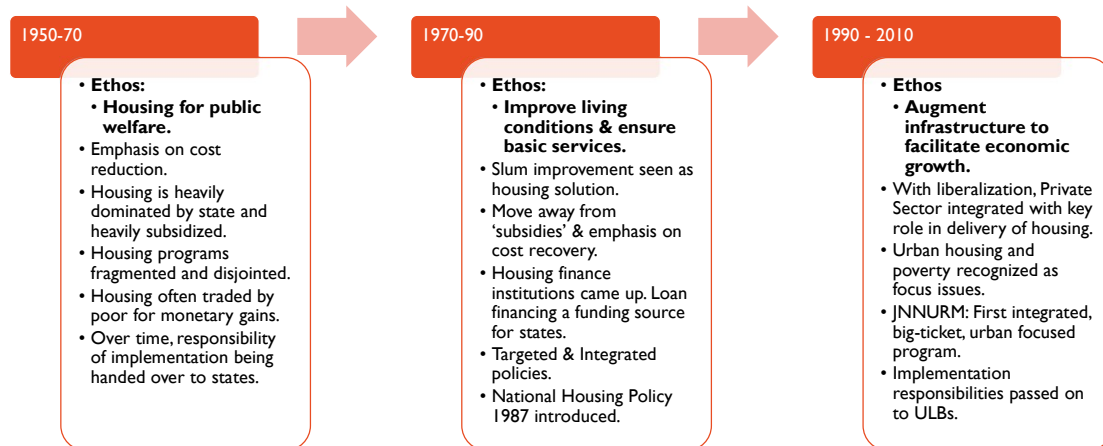
Affordable Rental Housing

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150

150

Evolution of Housing Policies in India



Source: Hingorani P., Revisiting Low Income Housing: A Review of Policies and Perspectives, Indian Institute of Human Settlements
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151

151

Advancement of Housing Policies in India

Five Year Plan (FYP)	Key features/coverage
First FYP (1951-1956)	<ul style="list-style-type: none"> - Housing for industrial workers; - National Building Organization (for cost reduction and improving building techniques) and Housing Boards (statutory autonomous bodies for implementation) (Tiwari & Rao, 2016); - Tax on vacant land (ibid.); - Low Income Group Housing Scheme (1954) led to addition of 1.3 million houses at year's end.
Second FYP (1956-1961)	<ul style="list-style-type: none"> - Industrial Housing Scheme extended to cater to EWS/LIG housing needs; - Construction of 1.9 million houses envisioned under National Housing Programme covering rural housing, 'sweeper's housing' and MIG housing - Life Insurance Corporation of India provided housing finance to MIGs and to State Governments for undertaking rental housing for low paid state employees; - State Housing Corporations (1957) to furnish debt finance for projects with CG subsidies.

Source: Herda, G., Rani, S., Caleb, P. R., Gupta, R., Behal, M., Gregg, M. and Hazra, S. (2017). Sustainable social housing in India: definition, challenges and opportunities - Technical Report, Oxford Brookes University, Development Alternatives, The Energy and Resources Institute and UN-Habitat, Oxford.
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152

152

Advancement of Housing Policies in India

Five Year Plan (FYP)	Key features/coverage
Sixth FYP (1980-1985)	- R&D grant to improve formulation of policy on urbanization and urban development.
Seventh FYP (1985-1990)	<ul style="list-style-type: none"> - Promotion of self-help housing, assistance to rural families - Promotion of low-cost housing techniques (BMTPC established in 1990) and standards along with modifications in building bye-laws, land use control, minimum plot sizes and others in order to reduce costs. - Minimum Needs Programme (MNP) to tackle rural housing deficit; - National Housing Bank (NHB), 1987; - National Housing Policy, 1988
Eighth FYP (1992-1997)	<ul style="list-style-type: none"> - Importance of urban sector for national economy recognized; - National Housing Policy replaced by National Housing and Habitat Policy, 1998, focussing on fiscal concessions, carry out legal and regulatory reforms and creating strong PPPs to resolve housing problem.

Key Organizations for Housing Finance and R&D setup
First National Housing Policy framed in 1987

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153

153

Advancement of Housing Policies in India

Five Year Plan (FYP)	Key features/coverage
Ninth FYP (1997-2002)	<ul style="list-style-type: none"> - Affordable housing program for Below Poverty Line (BPL) category - Social schemes with credit assistance from HUDCO and other monetary institutions. - Indira Awaas Yojana (IAY) to deliver free housing units to BPL rural poor - ULCRA, 1976, deemed unsuccessful: Urban Land (Ceiling and Regulation) Repeal Act, 1999
Tenth FYP (2002-2007)	<ul style="list-style-type: none"> - National Urban Housing and Habitat Policy, 2007, to increase and strengthen housing stock in vulnerable regions for EWS/LIG; - Expansion of housing for weaker sections in rural areas; provisions for free of cost housing only to landless SC/ST families and shift to credit-cum subsidy system for other BPL families.

Source: Herda, G., Rani, S., Caleb, P. R., Gupta, R., Behal, M., Gregg, M. and Hazra, S. (2017). Sustainable social housing in India: definition, challenges and opportunities - Technical Report, Oxford Brookes University, Development Alternatives, The Energy and Resources Institute and UN-Habitat, Oxford.

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154

154

Advancement of Housing Policies in India

Five Year Plan (FYP)	Key features/coverage
Eleventh FYP (2007-2012)	<ul style="list-style-type: none"> - Housing finance disbursements expected to increase along with growth in the volume of outstanding housing loans from commercial banks to households I0. - Initiatives for development of secondary mortgage market to increase liquidity of housing finance for EWS, LIG and MIG highlighted by National Housing Bank (NHB). - BMTPC to provide financial support for improving layout and design of EWS/LIG housings. - Proposal: five-year 5% pa interest subsidy to commercial lenders for lending to EWS/LIG - 1.24 crore houses constructed under Indira Awaas Yojana (IAY)

Source: Herda, G., Rani, S., Caleb, P. R., Gupta, R., Behal, M., Gregg, M. and Hazra, S. (2017). Sustainable social housing in India: definition, challenges and opportunities - Technical Report, Oxford Brookes University, Development Alternatives, The Energy and Resources Institute and UN-Habitat. Oxford.

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155

155

Advancement of Housing Policies in India


Five Year Plan (FYP)	Key features/coverage
Twelfth FYP (2012-2017)	<ul style="list-style-type: none"> - Availability of land to implement affordable housing plans recognized as major hurdle. - Phase II of Rajiv Awaas Yojana (RAY), discontinued in 2015, subsumed under PMAY-HFA (U) - Suggestions: reorienting the role of SLBs, establishing an agency under Metropolitan Development Authorities for delivery of affordable housing, promotion of PPPs, increasing the Credit Risk Guarantee Fund and simplification of approval processes for affordable housing projects; - Need for greater financial support, smoother transfer of funds, abolition of APL-BPL distinction, enhanced land access for the poor, improving quality of IAY houses, developing rural building centres, emphasis on disaster risk reduction, training of masons and artisans, and partnerships with civil society and Panchayati Raj Institutions (PRIs). - Increased assistance for house construction under IAY to adjust for increasing costs; increase in Differential Rate of Interest (DRI) loans to IAY families.

Source: Herda, G., Rani, S., Caleb, P. R., Gupta, R., Behal, M., Gregg, M. and Hazra, S. (2017). Sustainable social housing in India: definition, challenges and opportunities - Technical Report, Oxford Brookes University, Development Alternatives, The Energy and Resources Institute and UN-Habitat. Oxford.

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156

156



Housing Policies: States

This section provides an overview of the key policies on affordable housing

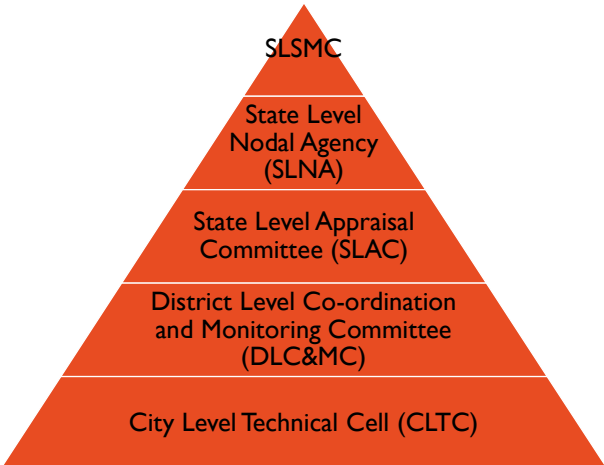
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157

157

State-level Implementation Framework

Agency	Primary Role
State Level Sanctioning and Monitoring Committee (SLSMC)	Approval of Housing for All Plan of Action (HFAPoA) Approval of Annual Implementation Plan Monitoring of implementation of Mission Coordination with CSMC & State agencies
State Level Nodal Agency (SLNA)	Technical scrutiny of Comprehensive City Housing Plan (CCHP) and DPRs
State Level Appraisal Committee (SLAC)	Techno-financial appraisal of the DPRs/CCHPs
District Level Co-ordination and Monitoring Committee (DLC&MC)	Coordination with implementing agencies of PMAY and the preparation of the CCHP, with assistance from the CLTCs
City Level Technical Cell (CLTC)	Prepare DPRs in coordination with PDAs and Private Developers. Lead implementation of approved DPRs Project management including post-occupancy management.

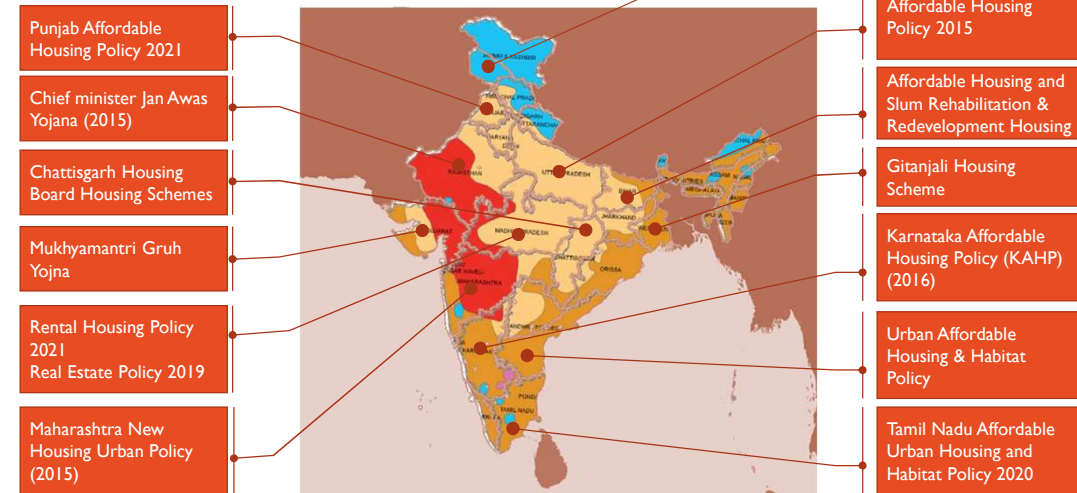


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158

158

State-level Policy Framework

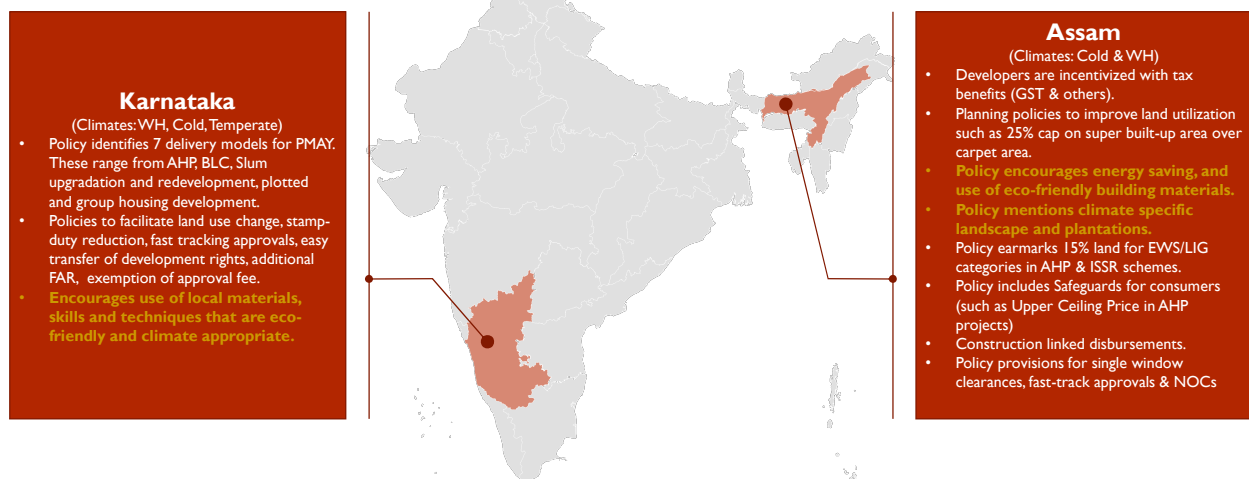


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159

159

Policy Highlights



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160

160

Policy Highlights

Gujarat

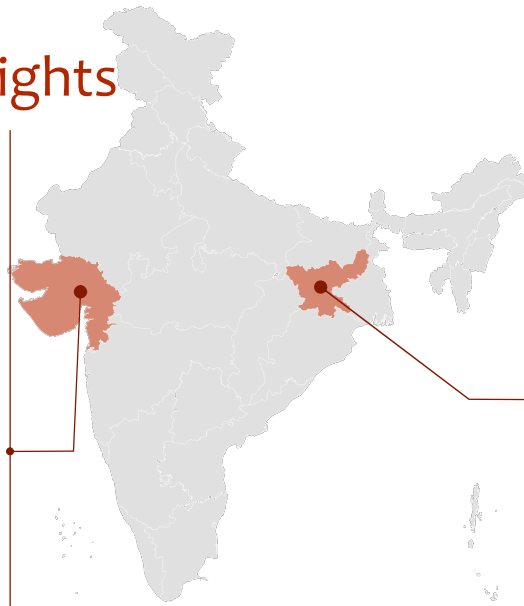
(Climates: Composite, HD, WH)

- Policy provides incentives like additional FSI, exemption from municipal charges and tax breaks. Policy also allows developing for commercial use in left over area.
- To improve land utilization, policy mandates 25% (of carpet area) cap on built-up area.
- For safeguarding consumer interests, policy outlines minimum specifications, processes for vigilance of quality construction, developers' accountability for defects.
- Policy for bar on selling/sub-letting allotted houses promotes judicious allocation.
- Provisions for maintenance in use and setting (housing infrastructure fund) corpus for amenities.
- Provisions for cross subsidization by Commercial/MIG developments is allowed provided mandated fraction of AH is met.
- **Policy encourages energy saving, and use of eco-friendly building materials.**
- **Policy mentions climate specific landscape and plantations.**

Jharkhand

(Climates: Composite)

- Developers are incentivized with tax benefits (GST & others).
- Planning policies to improve land utilization such as 25% cap on super built-up area over carpet area.
- **Policy encourages energy saving, and use of eco-friendly building materials.**
- **Policy mentions climate specific landscape and plantations.**
- Policy earmarks 15% land for EWS/LIG categories in AHP & ISSR schemes.
- Policy includes Safeguards for consumers (such as Upper Ceiling Price in AHP projects)
- Construction linked disbursements.
- Policy provisions for single window clearances, fast-track approvals & NOCs



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161

161

Policy Highlights

Jammu & Kashmir

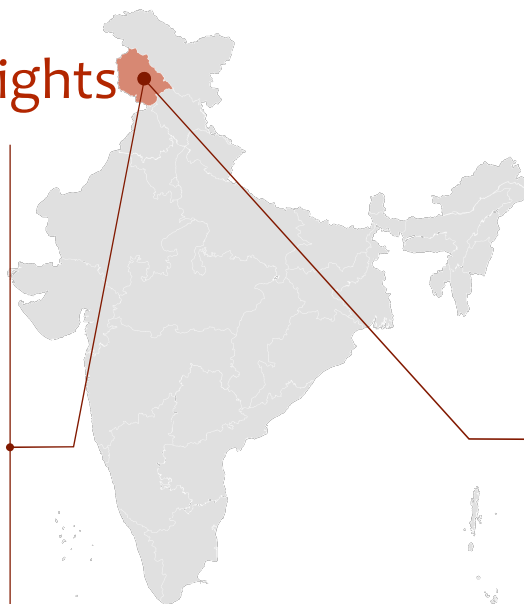
(Climates: Cold)

- Policy document outlines host of strategies to create a holistic policy framework. Policy outlines supply side, demand side, service level, and livelihood level strategies.
- Policy outlines establishment of development fund (CIDF) mechanisms for creating and monitoring the corpus.
- Policy identifies 7 models of implementation ranging from slum redevelopment, slum relocation, market-based and govt led EWS and LIG homes, beneficiary led housing/enhancement, rental housing and township schemes.
- Policy outlines measures for land availability; amendment of land reforms act, master plans to earmark 20% of housing as affordable, provision of additional FAR, etc..
- Single window clearances and fast track approvals and removing other administrative hurdles.

Jammu & Kashmir

(Climates: Cold)

- Promote inclusive mixed housing development by mandating EWS developments in housing projects.
- Provision for mixed use development including neighborhood shopping facilities.
- Flexibility for to developer offset EWS for practical reasons by either paying a Shelter fee or relocating EWS within 5 km.
- Cross subsidize developers by way of compensatory FSI and utilization of remaining land area for other housing and commercial purposes. These relaxations will also be extended to PDAs.
- Incentives to developers for exceeding mandatory allocation to EWS & LIG.
- Allotment of land to PDAs free of cost.



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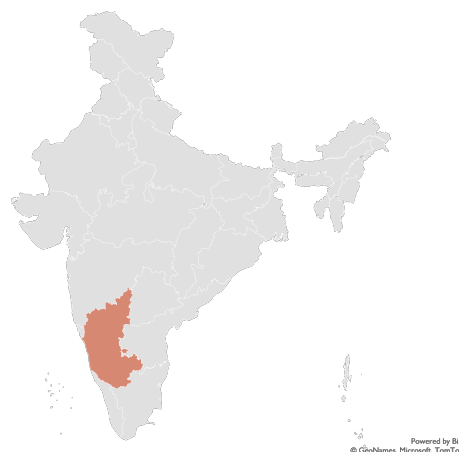
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162

162

Karnataka – Implementing Agencies

Agency	Primary Role
(SLSMC)	Approval of proposals.
Karnataka Housing Board (SLNA)	Technical scrutiny of Comprehensive City Housing Plan (CCHP) and DPRs
State Level Appraisal Committee (SLAC)	Techno-financial appraisal of the DPRs/CCHPs
District Level Co-ordination and Monitoring Committee (DLC&MC)	Coordination with implementing agencies of PMAY and the preparation of the CCHP, with assistance from the CLTCs
City Level Technical Cell (CLTC)	Prepare DPRs in coordination with PDAs and Private Developers. Lead implementation of approved DPRs Project management including post-occupancy management.



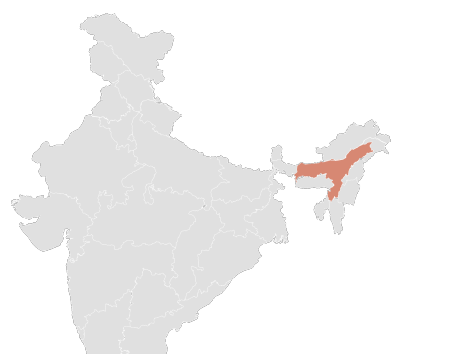
Source: Karnataka Affordable Housing Policy 2016, Government of Karnataka
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163

163

Assam – Implementing Agencies

Agency	Primary Role
State Level Sanctioning & Monitoring Committee (SLSMC) – Headed by Chief Secy	Scrutinizing and approval of proposals from private developers.
Project Approval Committee (PAC) – Headed by Principal Secy, Urban Development Department	Sanctioning of technical and financial DPRs.
State Level Nodal Agency (SLNA) – Headed by Director, Directorate of Town & Country Planning	Project formulation, monitoring and evaluation.
Sub-committee at District level for ULBs	Extended arm of SLNA for monitoring and evaluation at ULB level.
ULBs	Responsible for on-ground implementation.
Assam State Housing Board	Implementing Agency/Regulator for rental housing



List of Implementing Agencies

Development Authorities, Urban Local Bodies, Assam State Housing Board, Assam State Cooperative Housing Federation Ltd (HOUSEFED) and Guwahati Metropolitan Development Authority (GMDA)

Agencies notified Vide Notification No UDD(T) 155/2015/Pt III/108

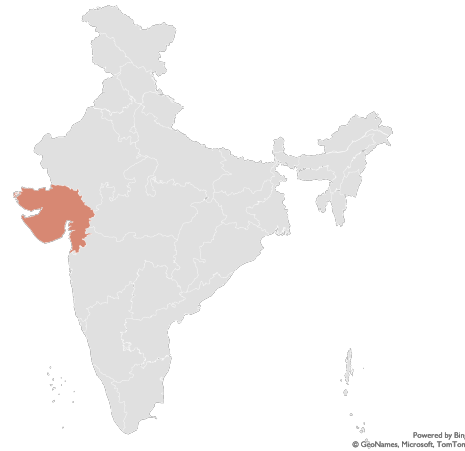
Source: Assam Urban Affordable Housing & Habitat Policy 2016, IPE Global, Development Alternatives
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164

164

Gujarat – Implementing Agencies

Agency	Primary Role
Affordable Housing Mission (SLNA)	Formulating policy and program. Evaluation of proposals. Capacity building of agencies. Facilitate project planning and implementation. (Limited information available)
Gujarat Housing Board	Para statal agency provides housing to all categories (Limited information available)
ULBs	Undertake demand surveys and prepare HFAPoA (Limited information available)
Urban Development Authorities Area development Authorities	(No information available)

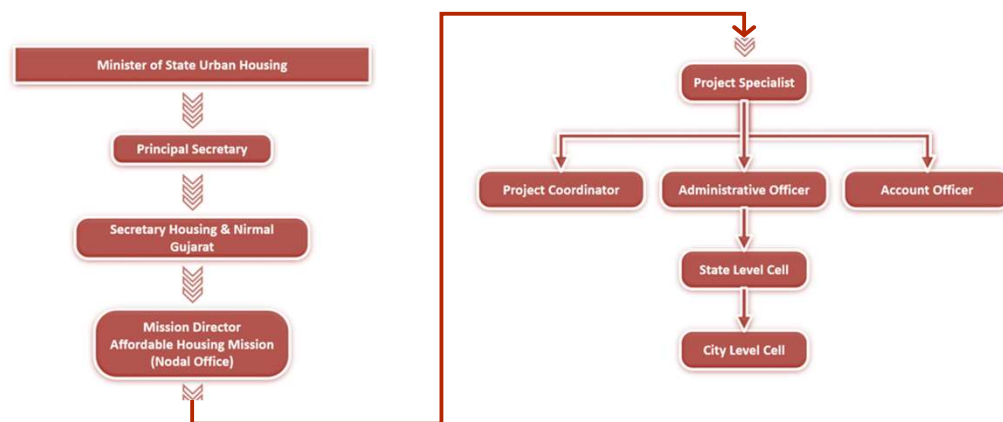


Source: Assam Urban Affordable Housing & Habitat Policy 2016, IPE Global, Development Alternatives
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165

165

Affordable Housing Organizational Framework: Gujarat



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166

166

Jharkhand – Implementing Agencies

Agency	Primary Role
Jharkhand Housing Mission Directorate (Urban Development & Housing Department)	Undertake policy decisions and necessary administrative and legislative measures to implement the policy. Amendments to policies and approvals for exemptions to projects.
High Level Committee (HLC)	Chaired by Chief Minister and includes state cabinet ministers for UD&H and Revenue & Land Reforms. Chief Secy, Dy Commissioner and Principal Secy complete the committee.
State Level Housing Sanctioning and Monitoring Committee (SLHSMC) Chaired by Chief Secy.	Prescribe detailed SOPs for implementation. Prioritize, approve & sanction projects. Streamline interdepartmental cooperation. Inspect, review and monitor projects. Provision technical and manpower support to PDAs and assign implementation targets. Empanel HFCs, MFIs, NGOs for successful implementation.



Source: Karnataka Affordable Housing Policy 2016, Government of Karnataka
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167

167

Jharkhand – Implementing Agencies

Agency	Primary Role
State Level Housing Sanctioning and Monitoring Committee (SLHSMC)	Promote and support R&D activities. Coordinate with Central Govt Departments.
Mission Director*	Ex-officio Additional / Joint Secretary to Govt. in UD & H Department.
Project Development Agency (PDA) (JUIDCO, Housing Board and Urban Local Bodies (ULB) can serve as PDA)	Coordinate amongst various govt agencies. Undertake planning, designing, obtaining approvals and implementation. Monitor construction and development of projects. Appraise, approve and recommend RFPs and bid process documents of PPP projects to Housing Mission. Appoint third party auditors to monitor quality construction. Ensure fair and transparent allotment.



* Limited information available on Constitution/Appointment

Source: Karnataka Affordable Housing Policy 2016, Government of Karnataka
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168

168

J&K – Implementing Agencies

Agency	Primary Role
J&K Housing Mission (JKHM) under the J&K H&UD Department (UT level Nodal Agency)	Undertake policy decisions and necessary administrative and legislative measures to implement the policy. Amendments to policies and approvals for exemptions to projects. Responsible for implementation of govt. schemes.
Hi level Committee*	Undertake policy decisions and necessary administrative and legislative measures to implement the policy.
UT level Sanctioning and Monitoring Committee (ULSMC)*	Sanctioning and monitoring committee for all housing other than Slum Redevelopment and Rehabilitation Housing (SRRH).
UT level Slum redevelopment Area (ULSRA) & City/District level Slum Redevelopment Committees*	

Source: J&K Housing, Affordable Housing, Slum Redevelopment and Rehabilitation and Township Policy 2020, Government of J&K

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* Limited information available on Constitution/Appointment

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169

169

J&K – Implementing Agencies

Agency	Primary Role
Mission Director* Ex-officio Special Secretary to Govt. in UD & H Department.	
Project Development Agency (PDA) J&K Housing Board, R&B, JKPCC, & ULBs act as PDAs	Coordinate with govt. agencies for on-ground implementation of projects. Coordinate with J&K housing mission. Mobilize NGOs for facilitating housing finance to vulnerable groups. Undertake planning and design, approval of projects, and implementation. Appraise, approve and recommend projects to J&K housing mission. Appoint 3 rd party auditors. Setup and oversee operations of Affordable Housing Facilitation Centre. Ensure fair, transparent and smooth allotment to beneficiaries. Ensure maintenance after completion of project.

Source: J&K Housing, Affordable Housing, Slum Redevelopment and Rehabilitation and Township Policy 2020, Government of J&K

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* Limited information available on Constitution/Appointment

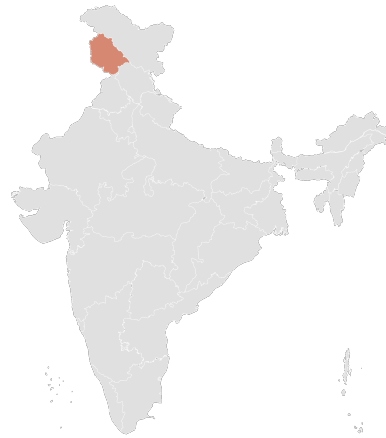
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170

170

J&K – Implementing Agencies

Agency	Primary Role
Affordable Housing Facilitation Centre (AHFC)	Experts from various fields (Finance, Social Development, GIS, e-Governance, etc.)



Source: J&K Housing, Affordable Housing, Slum Redevelopment and Rehabilitation and Township Policy 2020, Government of J&K

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171

171



Key Outcomes

I. Implementation challenges

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172

172

Impressions – Challenges

WRI India conducted Training Needs Assessment (TNA) survey b/w May & June 2018. Respondents included officials from Housing Board, Slum Development Board and Urban Local Bodies, and key representatives from Govt. agencies and academia. These interactions outlined following challenges.

• Contextualization

- Policies designed at Centre tend to overlook ground realities and complexities in the delivery of affordable housing.
- Central policies are replicated and not adapted. Few state govts have the expertise to develop housing policies and deliver affordable housing at scale.
- Diverse issues plague metros and non-metros

• Capacity Building

- Govt. agencies lack exposure to
 - new construction technologies,
 - development of DPRs, PoAs, etc.
 - knowledge of MIS and GIS
 - conducting social audits

Agencies keen to undertake trainings.

- 'Classroom; style training and capacity building in govt. agencies is ineffective. Learnings are rarely applied in practice.
- Limited capacity and experience of local agencies is a barrier to PPP schemes.

Source: Improving the Implementation of Affordable Housing in India: Issue Identification and Needs Assessment Report, WRI (2019)

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173

173

Impressions – Challenges

• Poor availability of serviced land

- Leads to distant allotments and consequently poor uptake

• Limited transparency

- Lack of trust in the way programs are conceived, beneficiaries/ projects, etc. are identified.
- Tendering systems are designed to promote low promote undeserving partners/beneficiaries.

• Poorly designed housing

- Inadequate natural light and ventilation
- Often thermally uncomfortable
- Simple passive design strategies and climate responsive architecture are not practiced; these can improve the livability of affordable homes

Source: Improving the Implementation of Affordable Housing in India: Issue Identification and Needs Assessment Report, WRI (2019)

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174

174

Impressions – Challenges

- **Poor private sector participation**
 - Limited participation of private sector is indicative of restrictive policy framework.
- **End-user/beneficiary apathy**
 - Absence of handholding for legal processes to attain tenure rights.
- **Limited financing**
 - Banks unwilling to finance affordable housing projects.
 - Funding from state and beneficiaries is often delayed, leading to project delays and cost overruns.
 - Unstable incomes from informal sector make formal finance inaccessible.

Source: Improving the Implementation of Affordable Housing in India: Issue Identification and Needs Assessment Report, WRI (2019)
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175

175

Implementation Challenges

- Lack of suitable low-cost land within the city limits.
- Lengthy statutory clearance and approval process.
- Shortcomings in development norms, planning and project design.
- Lack of participation of large organised real estate players due to low profit margins.
- High cost of funds for construction finance making the projects unviable.
- Lack of suitable mechanism for maintenance.
- Challenges in beneficiary selection.
- Capacity constraint or inadequate capacity of the implementing agencies.

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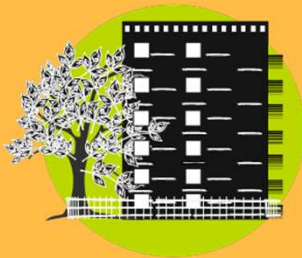
176

176

‘Sustainability’ aspect does not trickle into State Policies

- PMAY-U explicitly outlines Technology Sub-mission’s Mission Statement as **“Sustainable Technological Solutions for Faster and Cost-effective Construction of Houses suiting to Geo-Climatic and Hazard Conditions of the Country”**.
- State Policies outline comfortable homes as outcomes, but do not outline policy actions for meeting thermal comfort.
- Climate specific guidance is restricted to encouraging climate specific landscape and plantations in state policies.
- State policies do not include ECONIWAS requirements in specifications.
- International policies establish a clear case for developing Sustainable Affordable Housing.

177



Thanks!

178