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

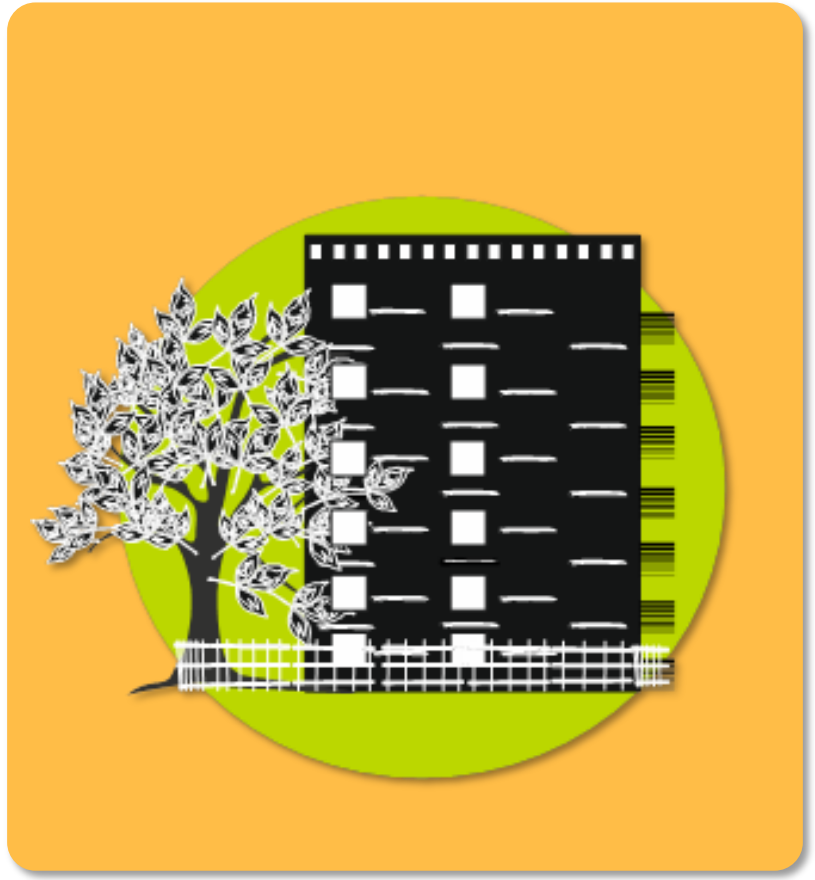
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

bmtpc

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH



Thermal Comfort Performance based Design Standard for Affordable Housing in India

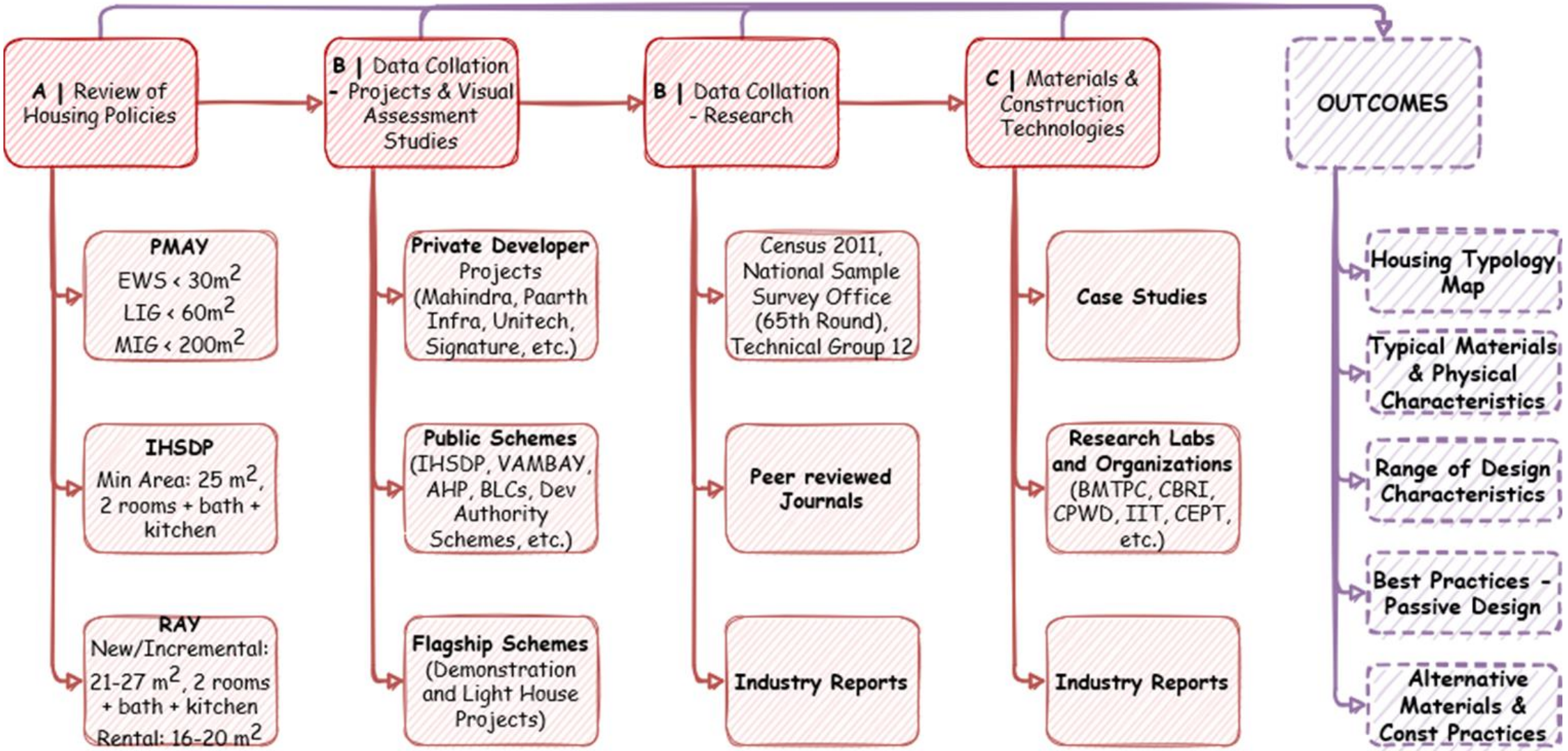
HOUSING SIZE & TYPOLOGY STUDY

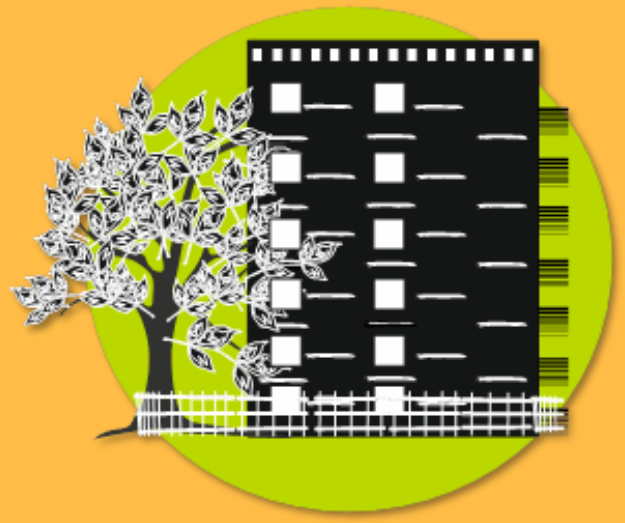
eds environmental design solutions

Wuppertal Institut

hunnarshālā FOUNDATION

Market Assessment Methodology





Review of Policies & Affordable Housing Projects

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

Review of policies identified area and spatial characteristics

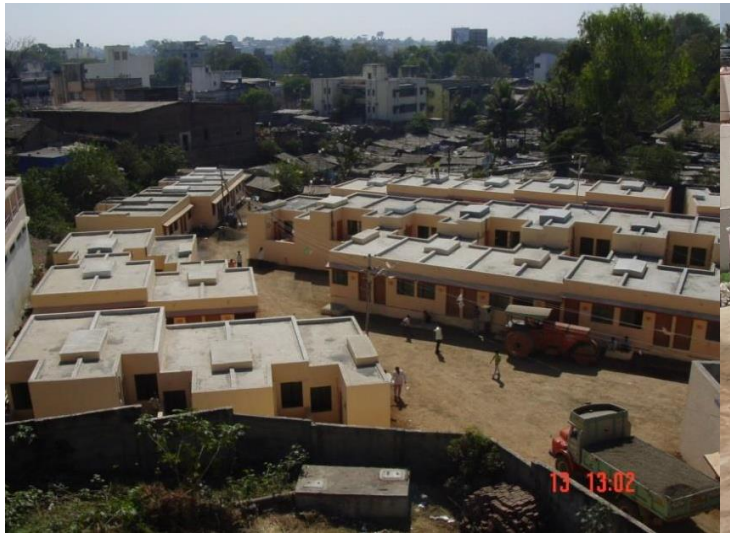
PMAY-U Schemes	ISSR	CLSS	AHP	BLC-N, BLC-E
EWS (upto 3 DRs)	Up to 30 sqm	Up to 30 sqm	21-27 sqm	Up to 30 sqm
LIG (upto 4 DRs)	Up to 60 sqm	Up to 60 sqm	-	NA
LIG-A (upto 4 DRs)	-	-	28-40 sq m	NA
LIG-B (upto 4 DRs)	-	-	41-60 sq m	NA
MIG-1 (4+ DRs)	Up to 160 sqm	Up to 160 sqm	NA	NA
MIG-2 (4+ DRs)	Up to 200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

Policy (PMAY)-Area-Typology Matrix

Visual Assessment of homes identified typologies: Single Family Homes




Plotted Development




Row-type

Visual Assessment of homes identified typologies: Multifamily Homes



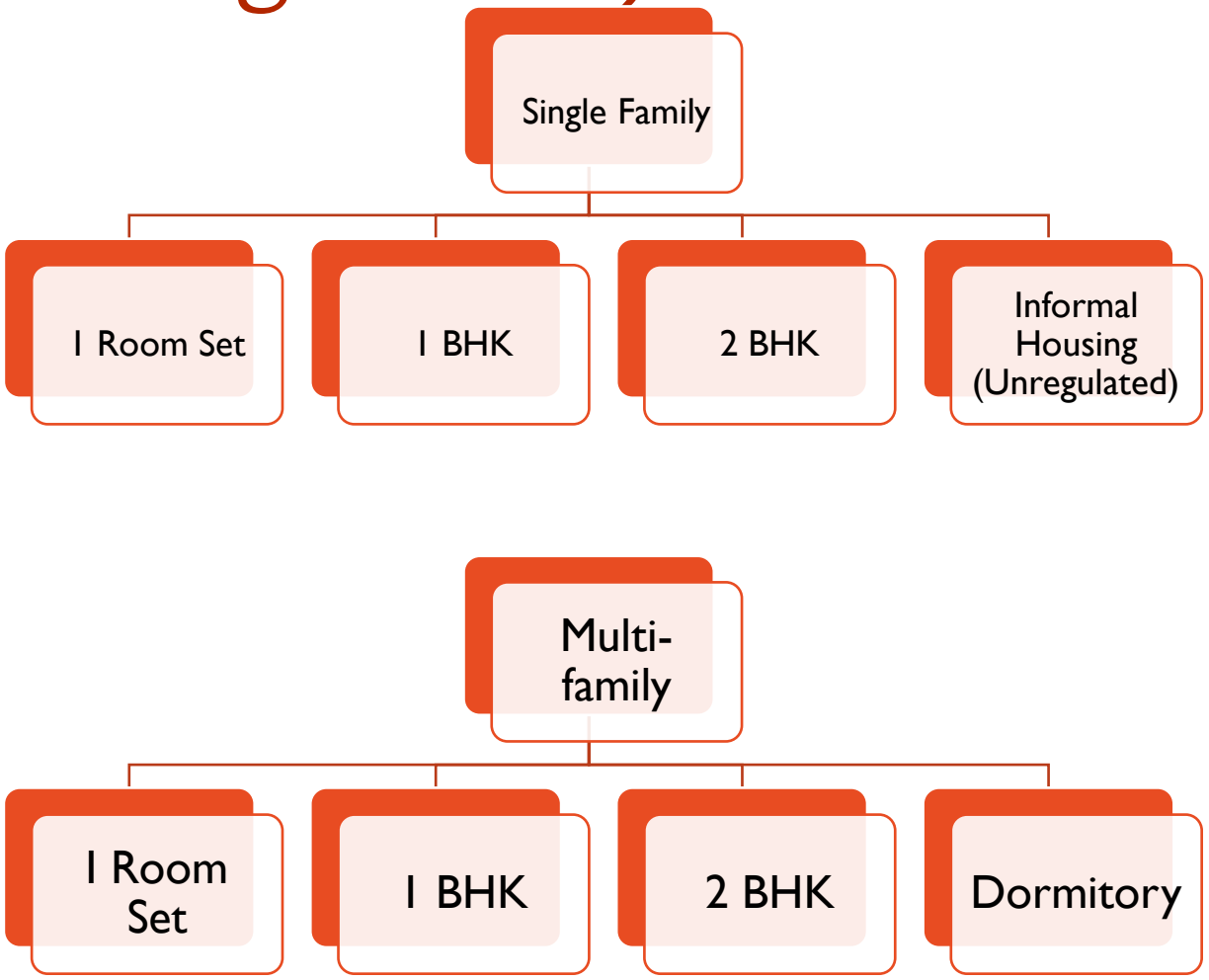


Low Rise Housing

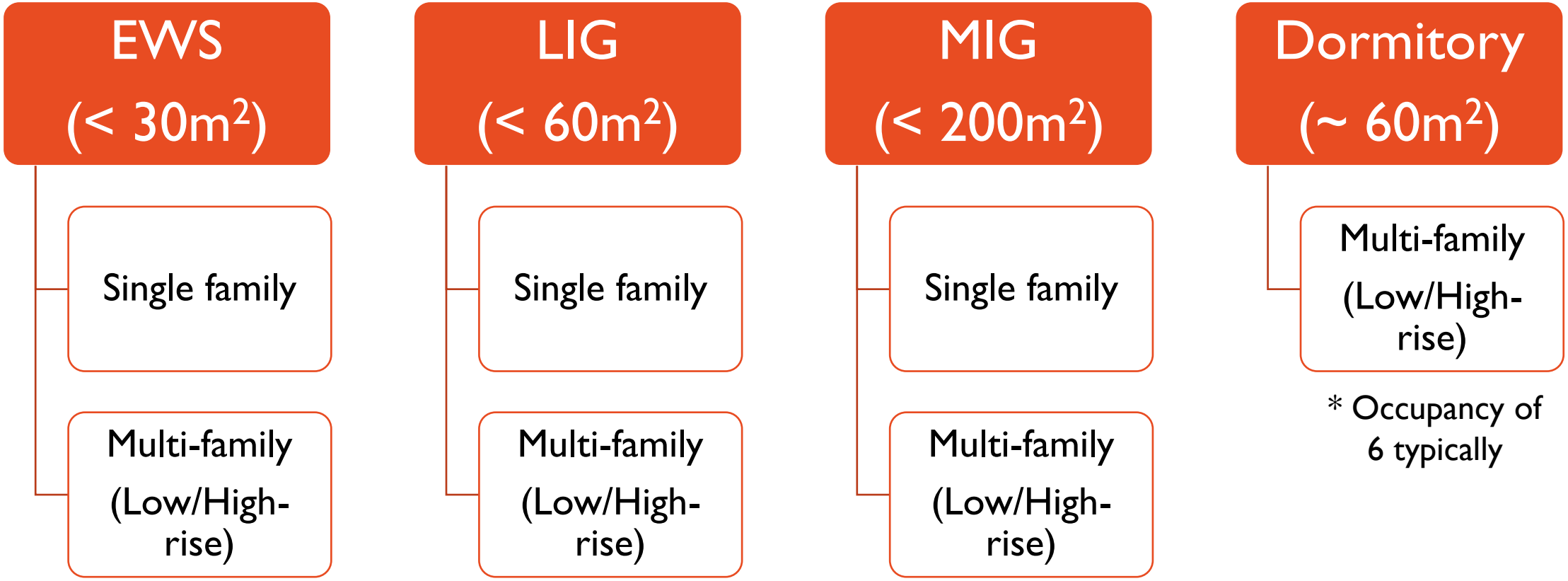


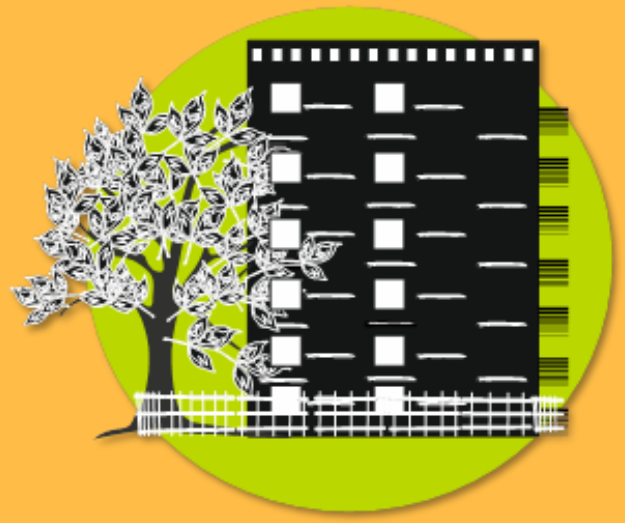

Mid/High Rise Housing

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



Low Cost/Affordable Homes Typology Map (by area)

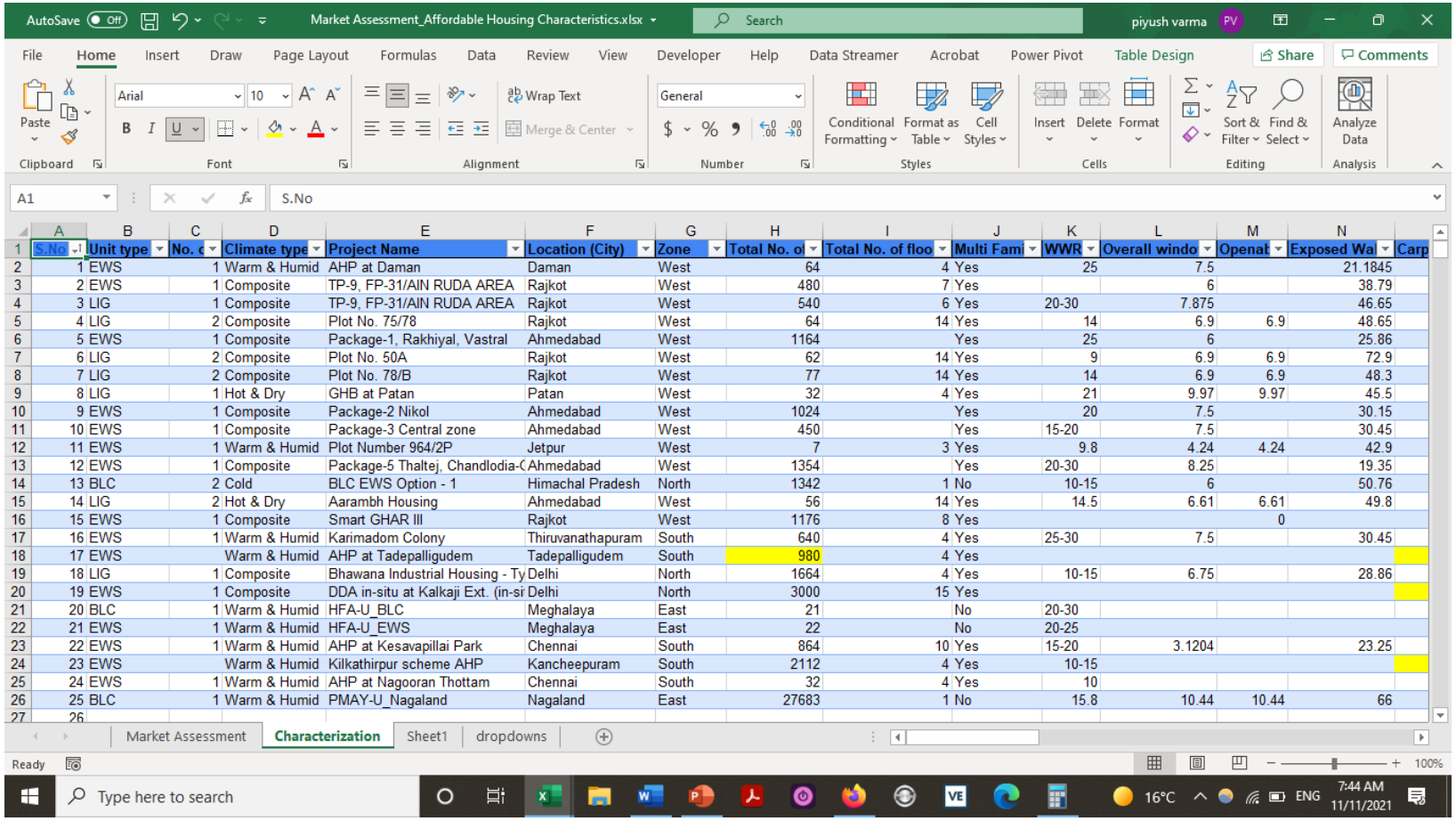




Housing Characteristics: Representative Projects

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

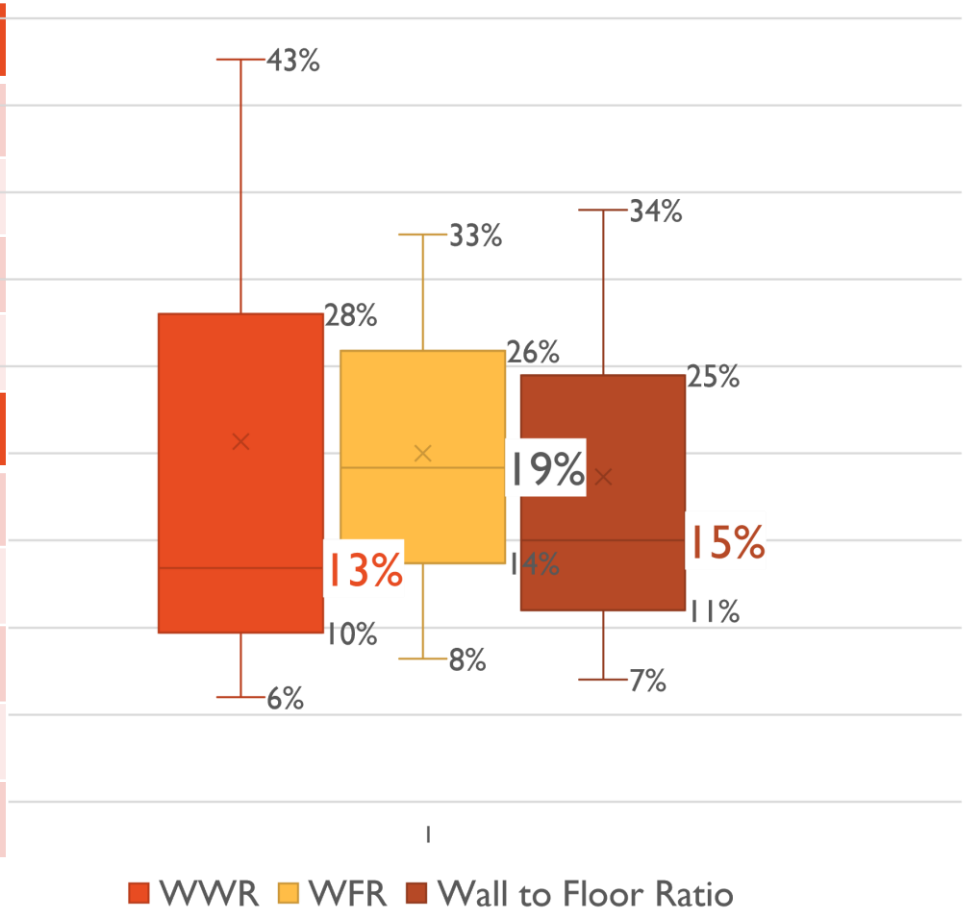
Data of ~100 affordable housing projects across Pvt Developers and Govt. Agencies compiled



S.No	Unit type	No. c	Climate type	Project Name	Location (City)	Zone	Total No. of	Total No. of floo	Multi Fami	WWR	Overall windo	Openat	Exposed Wal	Carp
1	EWS	1	Warm & Humid	AHP at Daman	Daman	West	64	4	Yes	25	7.5		21.1845	
2	EWS	1	Composite	TP-9, FP-31/AIN RUDA AREA	Rajkot	West	480	7	Yes		6		38.79	
3	LIG	1	Composite	TP-9, FP-31/AIN RUDA AREA	Rajkot	West	540	6	Yes	20-30	7.875		46.65	
4	LIG	2	Composite	Plot No. 75/78	Rajkot	West	64	14	Yes	14	6.9	6.9	48.65	
5	EWS	1	Composite	Package-1, Rakhiyal, Vastral	Ahmedabad	West	1164		Yes	25	6		25.86	
6	LIG	2	Composite	Plot No. 50A	Rajkot	West	62	14	Yes	9	6.9	6.9	72.9	
7	LIG	2	Composite	Plot No. 78/B	Rajkot	West	77	14	Yes	14	6.9	6.9	48.3	
8	LIG	1	Hot & Dry	GHB at Patan	Patan	West	32	4	Yes	21	9.97	9.97	45.5	
9	EWS	1	Composite	Package-2 Nikol	Ahmedabad	West	1024		Yes	20	7.5		30.15	
10	EWS	1	Composite	Package-3 Central zone	Ahmedabad	West	450		Yes	15-20	7.5		30.45	
11	EWS	1	Warm & Humid	Plot Number 964/2P	Jetpur	West	7	3	Yes	9.8	4.24	4.24	42.9	
12	EWS	1	Composite	Package-5 Thaltej, Chandlodia-(	Ahmedabad	West	1354		Yes	20-30	8.25		19.35	
13	BLC	2	Cold	BLC EWS Option - 1	Himachal Pradesh	North	1342	1	No	10-15	6		50.76	
14	LIG	2	Hot & Dry	Aarambh Housing	Ahmedabad	West	56	14	Yes	14.5	6.61	6.61	49.8	
15	EWS	1	Composite	Smart GHAR III	Rajkot	West	1176	8	Yes			0		
16	EWS	1	Warm & Humid	Karimadom Colony	Thiruvanathapuram	South	640	4	Yes	25-30	7.5		30.45	
17	EWS		Warm & Humid	AHP at Tadepalligudem	Tadepalligudem	South	980	4	Yes					
18	LIG	1	Composite	Bhawana Industrial Housing - Ty	Delhi	North	1664	4	Yes	10-15	6.75		28.86	
19	EWS	1	Composite	DDA in-situ at Kalkaji Ext. (in-si	Delhi	North	3000	15	Yes					
20	BLC	1	Warm & Humid	HFA-U_BLC	Meghalaya	East	21		No	20-30				
21	EWS	1	Warm & Humid	HFA-U_EWS	Meghalaya	East	22		No	20-25				
22	EWS	1	Warm & Humid	AHP at Kesavapillai Park	Chennai	South	864	10	Yes	15-20	3.1204		23.25	
23	EWS		Warm & Humid	Kilkathirpur scheme AHP	Kancheepuram	South	2112	4	Yes	10-15				
24	EWS	1	Warm & Humid	AHP at Nagooran Thottam	Chennai	South	32	4	Yes	10				
25	BLC	1	Warm & Humid	PMAY-U_Nagaland	Nagaland	East	27683	1	No	15.8	10.44	10.44	66	
26														

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^2K)	0.47	4.2	5.2
U_{wall} (W/m^2K)	0.45	3.35	10.0

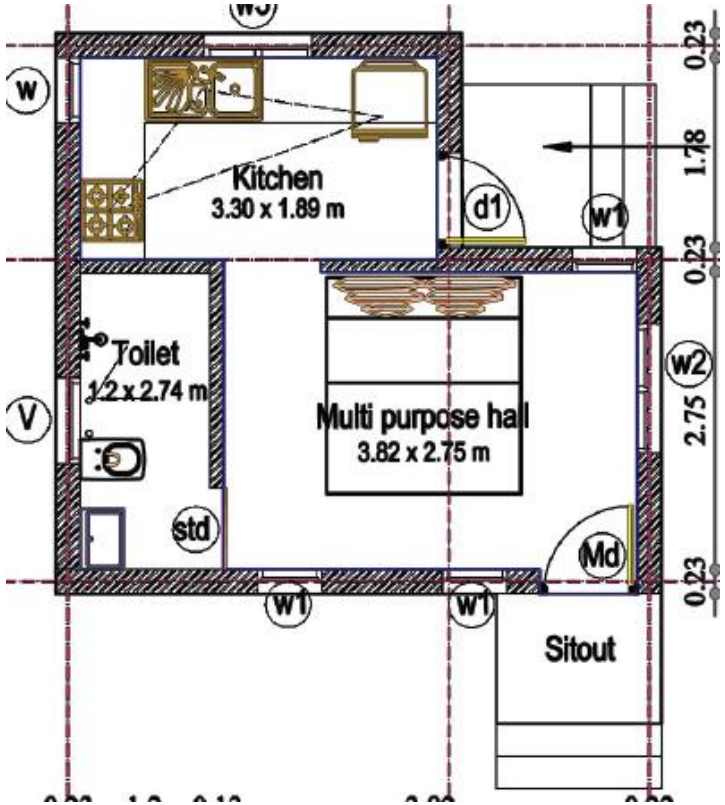


Range of Material Characteristics from Compiled Projects

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

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



BLC for PMAY, Kerala

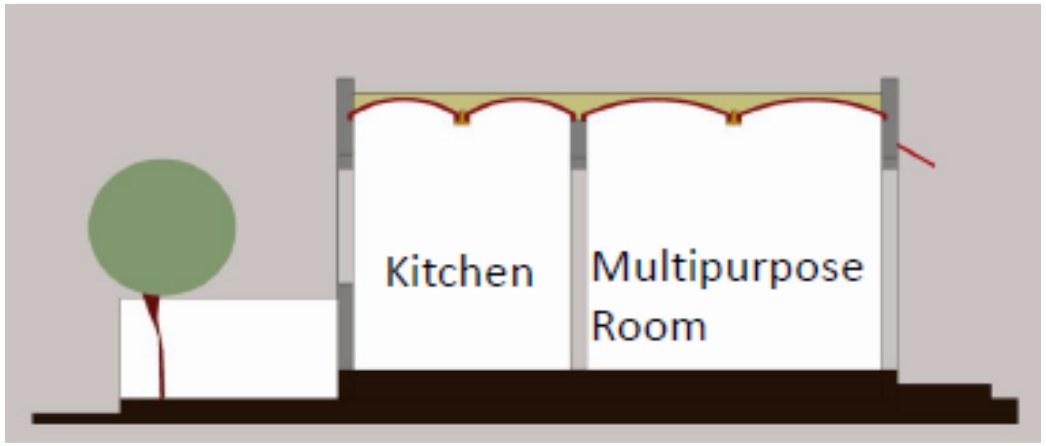
Details **Unit Plan** **View**

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

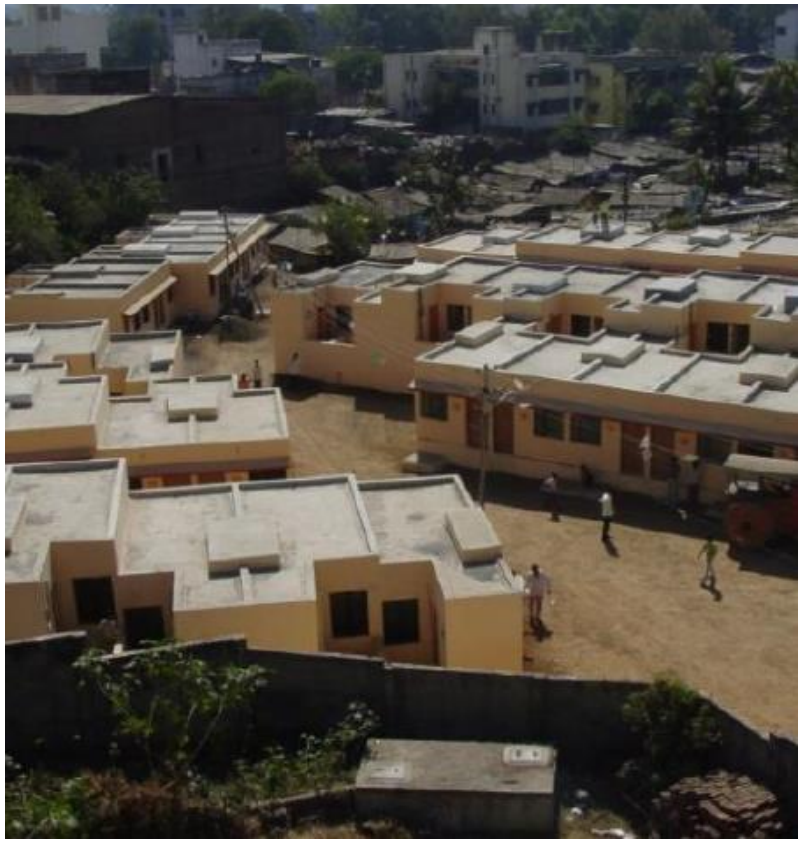
Area	m^2
Living Area	9.3
Toilet	1.4
Bath	1.4
Kitchen	6.5

Details



Unit Plan & Section

Slum Rehab, Erandwadi



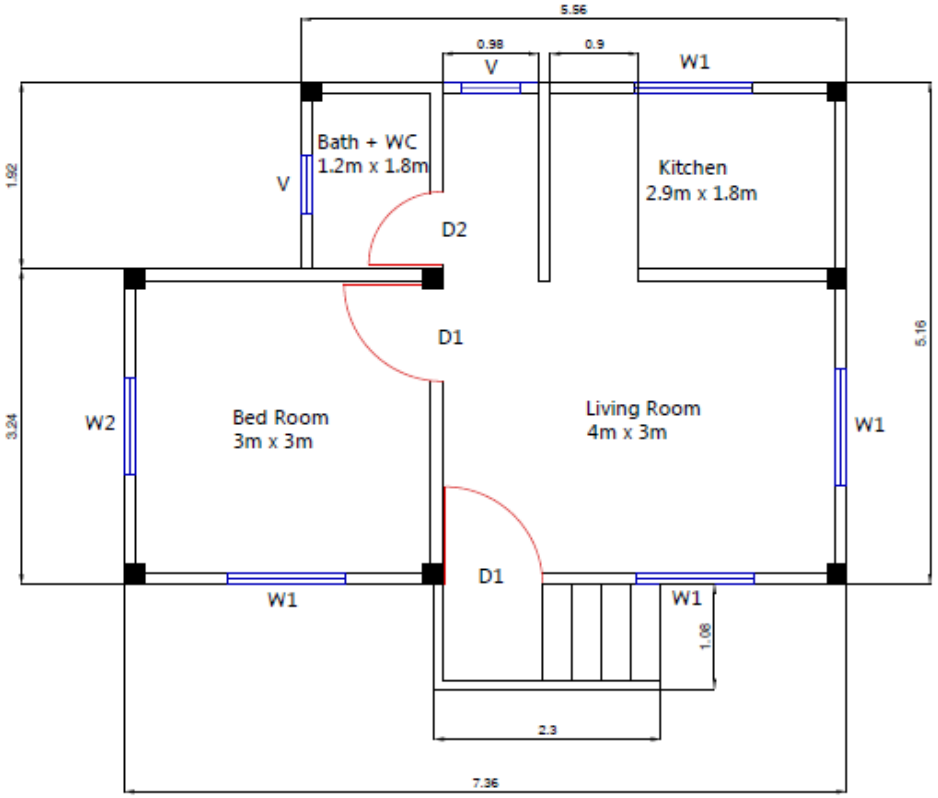
View

Source

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



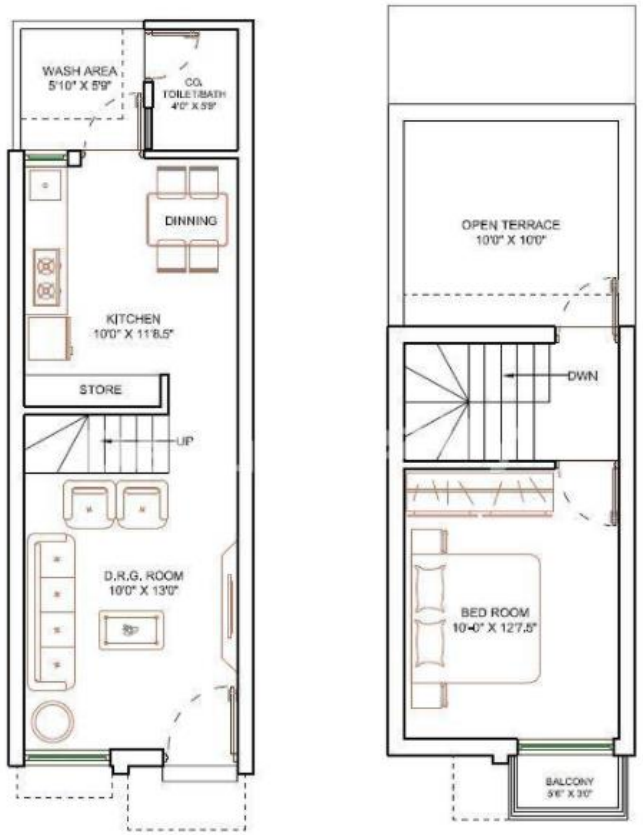
Model layout of BLC **Municipal Affairs Department, Govt. of Nagaland**

Details **Unit Plan** **View**

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

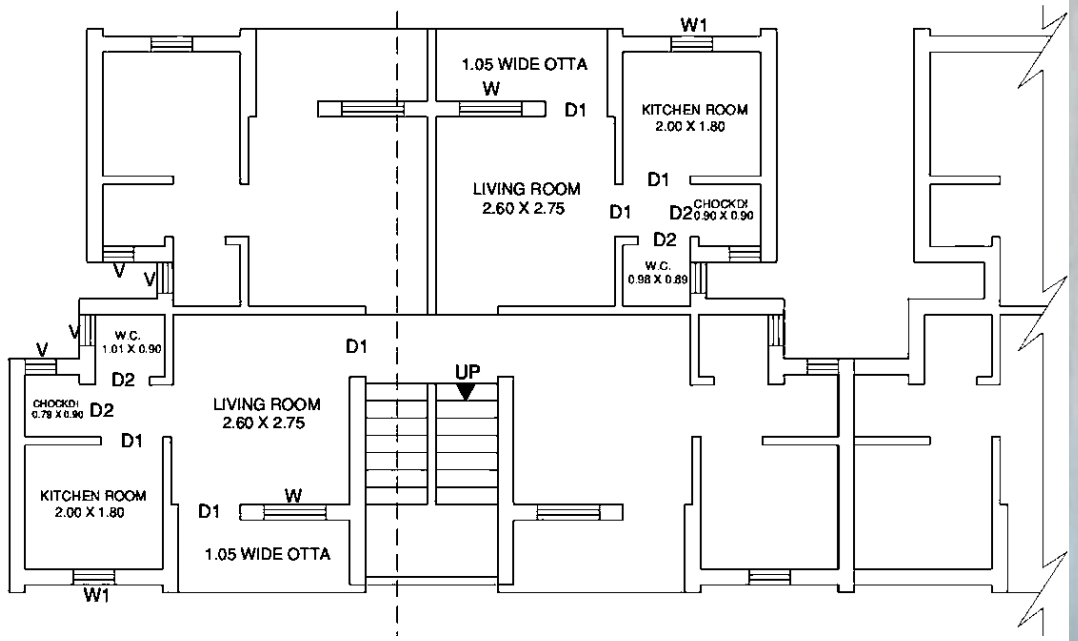
Details **Unit Plan** **View**

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

Details



Unit & Cluster Plan

VAMBAY (Slum Rehab), Surat

View

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		

Unit Plan

Details

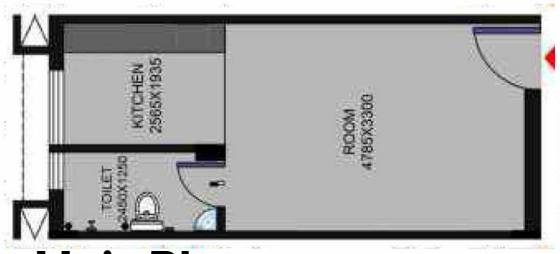
Cluster Plan

Private Developer, Boisar

View

Source

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

Details

Shading	Overhang
Orientation	NE-SW

Cluster Plan

Private Developer, Lucknow

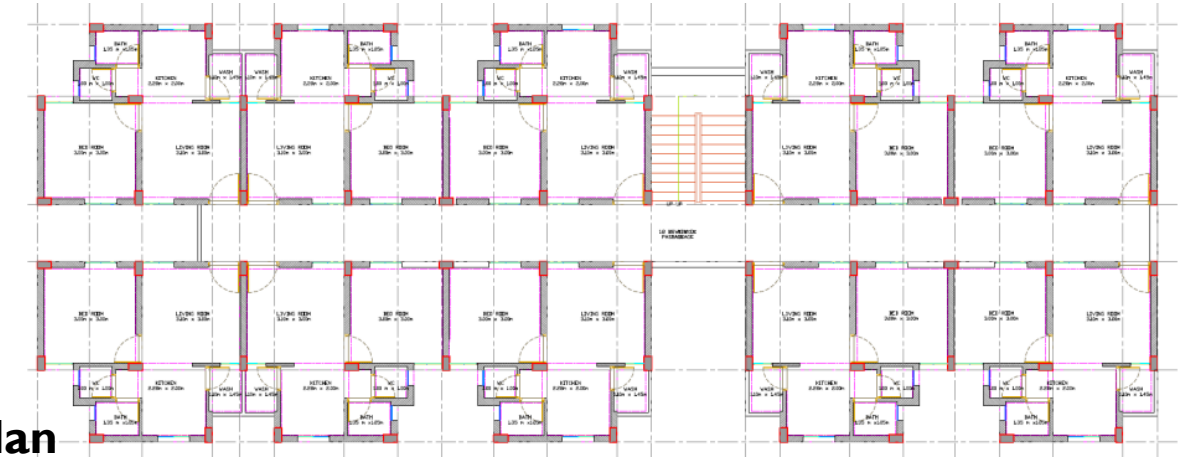
View

Source

Multi-family| 1 BHK| Low Rise

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		

Unit Plan



Cluster Plan

Daman Municipal Council, Daman

View

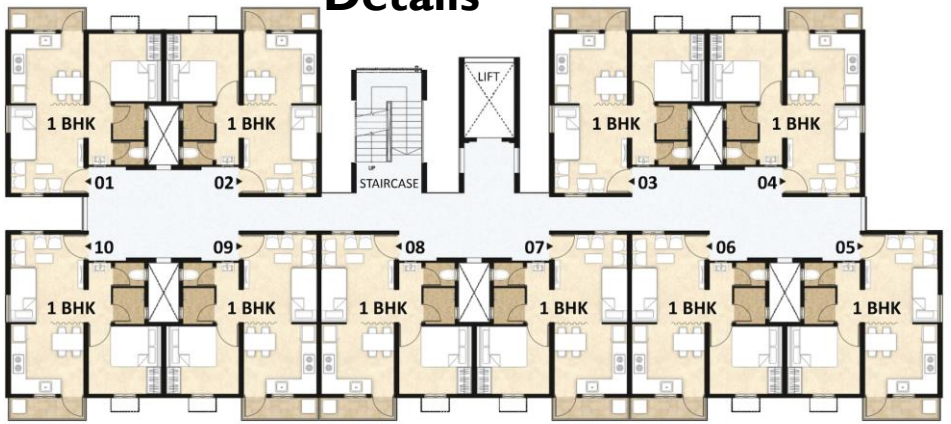
Source

Multi-family| 1 BHK| Mid Rise

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

Unit Plan

Details



Cluster Plan

Mahindra Happinest, Avadi

View

Source

Multi-family| 1 BHK| High Rise

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

Unit Plan

Cluster Plan

Light House Project, Lucknow

View

Source

Multi-family| 1 BHK| High Rise

Unit Plan

Details	
Cluster Size	11units
Carpet Area	26.02 m^2
WWR	16%
WFR	23.6%
Orientation	N-S
Shading	Overhang

Area	m^2
Bedroom	8.24
Living Area	8.18
Toilet	2.9
Utility	5.2
Kitchen	6.7

Cluster Plan

DDA flats (EWS) at Manglapuri, Dwarka, New Delhi

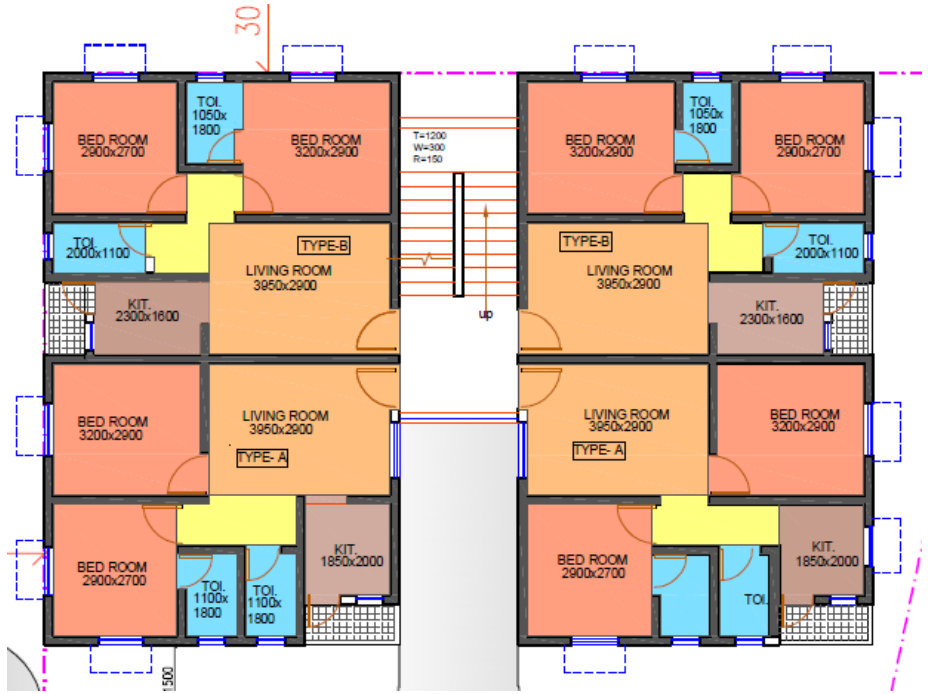
View

Source

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



Demonstration Housing Project, Hyderabad,Telangana

Cluster Plan **Unit & Cluster Plan** **View**

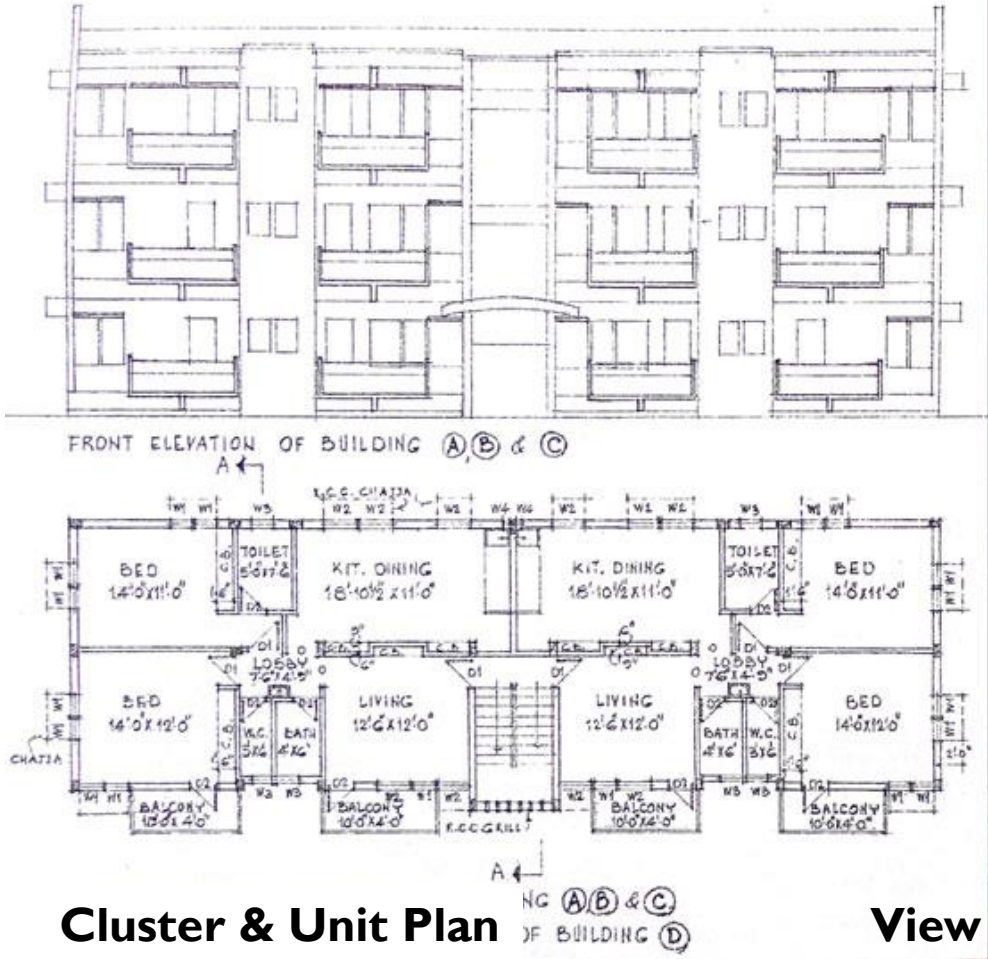
Source

Multi-family| 2 BHK| Low Rise

Private Developer, Co-operative Housing Society, Pune

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



Details **Cluster & Unit Plan** **View**

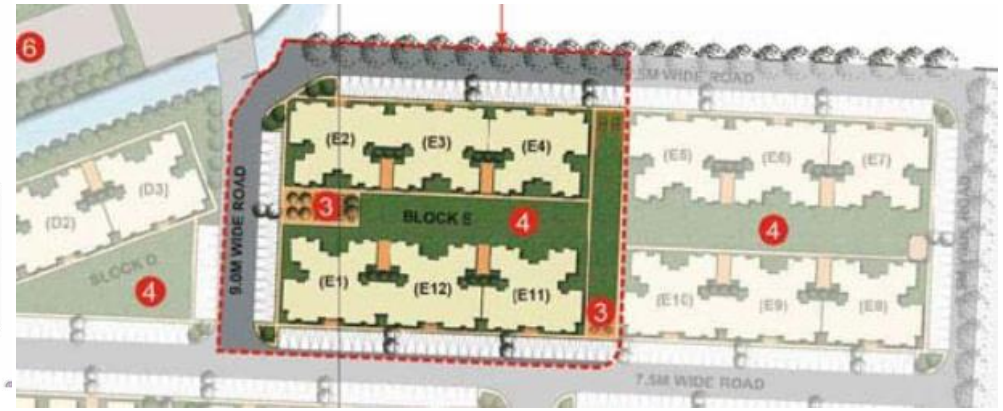
Source

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

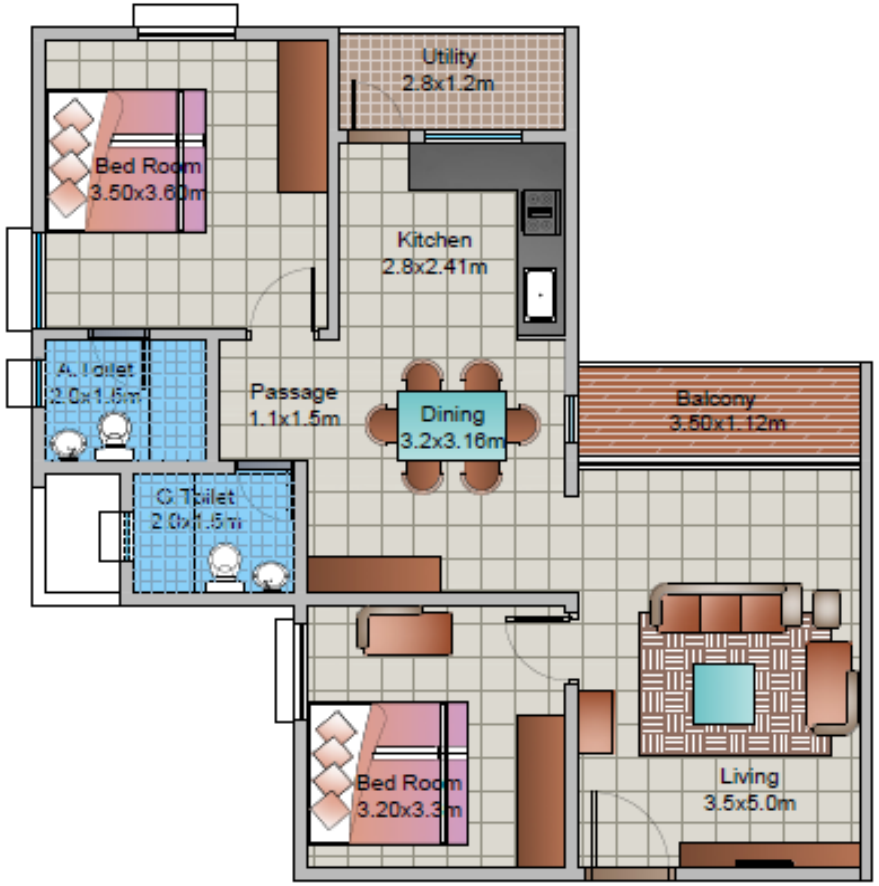


UniHomes, Bhopal

View

Source

Multi-family| 2 BHK| High Rise



Unit Plan

Details	
Cluster Size	4 units
Carpet Area	72 m^2
WWR	13%
WFR	18.5%
Orientation	N-S
Shading	Overhang

Area	m^2
Bedrooms	23.0
Living Area	29.0
Toilet	6.0
Kitchen	7.0

Details

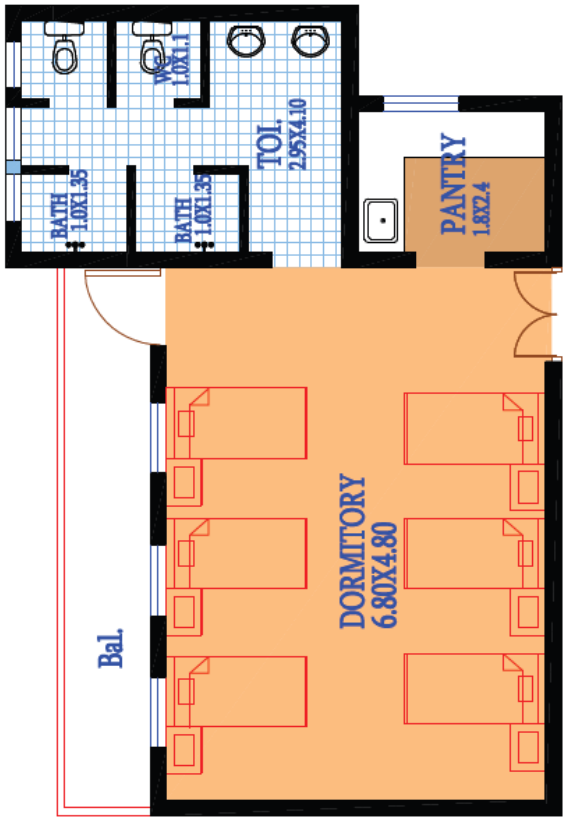
Bangalore Development Authority, Kaniminake Phase-3

Cluster Plan and View

Source

Multi-family| Dormitory| High Rise

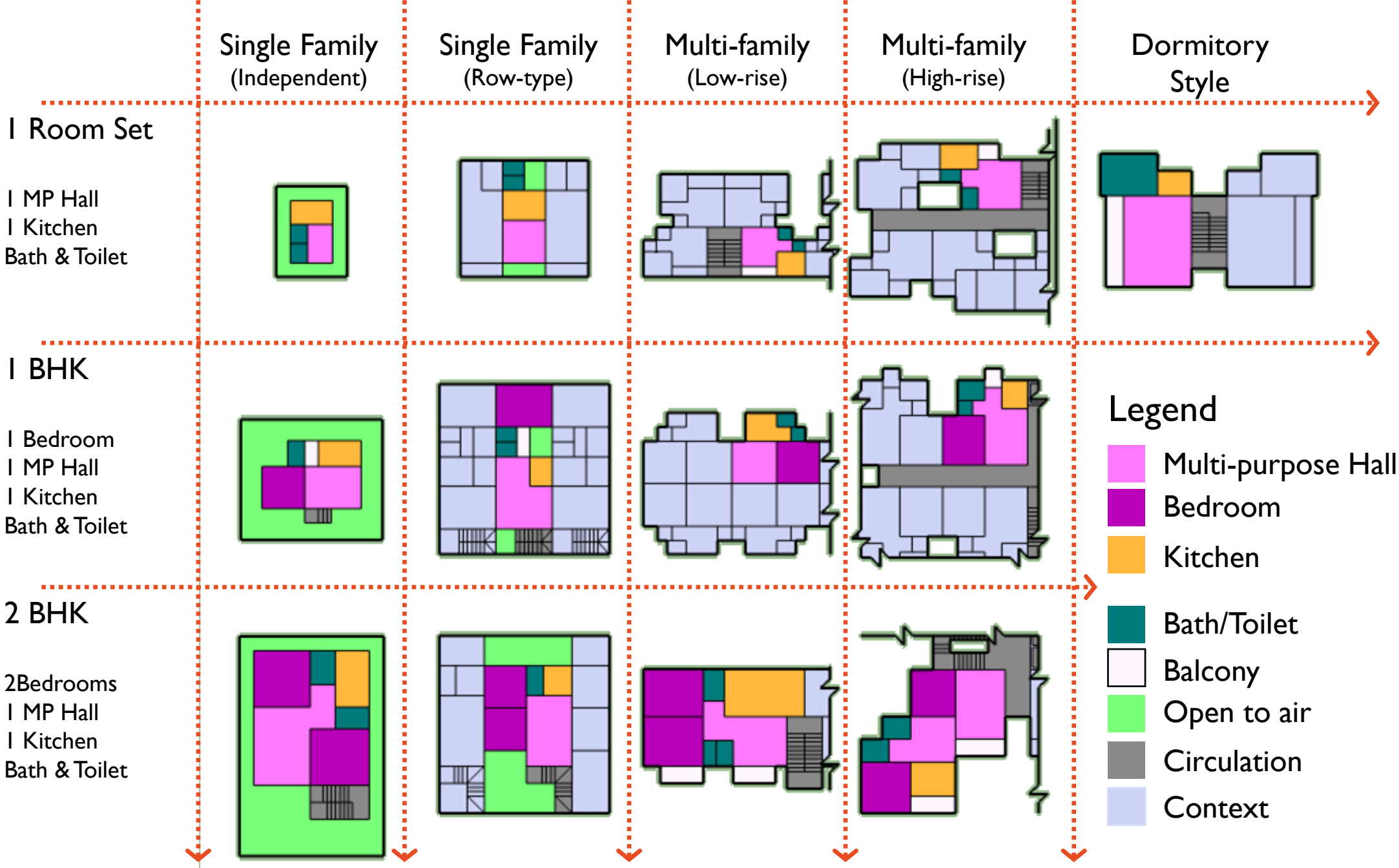
Private Developer, Hinjewadi, Pune

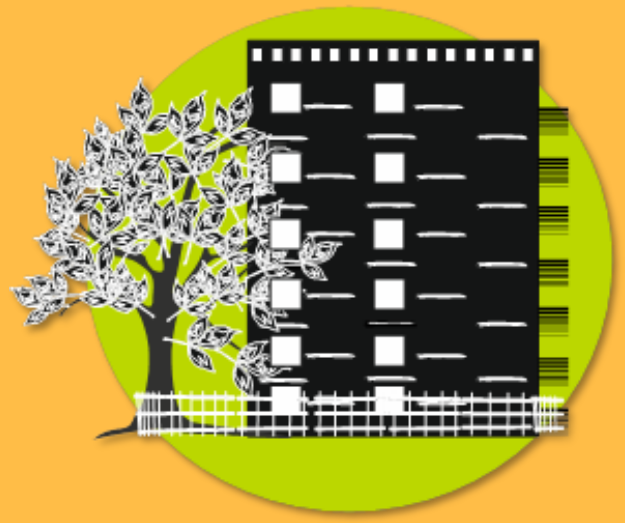


Sample Unit Plan

View

Source

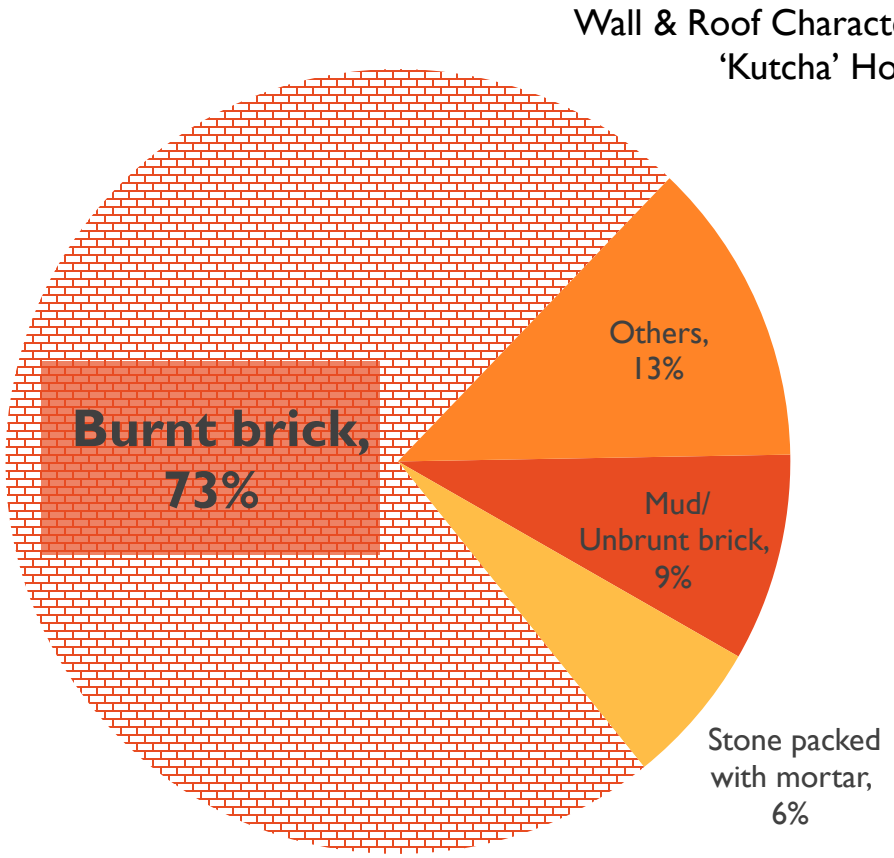

Single Family
(Independent)
Single Family
(Row-type)
Multi-family
(Low-rise)
Multi-family
(High-rise)
Dormitory
Style
1 Room Set
1 MP Hall
1 Kitchen
Bath & Toilet
1 BHK
1 Bedroom
1 MP Hall
1 Kitchen
Bath & Toilet
2 BHK
2Bedrooms
1 MP Hall
1 Kitchen
Bath & Toilet
Legend
Multi-purpose Hall
Bedroom
Kitchen
Bath/Toilet
Balcony
Open to air
Circulation
Context



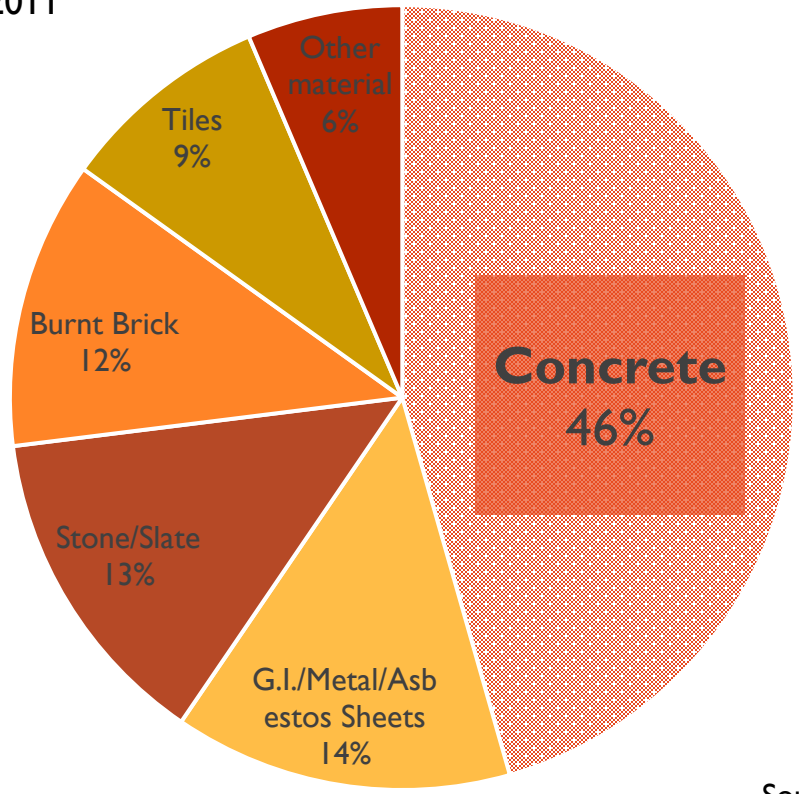
Affordable Housing Trends & Material Characteristics

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

Brick walls & Concrete Roof characterize 'Pucca' homes



Wall & Roof Characteristics for 'Pucca' and 'Kutcha' Homes in 2011



Source: Census 2011

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

Information from peer reviewed research is consistent with Census data

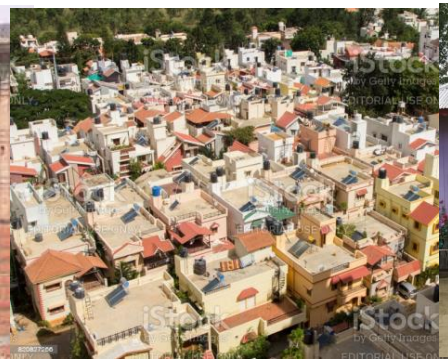
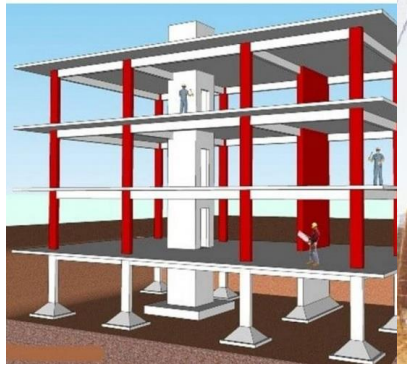
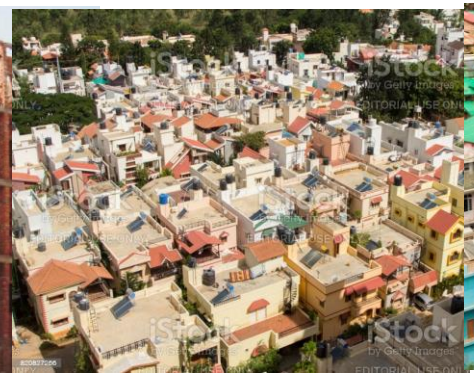
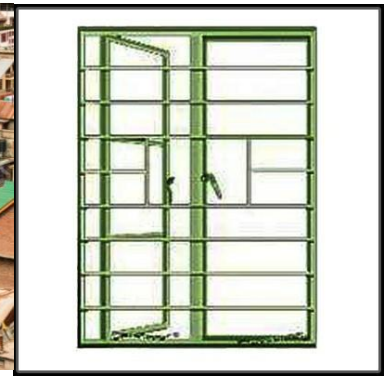
Source	Roof	Wall	Floor	Window	Remarks
Trust Fund for Environmentally and Socially Sustainable Development	No Information	Brick wall with plaster on both sides. (U: 2.8 $W/m^2.°C$)	concrete slab (U: 3.5 $W/m^2.°C$)	single plane, clear (U: 5.0 $W/m^2.°C$)	Alternative materials, technologies and practices 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/m^2
Occupancy: 4 (Husband, wife & 2 Children)

Information from peer reviewed research is consistent with Census data

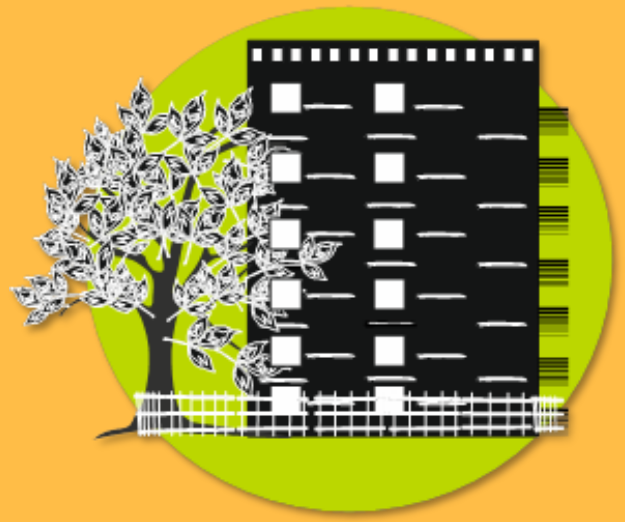
Source	Roof	Wall	Floor	Window	Remarks
Mainstreaming Sustainable Social Housing in India (MaS-SHIP)	No Information	230/250mm thick burnt clay brick masonry in cement-sand mortar (1:6) Cement-Sand Plaster 20mm thick (external)	Ceramic/ vitrified tiles Locally available (pre polished) stone tiles 20-30mm 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

Typical Material Specifications

	Structure	Wall	Roof	Roof-pitched	Frame/Glazing
Single-family	 Load bearing with stone/brick foundation	 Burnt Clay Brick 9”	 RCC Slab (4-6”)	 Corrugated GI Sheet	 Wooden Frame Wooden Shutter/Single Glazed
Multi-family	 RCC Frame	 Burnt Clay Brick 9”	 RCC Slab (4-6”)	 Corrugated Sheet	 Rolled Steel Section Single Glazed

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) Fly Ash bricks are being used as well now.	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.			Pressed steel door-window frames (125mmx65mm double rebate or 100mmx50mm single rebate)	



Housing Characteristics: Alternative practices

Review of alternative materials, construction technologies and passive design principles

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.**

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**

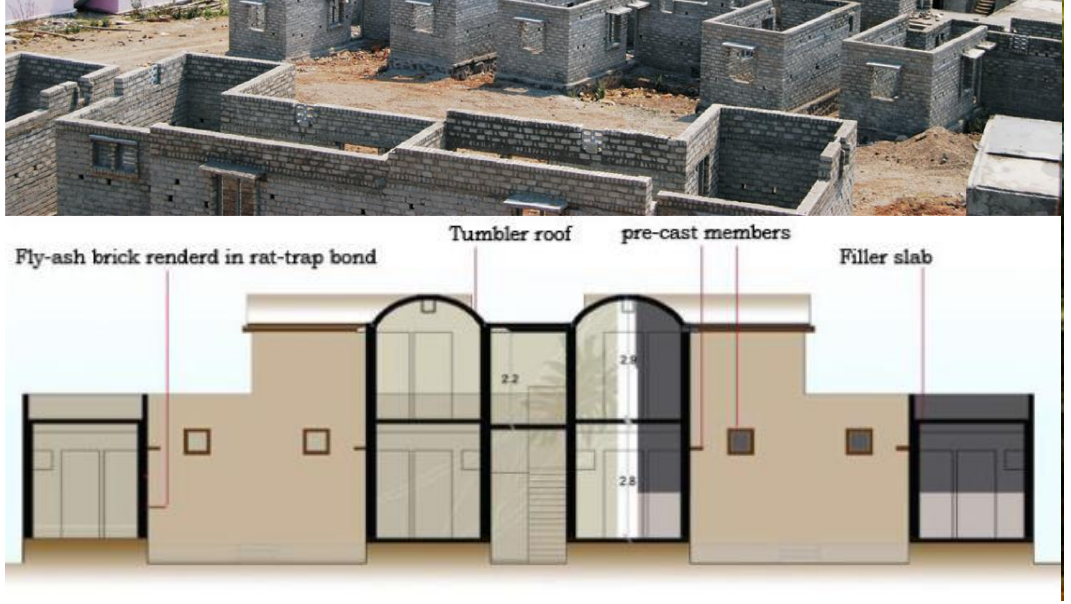
Realization Community	Tamil Nadu, Warm-Humid
Multi-family (G+2)	1BHK, 2 BHK
Wall	Compressed Stabilized Earth Blocks (CSEB) with lime stabilized earth plaster
Floor	Vaulted floor systems having cavities and ventilators
Roof	**CSEB vaulted roofing with insulation**
Openings	Single Glazed windows
Passive features	# **Double height spaces for stack cooling** # **Earth cooling tunnels** # **Hygrothermal cooling**

Humility	Tamil Nadu, Warm-Humid
Multi-family (G+3)	2 BHK (131 m^2), 3 BHK (170 m^2)
Wall	**Flyash bricks with Lime cement finish**
Floor	Vitrified tiles
Roof	**Styrofoam insulation and reflective tile finish**
Openings	Anodized Aluminium frame for windows
Passive features	# **Designed for cross ventilation** # Vegetation shading East and West walls

Slum Rehab	Bhuj, Hot-dry
Incremental Row-house (G+1)	2 BHK (21-35 m^2)
Wall	Light colored walls
Floor	
Roof	**Sloping roof with insulation layer, and Flat roof made of shallow domes using earth blocks**
Openings	
Passive features	#

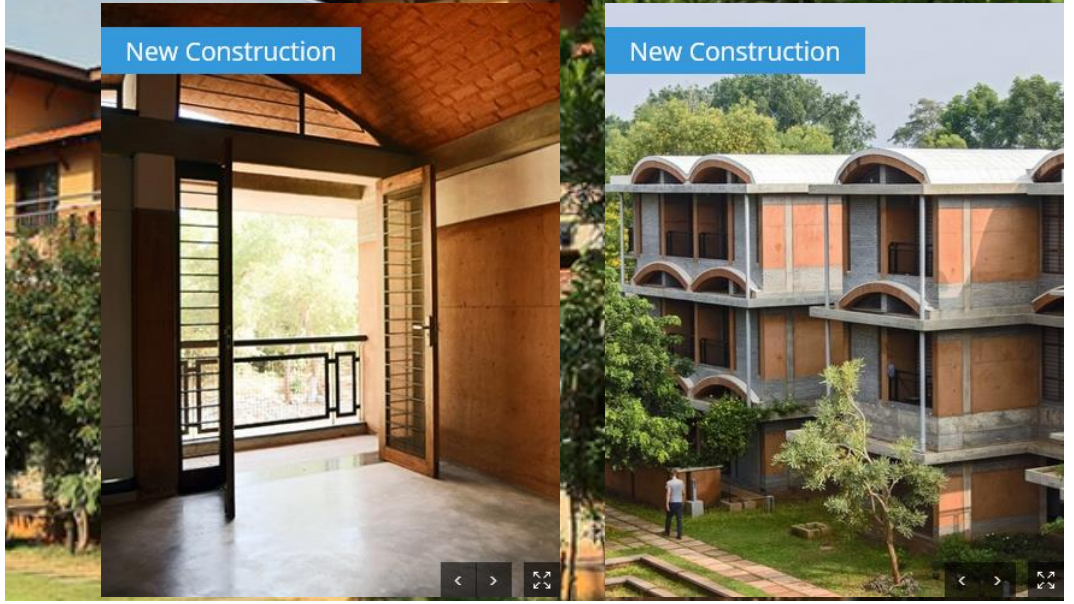
Smart Ghar III	Rajkot, Hot-dry
Multi-family, Stilt + 7	1 BHK (34 m^2)
Wall	Cavity wall (South façade), 230mm AAC block
Opening	Casement windows (shaded)
Roof	**Insulated (40mm Polyurethane foam insulation) and roof finished with china mosaic.**
Passive features	# **Mechanically assisted ventilation via shaft** # **Insulated roof with reflective finish** # **Windows with external movable shades**

Demonstration Housing Project	Rae Bareli, U.P., Composite
Multi-family (G+1)	1BHK (34 m^2)
Wall	Burnt Clay bricks in Rat Trap Bond
Floor	IPS flooring
Roof	**Reinforced Brick Concrete Slab for ground floor roof, Filler slab with Earthen Pots** for slope roofing, Mangalore tile cladding on sloping roof.
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**



IHSDP Phase II	Lonar, Maharashtra, Hot-Dry
Multi-family (G+1)	1 BHK (25 m^2)
Wall	**230 mm Rat trap bond using Flyash Bricks** and 15mm plaster on both faces.
Roof	**Tumbler roofing**, that is burnt clay conical tumblers are placed in the arch on the 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.

GERES	Leh, Cold
Single-family	1BHK (34 m^2)
Wall	**Rammed earth** or mud/cement bricks
Floor	**Insulated floor**
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.
Passive features	# **South facing solarium** # **Double wall with insulation** # **Insulated floor and roof**



Humanscapes Habitat	Puducherry, Warm-Humid
Multi-family (G+2)	1, 2, 3 & 4 BHK
Wall	**Poured Earth Concrete (PEC) wall** and Waste Cuddapah stone wall
Floor	Natural stone and IPS flooring
Roof	Brick vaults.
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

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

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)

Fly-ash Lime, Sand and Gypsum Composite Bricks

Compressed Earth/ Fly-ash Lime, Sand and Gypsum Composite Binterlocking blocks

Rat-trap Masonry

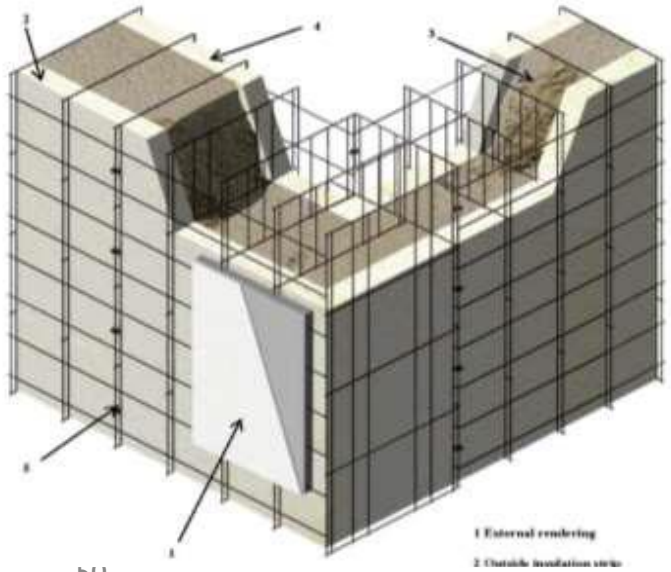
Compressed Earth Blocks

Cement Plaster on Bamboo Split

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

Expanded Plolystyrene Core Panel System

Monolithic Construction With Structural Stay-In-Place CR Steel Specially Designed Formwork System (Coffor)



Stay in place EPS double walled panel system

Light Gauged Steel frame Structure

Source: Demonstration Housing Project using Emerging Technologies, BMTPC

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 Interlocking blocks	Monolithic Construction with Structural Stay-In-Place CR Steel
Expanded Polystyrene Core Panel System	Specially Designed Formwork System (Coffor)
Exterior Insulation and Finishing System	Poured Earth Concrete
Factory Made Fast Track Modular System	Rat-trap bond
Fibre reinforced cement sheets on either side of light weight concrete core (Aerocon Panels)	Stay in place EPS double walled panel system
Glass Fiber Reinforced Gypsum (GFRG) Panel Building System	

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		

Bamboo Mat Corrugated Roofing sheet

Reinforced Brick Panel and Joists

Ferrocement Roofing Channels

Filler Slab

RCC Plank and Joists

Micro-concrete Roof Tiles

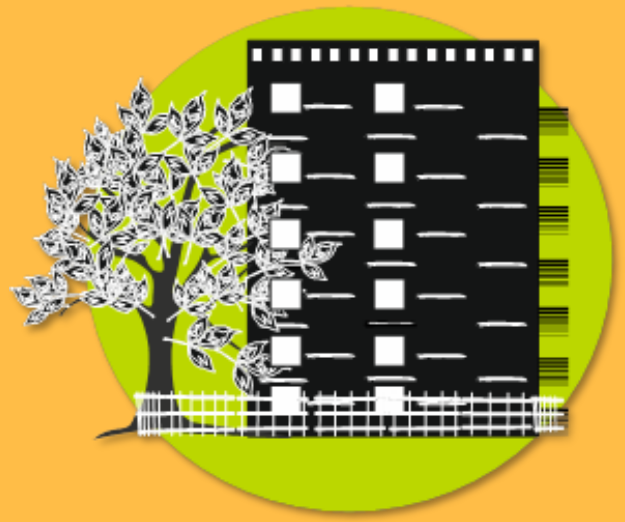
Source: Environment Friendly Indian Building Material Technologies for Cost Effective Housing.
Society for Excellence in Habitat Development, Environment Protection and Employment Generation (SHEE)

Range of Material Characteristics

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

Range of design characteristics

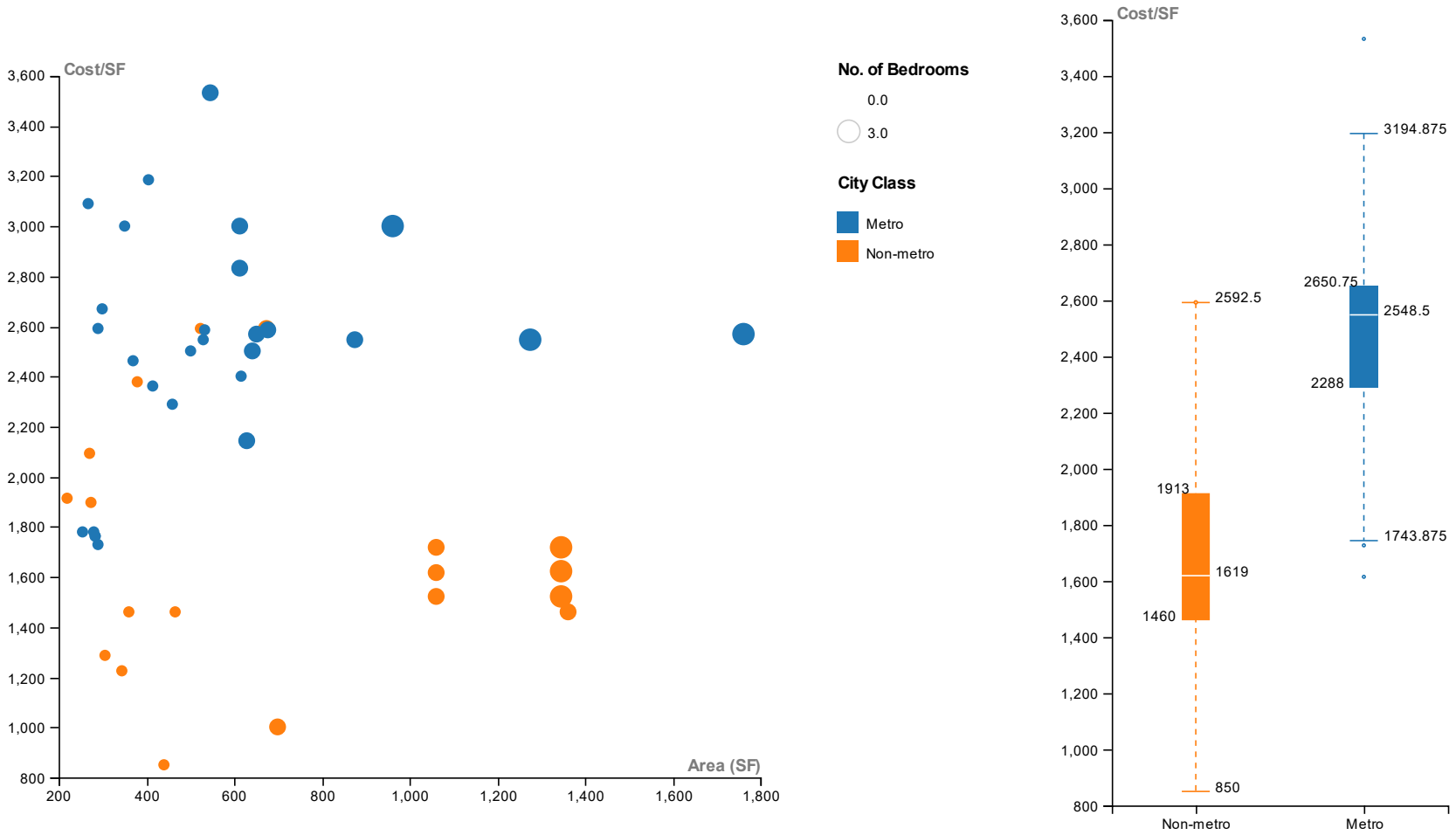
Item	Units	Range – Low	Range – High
Window Wall Ratio	%	5	50
Wall(Exposed) Floor Ratio	%	65	>100
Window (Operable Area) Floor Ratio	%	7	35
Shading (Projection Factor)	Fraction between (0 - 1)	No Shading (PF=0) Combination of Shading Devices • Overhang only • Fin only • Overhang and Fin	PF=1



Cost of Affordable Housing

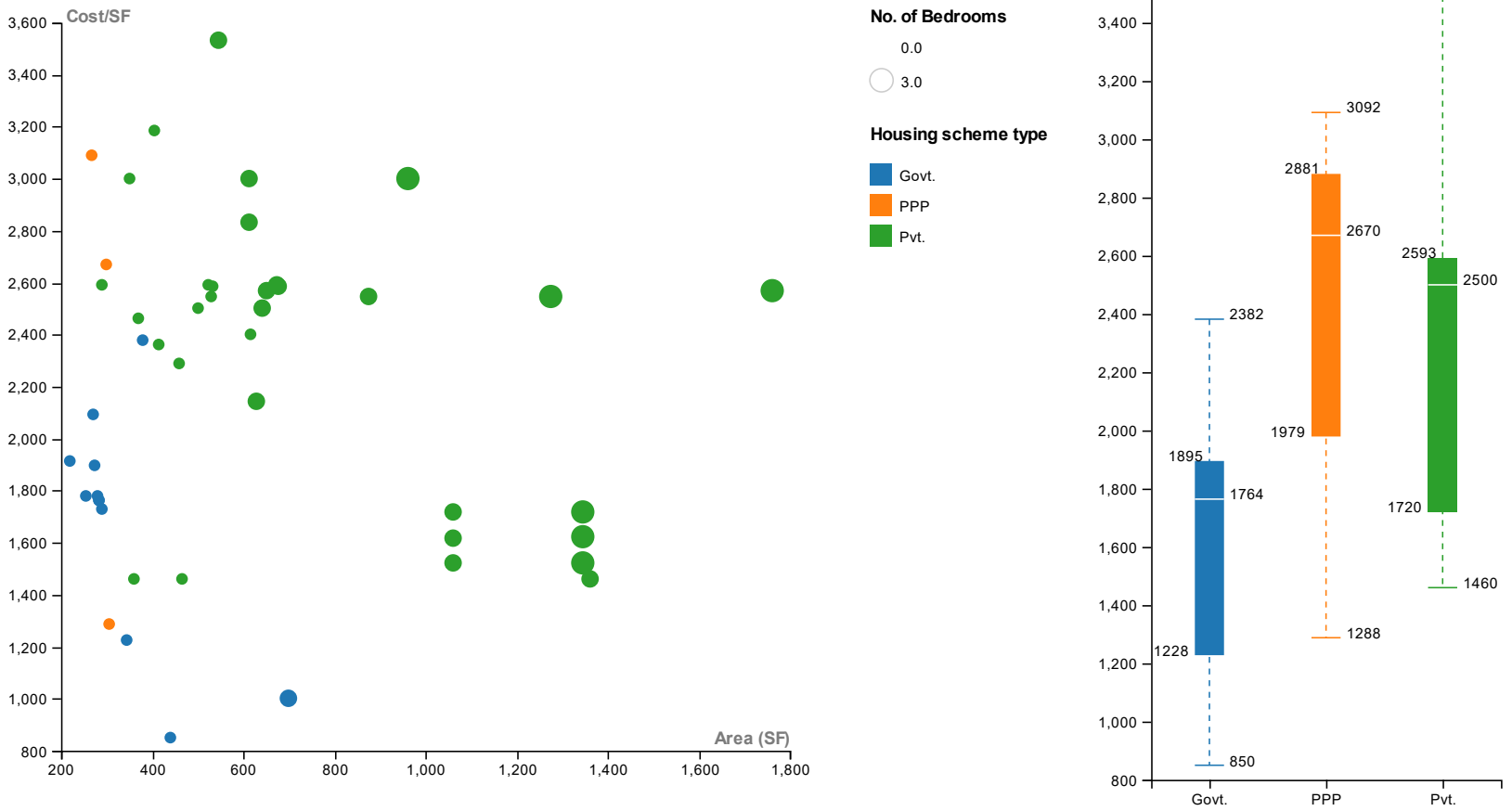
Analysis of cost data from projects by private developers and government agencies

Cost for Affordable Housing is Higher in Metros

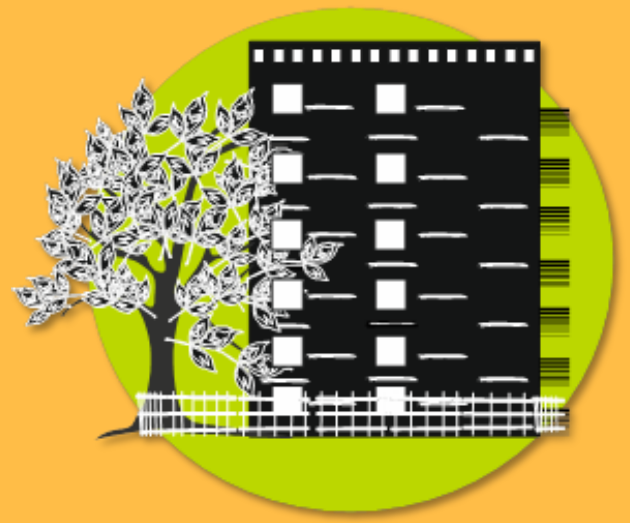


Analysis based on a sample set of 50 Housing projects spread across India

Government sponsored Affordable Housing is cheaper, but only after Subsidies



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



Thanks!