Replicable designs for Thermally Comfortable Affordable housing

First stakeholder meeting | 11 April 2022
PROJECT OVERVIEW

SESSION I
Overview of existing design and construction practices to identify gaps in achieving optimal Thermal comfort

- Objectives and deliverables
- Survey dataset
- Overview & inferences of General trends
- Gap analysis methodology
- Inferences

SESSION II
Framework for development of type designs

- Categorization of residential buildings for Type designs
- Type design matrix
- Principles for planning and passive design for thermally comfortable affordable housing
- Passive strategies to be adopted in different climate zones

SESSION III
Type design overview of Thermal Performance and Carbon Footprint of Construction

- Key indicators: Thermal Performance and carbon footprint of construction
- Thermal performance: Methodology for simulation
- Thermal Performance variants –DU location, orientation and walling/roofing material
- Embodied Energy Intensity (EEI) and carbon footprint of construction
1.1. Background

GOI’s flagship program under implementation since 2015 to provide ‘Housing for all’ by 2022

Provides **Central Assistance to implementing agencies through States and Union Territories** for providing houses to all eligible families/beneficiaries by 2022.

The Mission **will be implemented through four verticals** (as shown in the image)

**Urban**

**More than 12 million houses**

are being constructed within the Mission period

**“In situ” Slum Redevelopment**

**Affordable Housing through Credit Linked Subsidy**

**Affordable Housing in Partnership**

**Subsidy for Beneficiary-Led Individual house construction or enhancement**

**Multi-family homes in cities**

**Single-family homes on independent plots**
1.1. Background

Potential challenges

• Homes built today will last at least 50-60 years.

• They will impact resource usage during their life span.

• The design and construction of these homes will have an impact on the level of comfort that these dwellings provide to its occupants, thus impacting their energy use and costs to achieve environmental comfort and associated carbon emissions over their lifetime.

• The expected increase in cooling needs due to higher aspirations arising from enhanced access to housing will also significantly increase the projected electricity demand.

• With climate change temperature rise compounded by increasing UHI in urban areas will also add to this demand.

Optimizing thermal comfort by passive design means is imperative while designing and building homes affordable housing.
GIZ has supported GOI for:

- The development of Eco-Niwas Samhita
- Labelling mechanism for residential building
- Energy Efficient Building Material Directory
- Replicable designs for energy efficient residential buildings
- Smart Home program.

1.1. Background

**Climate Smart Buildings (GIZ – CSB)**

- Technical assistance in developing thermal comfort action plan for climate resilience building for mass scale application in selected states for Affordable Housing
- Technical support in implementation of Global Housing Technology Challenge-India (GHTC-India)
1.2. Project objective

To enhance climate resilience and thermal comfort in buildings by adopting appropriate passive measures, locally available and low embodied energy materials coupled with appropriate available technologies of construction for affordable housing.

The main objective is developing a Catalogue of Replicable Design options for Thermally Comfortable Affordable Housing by minimizing discomfort hours in homes through use of passive design measures.
### 1.3. Project team and roles

<table>
<thead>
<tr>
<th>TEAM LEAD</th>
<th>Environmentally sustainable and affordable architecture expert,</th>
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<tbody>
<tr>
<td>ASHOK B LALL</td>
<td>ABLA</td>
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<thead>
<tr>
<th>EXPERTS</th>
<th>Building Performance Analysis Expert</th>
<th>International Expert</th>
<th>BIM Expert</th>
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<tr>
<td></td>
<td>M SELVARASU LEAD</td>
<td>Dr. RAJAT GUPTA Oxford Brookes University</td>
<td>RAMNEET KAUR ASP Associates</td>
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<tr>
<td></td>
<td>RATHNASHREE LEAD</td>
<td>RAKESH DAYAL ABLA</td>
<td>PRASHANT BHANWARE GKSPL</td>
<td>KALHAN MITRA PCPL</td>
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<thead>
<tr>
<th>EXPERTS</th>
<th>Architectural Design Expert</th>
<th>Passive Strategies Expert</th>
<th>Webtool designer</th>
<th>Project management</th>
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<tr>
<td></td>
<td>ROOPA NAIR ABLA</td>
<td>SASWATI CHETIA GKSPL</td>
<td>SADDAM HUSSAIN IWL</td>
<td>GAUTAM NAGAR Optimus Energy Consultants</td>
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</table>
1.4. Our interpretation and approach

Develop a practical solution-set responding to the policy objectives of ‘Housing for All’, SDGs, and the Climate Change mitigation commitments of the GOI.

Focus on urban house types that are suitable for EWS and LIG categories since 80% of the current unmet need for homes are in these categories.

Consider the emergent future of affordable housing while also addressing the present need of affordable housing today.

Develop the replicable design set as a response to the modes of housing provision under PMAY(U) such as cooperative/local authority/institutional group housing, to developer built mass housing, to self-build beneficiary led mode.

Evaluate the designs using a techno-commercial matrix vis-à-vis the SDGs, affordability/economy, Climate mitigation potential considering embodied energy and potential operational energy, and thermal comfort.

Prioritize economy and simplicity of construction while optimizing thermal comfort is to be prioritized.

Introduce potential new materials and innovative methods of construction that enhance comfort and reduce Co2 emissions of construction.
1.5. Key project stakeholders

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<tr>
<td>POTENTIAL VALUE TO STAKEHOLDER:</td>
<td>POTENTIAL VALUE TO STAKEHOLDER:</td>
<td>POTENTIAL VALUE TO STAKEHOLDER:</td>
<td>POTENTIAL VALUE TO STAKEHOLDER:</td>
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<tr>
<td>• Support the fulfillment of the GOI commitments under ‘Housing for all’ and the SDG</td>
<td>• Support on the development of innovative technologies and sustainable construction materials through technical inputs.</td>
<td>• Support on effective implementation of affordable housing schemes through a better understanding on ‘affordability’.</td>
<td>• Access to the replicable design drawing set, BOQ and simulation packages.</td>
</tr>
<tr>
<td>• Technical inputs on developing the thermal comfort action plan for climate resilience building</td>
<td>• Provide a standard for thermal comfort in affordable housing.</td>
<td>INPUT REQUESTED:</td>
<td>INPUT REQUESTED:</td>
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<td>INPUT REQUESTED:</td>
<td>• Inputs on methodologies and design strategies proposed for the projects</td>
<td>• Inputs on gaps in the present scenario and any foreseen challenges in the implementation of the project outputs</td>
<td>• Inputs on gaps in the present scenario and any foreseen challenges in the interpretation and implementation of the project outputs</td>
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<td>• Inputs on assumptions and parameters for the project based on current research and policy</td>
<td>• Inputs on new materials and technologies based on research</td>
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SESSION I

Overview of existing design and construction practices to identify gaps in achieving optimal Thermal comfort
#### SESSION I: Objectives and deliverables

**OBJECTIVE**

Documentation of architectural typology, construction technology and materials used for affordable housing under PMAY-(U)

**PMAY(U) AFFORDABLE HOUSING DOCUMENTATION**

**PART A**

General trends of affordable housing construction

To understand the current housing typologies, construction technologies, associated costs, thermal performance and the possible correlation to their specific climate zones

- Observed trends in building plan types
- Observed trends in construction technologies
- Identification of plan types and construction technologies for thermal comfort

**PART B**

Prevalent gaps in design/construction practices in adopting strategies for thermal comfort

- Draw attention to gaps in adoption of passive design strategies
- Draw attention to embodied energy intensity of construction technologies and materials
- Show analytically, building types, construction technologies that are low carbon and economically suitable for affordable housing.

**DELIVERABLES**

- Report on documentation of typologies of affordable housing projects
- Gap analysis document w.r.t thermal comfort and sustainability
Criteria for project selection to be representative of the sets and categories shown below:

<table>
<thead>
<tr>
<th>A) PROJECT TYPE</th>
<th>B) CLIMATIC RANGE</th>
<th>C) BUILDING HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWS</td>
<td>Cold</td>
<td>Low –rise</td>
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<tr>
<td>LIG</td>
<td>Composite</td>
<td>Mid - rise</td>
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<td></td>
<td>Warm and Humid</td>
<td>High – rise</td>
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<td></td>
<td>Hot and Dry</td>
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<td></td>
<td>Temperate</td>
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<table>
<thead>
<tr>
<th>D) BUILDING PLAN TYPE RANGE</th>
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<tbody>
<tr>
<td>Plotted</td>
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<tr>
<td>Singly Loaded corridor(SLC)</td>
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<tr>
<td>Doubly Loaded corridor(DLC)</td>
</tr>
<tr>
<td>Row House (RH)</td>
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<tr>
<td>Tower Stand Alone (TSA)</td>
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<tr>
<td>Tower Connected (TC)</td>
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<table>
<thead>
<tr>
<th>E) CONSTRUCTION TECHNOLOGY RANGE</th>
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<tbody>
<tr>
<td>RCC Structure with AAC block</td>
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<tr>
<td>RCC Structure with burnt clay / flyash masonry</td>
</tr>
<tr>
<td>Monolithic concrete</td>
</tr>
<tr>
<td>RCC Structure with concrete blockwork</td>
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### SESSION I: Lighthouse Projects (LHP)

<table>
<thead>
<tr>
<th>NAME</th>
<th>LHP, Agartala, Tripura</th>
<th>LHP, Chennai, Tamil Nadu</th>
<th>LHP, Indore, Madhya Pradesh</th>
<th>LHP, Lucknow, Uttar Pradesh</th>
<th>LHP, Rajkot, Gujarat</th>
<th>LHP, Ranchi, Jharkhand</th>
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<tr>
<td><img src="image1.png" alt="Image" /></td>
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<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
</tr>
<tr>
<td>Building Plan Type</td>
<td>DOUBLY LOADED CORRIDOR</td>
<td>TOWER STAND ALONE</td>
<td>TOWER CONNECTED</td>
<td>DOUBLY LOADED CORRIDOR</td>
<td>TOWER STAND ALONE</td>
<td>DOUBLY LOADED CORRIDOR</td>
</tr>
<tr>
<td>Building Height</td>
<td>G+6</td>
<td>G+5</td>
<td>Stilt+8</td>
<td>Stilt+13</td>
<td>Stilt+13</td>
<td>G+8</td>
</tr>
<tr>
<td>Construction Technology</td>
<td>Light gauge steel structural system</td>
<td>Pre-cast concrete construction system</td>
<td>Prefabricated sandwich panel system</td>
<td>PVC Stay in place formwork system</td>
<td>Monolithic concrete construction using tunnel formwork</td>
<td>Pre-cast concrete construction system - 3D Volumetric</td>
</tr>
</tbody>
</table>
SESSION I: Survey dataset

The survey case studies have been shortlisted from the 5 major climate zones to ensure an adequate range in project types.

Projects surveyed:
Affordable housing schemes 65
Lighthouse Projects 6
Total survey case studies: 113 + 6

Representing different building plan types and dwelling unit sizes.

GRAPH 1: % of affordable housing projects in each climate zone

Cold Climate
Composite Climate
Warm and Humid Climate
Hot and Dry Climate
Temperate Climate

Total survey case studies: 113 + 6
SESSION I: Overview – General trends of affordable housing construction under PMAY(U)

1. BUILDING PLAN TYPE

GRAPH 1: Identified building plan types

2. CONSTRUCTION TECHNOLOGY

GRAPH 2: Identified construction technologies

3. BUILDING HEIGHTS

GRAPH 3: Identified building height range

4. CLIMATE

<table>
<thead>
<tr>
<th>Single Loaded Corridor (SLC)</th>
<th>Doubly Loaded Corridor (DLC)</th>
<th>Row House (RH)</th>
<th>Tower Stand Alone (TSA)</th>
<th>Tower Connected (TC)</th>
</tr>
</thead>
</table>
• **No correlation between climate zone and building plan type.** All building plan types are found in every climatic zone.

• General trend indicates **tendency towards high rise typologies.** These are **high on EE intensity and CO2 emissions on account of construction.**

• However, **the adoption of low/mid-rise buildings is also common.** These have lower EE intensity and CO2 emissions on account of construction.

• General trend indicates **increasing adoption of lightweight AAC blocks in RCC frame.** Most preferred for mid and high-rise construction.

• The building plan type, building height and construction materials and technology are **determined primarily by project economics and permissible F.A.R according to development control regulations.**
SESSION I: Existing gaps in implementation of strategies for thermal comfort

A) APPLICATION OF PASSIVE DESIGN STRATEGIES
- Compactness
  - RETV
- To understand the existing gaps in the designing of thermally comfortable Affordable homes

B) SIMULATING FOR THERMAL PERFORMANCE
- Degree discomfort hours (IMAC-R)
- Daylight
- ECBC-R Compliance
  - WFr
  - VLT
  - U-Value (roof)

For selected projects only

Similar data to be received for Light House Projects from other consultants

C) COMPARING EMBODIED ENERGY INTENSITY
- Steel Intensity (Kg/Sqm of Carpet Area)
- Concrete intensity (cum/ Sqm of Carpet area)
- Walling system (Building shell) intensity

- To understand the impact of the construction system and material on thermal performance

D) UNDERSTANDING COST TRENDS
- Cost of Steel per Sqm of carpet area
- Cost of Concrete per Sqm of carpet
- Cost of Walling material per Sqm of carpet area

- To understand implications of building plan type, building height and building EEI on affordable cost
Compactness of plan is desirable for reduction of heat transfer across the building envelop and for energy conservation.

Compactness is the ratio of the DU external wall area to the DU carpet area.

Higher the value of the ratio, lesser is the compactness of the DU.

*A compactness ratio of 0.8 may be considered as an efficiency target for compactness.
• In **SLC and DLC** building plan types **compactness is achieved** irrespective of DU size.

• In **Tower Connected (TC)** building plan type it is seen that **compactness is poor in small DUs** and **improves for DU size between 50-60Sqm.**

• However, in **Tower Stand Alone (TSA)** it appears that **reasonable compactness** can be achieved at **all DU sizes.**
• RETV (Residential Envelope Transmittance Value) is a measure of heat transfer through the building envelope.

• RETV has been adopted as an energy efficiency measure for the Eco Niwas Samhita-R (ENS) code for residential building design.

• An RETV of 15 is considered as the maximum compliance value for warm climates.
It is observed that if ideal orientation of the longer facade facing N/S is considered, RETV performance shows good results in most cases.

However, it is seen that in the case of TC and TSA building plan types RETV of 15 is not met by approximately half the projects.
RETV (Worst case) – South West

An RETV of 15 is considered as the maximum compliance value.

SESSION I: Gap analysis: Application of Passive Design Strategies

CLIMATE SMART BUILDINGS: Replicable Design options for Thermally Comfortable Affordable Housing
When considering the worst case **SW orientation** for the main facade, the RETV performance declines significantly.

The **TC and TSA** projects have the worst RETV performance between a range of 20 and 32.
• Embodied energy intensity (EEI) is measured as embodied energy of structural system and external walling per sqm of DU Carpet area.

• EEI will be the dominant source of CO2 emissions in affordable housing. This becomes very important given the large scale of housing anticipated in the near future.

• EEI is analyzed in relation to building height. Low EEI will be preferred.

*G+7 may be considered as the maximum building height for EEI control.
• It can be seen clearly that embodied energy intensity (EEI) rises significantly with increase in building height.

• It is seen that EEI rises steeply as we move towards taller buildings. It can be seen that the building height may be limited to G+7 for EEI control.
Affordability of construction system is an important concern for affordable housing.

Cost of construction systems is primarily determined by the structural system (RCC & Steel) employed and the external walling material.

Construction cost of these two components per sqm of carpet area is proposed as a comparative measure to understand cost trends in relation to building height and building plan type.
WP1: Gap analysis

TOTAL COST OF CONSTRUCTION = COST/Sqm carpet area RCC + COST/Sqm carpet area Steel + COST/Sqm carpet area Walling ONLY

*Does not include cost of finishes and secondary building components (doors, windows and cabinets)
• **Affordability** of building construction is directly proportional to building height and the construction technology adopted.

• It is observed that monolithic concrete technology is the most expensive cost/Sqm carpet area.

• Low to mid-rise buildings remain reasonably affordable at a price of approximately 10,000 INR /Sqm of carpet area.

• It is seen that steel contributes approximately 45-55% of the total building cost and concrete about 35-40% remaining cost.
**COMPACTNESS**

For smaller homes (25-45Sqm) it would be advisable to adopt SLC, DLC and RH since it is easier to design them compactly.

**RETV**

Approximately 60% projects do not meet RETV requirements.

This clearly indicates that buildings are not being designed with respect to orientation which indicates the need for external shading system and window sizing with response to orientation.

**EMBODIED ENERGY**

For building heights beyond G+7, the EEI value rises sharply. This is most evident in the high-rise tower typologies.

**COST OF CONSTRUCTION**

The cost of taller buildings rises with height. This may be correlated with the increase in the quantity of steel consumed in the structural system of taller buildings.

Building height of up to G+7 which curtail the intensity of steel would be a positive and productive strategy to maintain construction affordability.
End of Session 1

Points discussed

1. WP1 Documentation divided into two parts:
   • General trends of affordable housing construction
   • Prevalent gaps in design / construction practices in adopting strategies for thermal comfort

2. Survey dataset
   1. Climatic range
   2. Building height range
   3. Building plan type range
   4. Construction technology range

3. General trends of affordable housing construction
   • Building plan types are not climate specific
   • From the dataset: Most prevalent building plan type is tower connected, most prevalent construction technology is RCC with AAC and most prevalent building height range is high-rise

4. Criteria for gap analysis
   1. Passive strategies
   2. Thermal comfort simulation
   3. Embodied energy Intensity
   4. Construction cost trends

5. Gap analysis inferences
   1. Compactness ratio of 0.8
   2. Orientation and shading to improve RETV performance
   3. Building up to G+7 for better EEI control
   4. Reducing quantity of steel and building up to G+7 as positive strategies for affordability
SESSION II

Framework for development of type designs
SESSION II: Categorization of residential buildings for Type designs

Building Types

- COLD CLIMATE
- WARM CLIMATES
  - COMPOSITE
  - WARM AND HUMID
  - HOT AND DRY
  - TEMPERATE
SESSION II: Categorization of residential buildings for Type designs

Building Types

Cold Climate
- Single Family Plotted
- Multi-Family - Group development

Warm climates
- Single Family Plotted
- Multi-Family - Group development
SESSION II: Categorization of residential buildings for Type designs

Building Types

Single Family Plotted
- ROW HOUSE 2 SIDE OPEN (PMAY(U) BLC)
- ROW HOUSE SEMI-DETACHED (PMAY(U) BLC)

Multi- Family group development
SESSION II: Categorization of residential buildings for Type designs

Building Types

Single Family Plotted

- ROW HOUSE BACK TO BACK
  - 1 BHK
- ROW HOUSE 2 SIDE OPEN
  - 1 BHK
  - 2 BHK
- DOUBLY LOADED CORRIDOR
  - 1 BHK
  - 2 BHK
  - DORM (PMAY(U) Rental)
  - HOSTEL (PMAY(U) Rental)

Multi-Family Group Development

- TOWER CONNECTED
  - 2 BHK
  - 2.5 BHK
- TOWER STAND ALONE
  - 2 BHK
  - 2.5 BHK
### Replicable Type Design Matrix

#### Single Family Plotted

<table>
<thead>
<tr>
<th>ROW HOUSE – 2 SIDE OPEN</th>
<th>1BHK</th>
<th>1BHK</th>
<th>2BHK</th>
<th>2BHK</th>
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</thead>
<tbody>
<tr>
<td>ROW HOUSE SEMI-DETACHED</td>
<td></td>
<td>2BHK</td>
<td></td>
<td>2BHK</td>
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</tbody>
</table>

#### Multi-Family group development

**LOW RISE**
(BUILDING HEIGHT <=12M (G+3))

Selected type designs will –

- Consider 2 construction technologies
- 2 orientations (best and worst)
**SESSION II : Type Design matrix**

**Replicable Type Design Matrix**

**Multi- Family group development**

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**Selected multi-family type designs will –**

- **Consider 3 construction technologies**
- **2 orientations** (best and worst)
- **2 Vertical locations** (Middle and Bottom)
- **2 Horizontal locations** (Edge and Middle)

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### LOW RISE (BUILDING HEIGHT <=12M(G+3))

<table>
<thead>
<tr>
<th>ROW HOUSE – 2 SIDE OPEN</th>
<th>1BHK (&lt;= 30SQM)</th>
<th>1BHK (30-45SQM)</th>
<th>1BHK (30-45SQM)</th>
<th>2BHK (30-45SQM)</th>
<th>2BHK (45-60SQM)</th>
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</thead>
<tbody>
<tr>
<td>ROW HOUSE BACK TO BACK</td>
<td>1BHK (&lt;= 30SQM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SINGLY LOADED CORRIDOR</td>
<td>1BHK (&lt;= 30SQM)</td>
<td>DORM 1 (&lt;= 30SQM)</td>
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<td></td>
</tr>
<tr>
<td>DOUBLY LOADED CORRIDOR</td>
<td>1BHK (&lt;= 30SQM)</td>
<td>DORM 2 (&lt;= 30SQM)</td>
<td>HOSTEL (&lt;= 30SQM)</td>
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</tbody>
</table>
Selected multi-family type designs will –

- Consider 3 construction technologies
- 2 orientations (best and worst)
- 2 Vertical locations (Middle and Bottom)
- 2 Horizontal locations (Edge and Middle)
SESSION II: Principles for planning and passive design for thermally comfortable affordable housing

1. COMPACTNESS

Surface to Volume ratio increase from A to C as the built form gets more complicated

2. PROTECTION FROM HEAT

- Controlling Window to Wall area Ratio (WWR)
- Selecting external wall/roof materials for insulation value

3. PROTECTION THROUGH SHADING

Use of shading devices to cut Solar gains

4. OPTIMIZING OPENINGS FOR VENTILATION

Ensuring cross ventilation through all living spaces of the house

5. USE OF THERMAL MASS & SOLAR GAINS TO ENSURE INDOOR COMFORT

- Winter day: Solar heat gets stored in the built mass
- Winter night: the heat stored during the day is radiated inside
- Summer day: Ventilation on right will help cool the building mass down
- Summer night: Ventilation on left will help cool the building mass down
End of Session 2

Points discussed

1. Climate classification
   1. Warm climates
   2. Cold climate

2. Building Plan types
   1. Single family plotted
   2. Multi family group development

3. Principles for planning and passive design for thermally comfortable affordable housing
   1. Compactness
   2. Protection from heat
   3. Protection through shading
   4. Optimizing openings for ventilation
   5. Use of thermal mass and solar gains to ensure indoor comfort
SESSION III

Type design overview of Thermal Performance and Carbon Footprint of Construction
**CLIMATE SMART BUILDINGS**: Replicable Design options for Thermally Comfortable Affordable Housing

### SESSION III: Thermal Performance and carbon footprint of construction

#### Type design performance

**Thermal performance**

**Embodied Energy Intensity**

#### 1. ENS compliance for Envelope

- Check for compliance for WFR, WWR, U value (Walls, Roof), RETV for Composite, Warm & Humid, Hot & Dry and Temperate climates
- Check for compliance for WFR, WWR, U value (Roof), for Cold climates

**Software used**: N.A.

**Outputs**:  
1. **ENS Value** for each type design

#### 2. Energy Simulation

The building design - architectural, mechanical and electrical systems will be replicated in the energy simulation software to analyze the energy data, design effectiveness, performance of different systems, energy demand, energy consumption etc.

**Software used**: Design builder and Energy plus engine

**Outputs**:  
1. Degree-discomfort hours  
2. Daylight performance
Energy simulation is carried out in Design Builder software and detailed modelling is carried out in the Energy Plus engine.

Detailed inputs in terms of number floors, building geometry, Envelope details, and internal loads are provided in the simulation software. Detailed natural ventilation modelling is carried out in Energy Plus.

The schedule of occupancy is considered based on general practice in Indian household. No. of occupants are taken from NBC standards varies based on 1BHK/2BHK/3BHK.

IMAC-R will be used as the setpoint temperature. For window operating schedules NV is considered as the upper and lower limit.

80% Acceptability at ± 3.60 °C
90% Acceptability at ± 2.15 °C
Source: CARBSE, CEPT, 2022 (unpublished)

Lighting assumption for Baseline case study models is 4 W/m2 LPD.

Equipment is considered as BEE 3-star equipment, default from BEE Star Labelling for Residential buildings.)
SESSION III: A) Thermal Performance variants – DU location, orientation and walling/roofing material

<table>
<thead>
<tr>
<th>LOCATION</th>
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<tbody>
<tr>
<td>• VERTICAL</td>
</tr>
<tr>
<td>Ground, Middle and Top floor</td>
</tr>
<tr>
<td>• HORIZONTAL</td>
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<tr>
<td>Edge and middle units</td>
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<table>
<thead>
<tr>
<th>ORIENTATION</th>
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<tbody>
<tr>
<td>• The variants are in turn tested for different orientations with respect to true North.</td>
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<td>• The proposed type designs will be such that all unit variants meet the minimum standards of thermal performance.</td>
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<tr>
<th>WALLING / ROOFING MATERIAL</th>
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<tbody>
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<td>• The variants are in turn tested for different orientations with respect to true North.</td>
</tr>
</tbody>
</table>

Simulation results will be given for 1000 cases.
EEI will help understand the correlation between the building types and construction systems. It is measured as Kg of CO2 emitted per sqm of carpet area of dwelling unit. Total EEI for each type design will be a sum of three quantities:

1. Steel EEI
2. Concrete EEI
3. Walling EEI

Software used: NA

Outputs:

1. Embodied energy intensity (EEI) / Sqm of carpet area for all typed designs.
SESSION III: Embodied Energy Intensity (EEI) and carbon footprint of construction

- The EEI is measured as Kg of CO2 emitted per sqm of carpet area of dwelling unit
- Depends on type of structural system, building height and earthquake zone location
- Calculating the EEI will allow comparative observations of the type designs, construction technologies and building height

**Total Embodied Energy Intensity (EEI)**

**30%**
Finishes and sub-components

**70%**
Structural support and walling system

**EEI Steel**
- Highest contributor to EEI
- EE of total volume of structural steel / Sqm of carpet area

**EEI Concrete**
- Second significant component of building EEI
- EE of total volume of concrete / Sqm of carpet area

**EEI Walling**
- Significant contributor of building EEI
- EE of total walling area / Sqm of Carpet area

**EEI** + **EEI Concrete** + **EEI Walling**

**Notes:**
- The EEI is measured as Kg of CO2 emitted per sqm of carpet area of dwelling unit.
- Depends on type of structural system, building height and earthquake zone location.
- Calculating the EEI will allow comparative observations of the type designs, construction technologies and building height.

**Total EEI Building**:
- 30% finishes and sub-components
- 70% structural support and walling system
End of Session 3

Points discussed

1. Key parameters for analyzing type design performance
   • Thermal performance - ENS Compliance for envelope, Energy simulation
   • Embodied energy intensity – Total EEI = Steel EEI + Concrete EEI + Walling / Infill material EEI

2. Methodology for simulation

3. Thermal Performance variants
   • Location
   • Orientation
   • Walling / Roofing material

4. Embodied Energy Intensity and carbon footprint of construction
## Way Forward

### WEBINAR 1
- Overview of existing design and construction practices to identify gaps in achieving optimal thermal comfort
- Framework for development of type designs
- Overview of thermal performance and carbon footprint of construction

### WEBINAR 2
- Range and size of type designs
- Logic and methods of planning and construction of the type designs
- Passive design strategies that have been adopted
- Methodology and input parameters for the simulation models and results obtained

### WEBINAR 3
- Discussing the simulation results of different building plan typologies to understand their thermal performance.
- Thermal performance results across different climate zones and trends observed in different orientations
- General observations and learnings from the project with examples and comparisons across different typologies.

### WEBINAR 4
- Webtool structure and layout
- Navigating the web-tool
THANK YOU

Knowledge Partners:

- Ashok B Lall Architects
- LEAD Consultancy
- Greentech Knowledge Solutions