Energy-Efficient Housing
Outline

• Introduction to Energy Efficient Housing
• Climate analysis of Rajkot & its impact on design of buildings
• Key Design Strategies for Energy Efficient Housing
• Conclusions
Survey of electricity use and designs of flats – NCR & Chennai

- Flat Area ~ 800-1300 sq. ft
- Year 2009/2010

NCR: 732 Flats
Chennai: 417 Flats
Conclusions - Survey

Climate Responsive Design + EE Appliances + Energy conscious occupants

20-40 kWh/m\(^2\)/year (Rs 1000-1500 per month)

Average EPI 45-50 kWh/m\(^2\)/year (Rs 2000-3000 per month)

Poor Design + High reliance on AC

80 - 100 kWh/m\(^2\)/year (Rs 5000 per month)
Energy-Efficient Housing?

- Does not heat up abnormally during long summer season.
  - The requirement for use of coolers and ACs is minimized.
- Good ventilation to utilize cool breeze during evening, night and mornings.
- Adequate day lighting (kitchen, corridors, rooms,..); minimizes the need to switch-on artificial light during day.
- The use of electricity/fuel for heating water is minimized. Utilizes solar energy for meeting part of electricity/ water heating requirements.
- Energy-efficient lighting, equipments, appliances, ...
- Low embodied energy in construction - minimizing the use of energy intensive materials - steel, cement, glass,...
- Affordable
  - No/low additional construction cost.
  - Low electricity bill for occupants.
  - Easy and low-cost maintenance.
A design approach that integrates architectural and engineering solutions at an **early design stage** is required for getting an energy-efficient design.
Climate

- Temperature
- Humidity
- Solar Radiation - Direct & Diffused
- Wind
- Rain

Map showing climate regions in India, with Rajkot highlighted.
Rajkot - Ambient Temperatures

Avg. Max. Temperature > 35 C \(\rightarrow\) reducing heat gains from building envelope

Evening, night, morning temperatures < 24 C \(\rightarrow\) natural ventilation can be used
Rajkot- Solar Radiation

**India Solar Resource**

Global Horizontal Irradiance - Annual Average

This map depicts model estimates of annual average global horizontal irradiance (GHI) at 10 km resolution based on hourly estimates of radiation over 10 years (2000-2014). The inputs are visible imagery from geostationary satellites, aerosol optical depth, water vapor, and ozone. The country boundary shown is that which is officially sanctioned by the Republic of India.

- **Very high solar radiation**
- **Insulation of roof/cool roof a must**
- **Reasonable window to wall ratio (< 30%). High glazing area to be avoided**
- **Windows shading a must – static and shutters**
- **Good outputs from solar PV or hot water systems**
Oct to May → Dry Climate → Evaporative cooling possible
June to August → Warm & Humid → Air Conditioning
Rajkot - Sun Exposure In Different Directions

- North façade receives very little direct radiation, only in summer mornings and evenings.
- East and West façades receive high amount of radiation both in summer and winter.
- South façade is highly exposed in winter, but less in summer.
- Horizontal surface receives the greatest intensity.

- Reducing heat gains from roof – insulation, shading, reflection, ..
- Minimizing exposed surfaces on east & west; fixed shades not effective
- Windows on north & south can be protected to some extent by fixed shades.
1. Reducing Solar Heat Gains Through Proper Orientation & Massing

Reduction in solar exposure:
1. By orienting the buildings i.e. larger façade on North and South direction.
2. Double Loaded Corridors, to reduce exposed wall area.

Source: Happinest, Mahindra, Chennai
2. Reducing Heat Flow Through Roof

- In case of uninsulated concrete roof slab, the inside roof surface temperature in summer > 40 °C.
- Proper treatment of roof can help in reducing room temperatures by 4-5 °C.

Source: Coolroofs for cool Delhi, EDS
Reducing Heat Flow Through Roof

- RCC SLAB
- BRICKBAT COBA
- CEMENT SCREED
- INSULATION
- REFLECTIVE SURFACE FINISH
Reducing Heat Flow Through Roof

- Broken China Tiles
- Fresh Reflective Paint
- Shading of roof
- Hollow Clay Tiles

Source: TARU & BEEP
3. Reducing Heat Flow Through Walls

- 150 mm concrete wall; $U = 3.3 \text{ W/m}^2\cdot\text{K}$
- 230 mm brick; $U = 2.8 \text{ W/m}^2\cdot\text{K}$
- 115 mm brick; $U = 2.0 \text{ W/m}^2\cdot\text{K}$
- 115 mm + 50 mm cavity + 115 mm brick; $U = 1.4 \text{ W/m}^2\cdot\text{K}$
- 230 mm + 50 mm cavity + 115 mm brick; $U = 1.1 \text{ W/m}^2\cdot\text{K}$
- 200 mm AAC; $U = 0.7 \text{ W/m}^2\cdot\text{K}$
- 230 mm brick + 65 mm XPS; $U = 0.4 \text{ W/m}^2\cdot\text{K}$
Reducing Heat Flow Through Walls

Source: Happinest, Mahindra, Chennai
Use Light Colours/ Lime White Wash on External Walls
4. Cross Ventilation at Flat & Room Level
Cross Ventilation

In a room of 120 sq ft, having two openings of 4x3 ft (fully openable)
- 10 ACH at very low velocities
- 20-30 ACH at higher velocity.

Openable area of openings on external walls of a flat ~ 20-25% of the flat area.

Provision of ventilators above doors.
Single-Sided Ventilation

Single sided ventilation 3°C
Temperature difference inside-outside

Taller windows provide better ventilation.
The window is designed as a system - one that brings in daylight, has a shading fixture, can be opened to bring in cool air and can also accommodate an AC if required.

Source: Happinest, Mahindra, Chennai
Design kitchen for good ventilation

Poor ventilation

Good ventilation
Analysis of wind flow for large projects
5. Daylighting & Ventilation of Corridors

Break in the corridor which allows air movement

Source: Happinest, Mahindra, Chennai; Kesar City, Ahmedabad
6. Shading of Windows

Source: Adlakha Associates; Kesar City, Ahmedabad
Shading of windows

MS frames in balcony for possible installation of chiks and blinds.

Source: Happinest, Mahindra, Chennai
External Movable Shading of Balcony

Source: M A Architects, Jaipur

- Utilise rooftops for the generation of hot water and/or electricity using solar energy
- For energy-efficient residential buildings (overall EPI < 30 kWh/m²/year) of up to 4 storey, it is possible to generate enough electricity over a year through rooftop solar PV to meet all electricity requirements.

Project: Topland Residency, Rajkot
8. Embodied Energy (MJ/m³) – Walling Materials

AAC blocks
Flyash bricks
Perforated and hollow clay fired bricks are better options
Embodied Energy – Complete House

Load bearing structure of up to 4 storey using perforated clay bricks/ flyash bricks

Savings in plaster

Savings in material consumption

No shuttering

Minimum transportation and fuel cost

Low maintenance and high life cycle

Roof slab of precast RC planks and joist system

Steel consumption <1 kg/ ft$^2$ (conventional 3-4 kg/ ft$^2$)

Cement consumption <0.25 bags/ ft$^2$ (conventional 0.45 kg/ ft$^2$)

Source: Adlakha Associates
Not a good example

- Monolithic Concrete Construction: Large heat gains through walls; High consumption of steel and cement high embodied energy.
- Windows not shaded and hence high heat gains
Conclusion: Appropriate design interventions can lead to energy efficient housing

- Houses that are thermally comfortable and use small amount of energy for operation.
- A significant part of this energy is produced by renewable energy systems and it might be possible to approach net-zero energy housing.
- The embodied energy of the houses can be reduced by upto 50% and the use of highly energy intensive materials like cement, steel, glass reduced.

& Happy Occupants!
THANK YOU!

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