SUSTAINABLE SPACE COOLING
THE NEW ‘HOT’ TOPIC

Our cities are in a heat trap. How can we reimagine our buildings and urban spaces to escape it?
Heat onslaught – climate change to make this trend worse

- The world is experiencing record breaking temperatures.
- **July 2023** -- recorded as the **hottest month globally**.
- India received its **first heatwave** of the year by **3rd March 2023**.
- World Meteorological Organisation predicts hotter times in the next five years.
- This means more and more air-conditioners to cope with heat.
- Threat to public health
- To upset the energy budget of the country.

Amongst the 30 warmest days recorded globally, 21 were in July 2023.
Energy demand from space cooling is already a major energy guzzler

- 65 per cent of the energy demand in buildings come from space cooling and heating --- Niti Aayog's India Energy Security Scenarios (2017)

Rising heat = Rising cooling demand
Policy response: India Cooling Action Plan

- 2019: India amongst the first countries to launch a cooling action plan.

- Its targets include reduction in cooling demand across sectors by around 25 per cent and reduction in cooling energy requirements by around 35 per cent by 2038.

- Emphasises the need for non-refrigerant based and not-in-kind technologies.

- The focus is on ‘sustainable cooling’.

- Moots the idea of ‘thermal comfort for all’.
Cooling demand predictions

• The Ministry of Environment, Forest and Climate Change predicts **cooling demand in buildings to grow 11-fold** by 2037–38.

• Prevalence of space cooling to increase from **one AC per 100 persons in 2015**, to **15 ACs per 100 persons by 2047** – estimated by 2015 NITI Aayog report

• Approximately **8% of the households** in 2017-18 had room air conditioners.

• This is anticipated to rise to **40%** in 2037-38
What has changed or is changing

1. **Denser cities**
2. **Disappearing blue and green infrastructure**
3. **Anthropogenic heat**
   This has affected the **ambient temperature**.
   By **2100**, cities across the world could warm by as much as **4°C**.
4. **People’s expectation**
Energy demand shoots up dramatically beyond 32 °C ambient temperature.
Prevalent response to cooling demand by market

**Ambient temperature**

Reduction in temperature by **5 to 7 degree** centigrade
Or even more.

**Operative temperature**

This includes the effect of materials, window wall ratios, shading etc.

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**Delhi’s scenario**

- In Delhi, energy demand shoots up at 32 °C ambient temperature
- The upper limit of comfortable operative temperature is 32 °C (As per NBC 2016)
- This implies that Delhi’s building stock is ineffective in shielding its occupants from high ambient temperatures.
- Ineffective design, layout, orientation, envelope design might be responsible for Delhi’s high energy demand.

<table>
<thead>
<tr>
<th>City</th>
<th>SI No.</th>
<th>Mode of Operation</th>
<th>Naturally Ventilated</th>
<th>Mixed Mode</th>
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<td>90 Percent Upper Band</td>
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</tbody>
</table>

A 4.7 degree C difference between thermal comfort of mixed mode vs. Air-Conditioned spaces.

Highest level of tolerance in naturally ventilated spaces.
Indian Cities in the grip of growing heat

- CSE analysed temporal Land Surface Temperature (LST) alterations across cities --- Jaipur, Delhi, Pune, and Kolkata.
- A considerable rise in mean LSTs ranging from 2.08°C to 5.5°C was observed.
Urban Heat Centres (UHC)

- Analysis of decadal data (2013 - 2023) carried out ---locations with LSTs exceeding the 45°C mark for six or more years were designated as Urban Heat Centres.

Jaipur: UHC = ~42 per cent of total area

Delhi: UHC = ~35 per cent of total area

Pune: UHC = ~82 per cent of total area

Kolkata: UHC = ~12 per cent of total area
The way out – innovate to make a paradigm shift

Need contextual and climate sensitive cooling solutions in regions

• **Site/area level** - Passive measures that **enhance microclimate**, including vegetation, water features, permeability, clustering and layout etc.

• **Buildings form** that leverages micro climatic advantages, enhances link between buildings and open spaces, sun, mutual shading, natural ventilation, utilizing the courtyard effect etc.

• **Envelope and Material** - interplay of materials, shading devices, insulation, and reflective surfaces in reducing heat gain inside spaces.

• **Innovative active cooling methods** that reduces energy consumption
Traditional design provides some answers

- Indian traditional architecture recognizes that buildings need to respond to the native climate and geography.

*Site planning*
*Building form*
*Envelope*
*Materials*
*Opening sizes*
*Vegetation*

All tweaked in response to the local context to achieve bioclimatic design.

- As a result, India maintains a remarkably low per capita space cooling energy consumption of **69 kWh per person**, which is nearly four times less than the global average.
Prevalent response to cooling demand by market

THE COOLING WEB

- Microclimate Enhancement
- Envelope/Material
- Building Form
- Apt cooling technology

Comfort Zone

Comfort Zone
CSE’s previous research: A well designed building can lose its advantage in a badly designed site plan.
Codes are weak at regulating urban forms at area scale

City scale
- Town and country planning act
- Master Plan
- Bye laws

Area scale
- Fire tender - paths?

Building scale
- National Building Code
- Energy Conservation Building Code
- Building Bye-laws
Case studies: ‘The cooling web’ components

Passive Measures applied

- Reduced cooling demand through passive measures employed
  - Microclimate Enhancement
  - Building Form
  - Envelope/Material

Active cooling technologies applied

- Low impact cooling
  - Type of low-impact cooling employed
- Refrigerant based cooling
  - Type of refrigerant based cooling employed

Each sub-measure under these categories is mentioned here.

Some case studies rely only on refrigerant based cooling, some employ only low-impact cooling solutions while some have worked with both.
Passive Measures and their sub-components

PASSIVE MEASURES

- Microclimate Enhancement
  - Water bodies
  - Plantation
  - Shading of open areas
  - Vertical plantation
  - Permeability of surfaces.
  - Etc.

- Building Form
  - Courtyard planning
  - Mutual Shading of building blocks
  - Favourable orientation
  - Etc.

- Daylighting strategy
  - Courtyard planning
  - Mutual Shading of building blocks
  - Favourable orientation
  - Etc.

- Ventilation strategy
  - Courtyard planning
  - Mutual Shading of building blocks
  - Favourable orientation
  - Etc.

- Envelope/Material
  - Window shading
  - Building envelope’s heat resistance
  - Cool Roofs
  - Insulated roofs
  - Creation of buffer zones.
  - Appropriate building materials.
  - Etc.
Microclimate Enhancement

- Water bodies
- Plantation
- Shading of open areas
- Vertical plantation
- Permeability of surfaces.
- Etc.

External shading: IIT Gandhinagar

Vertical Plantation: IIPH Gandhinagar

Permeable surfaces: NIIT Neemrana

Plantation: NIIT Neemrana
Building Form

- Courtyard planning
- Mutual Shading of building blocks
- Favourable orientation
- Etc.

N-S orientation: IIIT Delhi, most case studies

Courtyard: NIIT Neemrana

Mutual Shading: NIIT Neemrana

Mutual Shading: IIT Gandhinagar
Envelope/Material

- Window shading
- Building envelope’s heat resistance
- Cool Roofs
- Insulated roofs
- Creation of buffer zones.
- Appropriate building materials.
- Etc.

Window Shading: IIIT Delhi

Window Shading: IIPH Gandhinagar
Envelope/Material

- Window shading
- Building envelope’s heat resistance
- Cool Roofs
- Insulated roofs
- Creation of buffer zones.
- Appropriate building materials.
- Etc.
Envelope/Material

- Window shading
- Building envelope’s heat resistance
- Cool Roofs
- Insulated roofs
- Creation of buffer zones.
- Appropriate building materials.
- Etc.

Cool roof: IIT Gandhinagar
Envelope/ Material

- Window shading
- Building envelope’s heat resistance
- Cool Roofs
- Insulated roofs
- Creation of buffer zones.
- Appropriate building materials.
- Etc.

Double facade: Gujarat Vidyapith, Ahmedabad
Active Cooling: Things get even more interesting

**Active Cooling**

- Low impact cooling
  - Geothermal
  - Evaporative cooling
  - Passive Downdraft
  - Etc.

- Refrigerant based cooling
  - District cooling
  - Radiant cooling
  - Any innovation that cuts down energy consumption
  - Etc.

**Renewable Cooling**

- Renewable energy
Temperature

Humidity

Cooling

Temperature

Humidity

Ventilation

Temperature

Humidity

De-humidify

Earth air tunnel

Wind towers

De-humidification
Indian Institute of Technology, Gandhinagar

**Total Site Area**: 399 Acres

**Climate Zone**: Hot and Dry

**Established In**: 2008

**Location**: Gandhinagar, Gujarat

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### Passive Measures Applied

- Reduced cooling demand through passive measures employed

- Microclimate enhancement
- Courtyard
- Vertical promotion
- Permeable pavement
- Open area shading

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### Active Cooling Technologies Applied

- **Low Impact Cooling**
  - Passive Downdraft Cooling

- **Refrigerant Based Cooling**
  - District Cooling System

- **Total Tonnage**: 1,820 TR + 700 TR
- **Total Air-Conditioned Area**: 610,165 sq. ft.
- **Refrigerant used**: R-134a
- **Chiller type**: 350 TR X 4 Screw chillers and 600 TR Centrifugal chiller + 350 TR X 2 (For research park only)
GUJARAT VIDYAPITH, SABHAKHAND
AHMEDABAD

TOTAL SITE AREA
1340 Sq.m

CLIMATE ZONE
Hot and Dry

BUILT IN
2007-2008

LOCATION
Ahmedabad, Gujarat

PASSIVE MEASURES APPLIED
Reduced cooling demand through passive measures employed

- Microclimate enhancement
- Building form
- Envelope/Material
- Plantation on site
- Shaded windows
- Buffer zones
- Double skins façade

ACTIVE COOLING TECHNOLOGIES APPLIED
Low impact cooling

- Evaporative/Misting cooling system
- Earth tunnel/wells
- Combination of evaporative cooling and earth air tunnels
Trees and roof shade the well and create a cooler microclimate.

Warmer air rises and gets exhausted through the exhaust shafts and eventually through the outer layer of roof.

Water sprinkling humidifies and cools the air.

Earth tunnel cools the air as earth acts as a heat sink.

This cool air is introduced inside the auditorium closer to the floor.
Wells are covered and shaded by trees.
Fans over wells
PASSIVE MEASURES APPLIED
Reduced cooling demand through passive measures employed

- Microclimate enhancement
- Vegetation on site
- Permeable pavement
- Orientation
- Natural shading
- Shaded windows
- Insulation
- Irrigated roofs
- Minimal penetrations in East/West

ACTIVE COOLING TECHNOLOGIES APPLIED
Refrigerant based cooling

- District Cooling System

- Total Tonnage: 313.72
- Total Air-Conditioned area:
  - Phase 1: 24,691
  - Phase 2: 24,814
- Refrigerant used: R-134a
- Chiller type: 165 TR X 2 and 240 TR X 2
- Screw chillers
Entrance points
Tunnel in which air travels
Entry points into space
Entry points into space

Exit points for air
Wind exit points
Plantation for microclimate enhancement

- Water bodies
- Plantation
- Shading of open areas
- Vertical plantation
- Permeability of surfaces.
- Etc.
Courtyard typology

- Courtyard planning
- Mutual Shading of building blocks
- Favourable orientation
- Etc.
Narrow courtyard

Building Form

• Courtyard planning
• Mutual Shading of building blocks
• Favourable orientation
• Etc.
Orientation: North-South facing façade

Building Form

- Courtyard planning
- Mutual Shading of building blocks
- Favourable orientation
- Etc.

Shading on the south facing windows
Envelope: Buffer zones

- Window shading
- Building envelope’s heat resistance
- Cool Roofs
- Insulated roofs
- Creation of buffer zones.
- Appropriate building materials.
- Etc.
Materials: Rammed Earth, AAC + insulation

The initial buildings of the campus were constructed in rammed earth technology. A rammed earth wall has excellent thermal mass properties sufficient to provide occupant thermal comfort specially in non-air conditioned spaces. The thatch roof is also an excellent insulator, both materials were locally available.

Thermal Transmittance Value achieved (U-Value) : 0.36

Transmits **five to six times lesser** heat compared to a conventional nine inch (230mm) red brick wall.
Material: Cool roof, insulated walls, double glazed units

Projection factor reduces direct incidence of solar heat gain
Effective Solar Heat Gain Co-efficient: 0.25

Window to Wall ratio of 30%
Double Glazed Unit
U-Value: 2.8 W/ m²K

Transmits five to six times lesser heat compared to a conventional nine inch (230mm) red brick wall
Overall energy savings due to careful envelope design: 25%
The campus has an installed capacity of 150 kVa
Heat pump transfers heat to cooking and bathing areas
Use of natural refrigerant: Propane or R-290 in stand-alone Air-Conditioners.

<table>
<thead>
<tr>
<th>Model Name</th>
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3 stage cooling system