NEED FOR CENTRALIZED COOLING SYSTEMS IN HIGH DENSITY MASS HOUSING IN INDIA

Towards smart energy policy in residential communities

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Centralized cooling systems in high density mass housing in the developing world

Agenda

Background- energy scenario in India in international context, affordable housing sector in India

Cooling need in residential communities from household primary surveys

Current scenario of unitized AC and district cooling as an alternative low exergy cooling scenario

Key benefits of centralized cooling

Institutional mechanisms acting as enablers of district cooling

Summary of conclusions and future work
Per capita energy consumption is expected to increase rapidly in the coming decades.

Presently, India is heavily dependent on fossil fuel imports which meet 70 percent of the country’s energy demands (IEA 2012)- pushes India to geopolitical risk and international energy market volatility.

Source- World Bank, 2014
Background: Affordable housing sector in India

- The building sector is the second largest energy consuming sector after the power sector.
- With almost 95% of people falling in middle and lower income brackets, there is a huge demand for affordable mass housing in the coming decades.

Source: Confederation of Real Estate Developers’ Associations of India (CREDAI). The Economics of Low Income Housing. 2010.
Cooling need in the developing world: the case of urban India

Percentage growth of air cooler (including air conditioner) usage in urban households
(Data source: NSSO, India)

(Source: Sivak, M., 2009. Potential energy demand for cooling in the 50 largest metropolitan areas of the world: Implications for developing countries. Energy Policy 37, 1382–1384)
Cooling demand from household primary surveys in Rajarhat Township- an eastern metropolitan extension of Kolkata
Volunteering location

EAST ENCLAVE (LIG)
Total no of households - 80
No of samples - 20
% AC households - 30
Monthly summer electricity:
Avg AC households - 197.087
Avg Non AC households - 100.92

EAST ENCLAVE (MIG)
Total no of households - 96
No of samples - 59
% AC households - 50.85
Monthly summer electricity:
Avg AC households - 295.89
Avg Non AC households - 146.57

BALAKA (LIG/EWS)
Total no of households - 928
No of samples - 128
% AC households - 2.34
Monthly summer electricity:
Avg AC households - 172.343
Avg Non AC households - 129.47

BALAKA (EWS/LIG)
Total no of households - 48
No of samples - 24
% AC households - 37.5
Monthly summer electricity:
Avg AC households - 204.317
Avg Non AC households - 125.75

UTTARA (LIG)
Total no of households - 48
No of samples - 24
% AC households - 37.5
Monthly summer electricity:
Avg AC households - 204.317
Avg Non AC households - 125.75

UTTARA (MIG)
Total no of households - 184
No of samples - 48
% AC households - 77.08
Monthly summer electricity:
Avg AC households - 350.207
Avg Non AC households - 158.69

MOONBEAM (MIG)
Total no of households - 560
No of samples - 128
% AC households - 53.91
Monthly summer electricity:
Avg AC households - 230.261
Avg Non AC households - 170.49

STARLIT (LIG)
Total no of households - 72
No of samples - 59
% AC households - 50.85
Monthly summer electricity:
Avg AC households - 295.89
Avg Non AC households - 146.57

STARLIT (MIG)
Total no of households - 560
No of samples - 128
% AC households - 53.91
Monthly summer electricity:
Avg AC households - 230.261
Avg Non AC households - 170.49

SUKHABRISHTI (MIG)
Total no of households - 3287
No of samples - 170
% AC households - 35.88
Monthly summer electricity:
Avg AC households - 227.583
Avg Non AC households - 131.59

SUKHABRISHTI (LIG)
Total no of households - 2118
No of samples - 141
% AC households - 12.42
Monthly summer electricity:
Avg AC households - 159.297
Avg Non AC households - 87.877

Monthly summer electricity billing data unit - kWh
### Results and deductions

<table>
<thead>
<tr>
<th>Name of the housing complex in Rajarhat Township</th>
<th>Total no. of households</th>
<th>No. of households surveyed</th>
<th>% households with AC</th>
<th>Mean monthly energy consumption units (kWh) during peak summer in households with AC units</th>
<th>Mean monthly energy consumption units (kWh) during peak summer in households without AC units</th>
<th>Mean % increase in monthly energy consumption in household with AC units</th>
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</tbody>
</table>

Dataset for AC electricity consumption in LIG and MIG households from household primary surveys
Results and deductions

- 35-77% middle income group (MIG) housing units and 5-37% low income group (LIG) housing units were found to have air conditioning units. On average about **50% MIG** houses and **10% LIG** houses had ACs.

- % increase in electricity billing varies between 35-120% for MIG and 33-95% in LIG, the average total increase being **80% excess electricity consumption**.

- Implied current low AC saturation and **future growth in cooling demand**.

- Implied **high operating cost** of individual room air conditioners.
Existing scenario – individual room air conditioners

- **Easily available**, consumer market driven
- **High operating costs** and AC electricity consumption – hence **low efficiency**
- Rejected heat from AC condensers giving rise to the ‘**stack effect**’ – reduction of AC efficiency in upper floor

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**Refrigeration cycle** – how individual room air conditioners work

- **EXPANSION VALVE**
- **COMPRESSOR**
- **EVAPORATOR COIL**
- **CONDENSER COIL**

**Th** = 55-60°C
**Tc** = 8°C

**COP ~ 2.7-2.9**

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g = 0.5
**Th** = 55-60°C
**Tc** = 8°C
Community scale cooling scenario – district cooling system

- **Chilled water is distributed** from a centralized chiller plant to the housing complexes.
- Consists of a central **chiller** plant, chilled water supply network and building heat exchanger.

Centralized heat rejection (assumed temperature at evaporative cooling tower \( T_h = 30-35^\circ C \))

- **Higher exergetic efficiency**

**Thermal data**

\[ T_h = 30-35^\circ C \]
\[ T_c = 8^\circ C \]
\[ \text{COP} \approx 6.2-7.6 \]

**Diagram details**

- Schematic view of a district cooling network (source: authors)
- \( g = 0.6 \)
Key benefits of centralized cooling

**ENERGY EFFICIENCY BENEFITS**
- Higher COP and hence lower cooling energy consumption

**CLEAN ENERGY AND EMISSION REDUCTION BENEFITS**
- Easy integrability with renewable energy sources in centralized chiller plant
- Prevents GHG emissions from air conditioning refrigerants

**FINANCIAL BENEFITS**
- Lower operating costs in the long run
- Shift of capital cost of buying split units from individual to community level

**QUALITATIVE BENEFITS**
- Centralized O&M makes it a more reliable service
- Improves urban microclimate by centralized heat rejection
- Improves urban aesthetics as individual units disrupt view of facades
Institutional mechanisms for implementing district cooling

Private Developer  
Energy Servicing Companies (ESCO)  
Governmental support  
International Actors
Private Developer as enabler of district cooling infrastructure

- Potential actor for capturing cost effective energy efficient technologies in mass housing communities

1 ton DHC would be around 60000-70000 INR without thermal storage and around 100000 INR with thermal storage against 50000 INR for 5 star rated and 30000 INR for 2 star rated 1.5 ton AC.
Private Developer as enabler of district cooling infrastructure

A Build-Own-Operate (BOO) model for implementing district cooling as community level infrastructure by private developer

- Market survey revealed district cooling has 40-70% more upfront investment costs as compared to individual units, however the investment is shifted from individual to community level.

- District cooling constitutes only 4-8% construction cost of an entire apartment complex- and could act as a subsequent source of revenue generation during the operating phase of the housing complex.

1500 INR/sq ft, 750-1500sqft >> 1125K-2250K INR capital cost with 60-100K INR AC construction cost

4-8% of construction cost
Role of other enabling actors

ESCOs – enablers of energy infrastructures, services offered are as follows

- Project Identification
- Financing/arrangement for financing
- Installation of Technology/Equipment
- Operation and Maintenance
- Monitoring and Measurements of project energy savings

Offering energy services—design, retrofitting and implementation—after identifying energy saving opportunities

Source: Bureau of Energy Efficiency, India
Role of other enabling actors

- **Governmental support** –
  - Incentives
  - Subsidies
  - Tax Exemptions

- **International actors** -
  - Project Financing
  - Increasing awareness among stakeholders
SUMMARY OF CONCLUSIONS

- **Rapid increase in household air cooler ownership** in India every year from National Sample Survey Organization-reported increase in 2% households from 2009-2010 to 2010-2011.

- As observed from household primary surveys, 35-77% MIG housing units and 5-37% LIG housing units were found to have air conditioning units. On average about **50% MIG houses and 10% LIG houses had ACs**.

- Percentage increase in electricity billing varies between 35-120% for MIG and 33-95% in LIG, the **average total increase being 80%**.

- District cooling systems could decrease the summer monthly AC electricity consumption by **60-65%**.

- Easy integrability with renewable energy sources, avoiding GHG emitting air conditioning refrigerants, lowering operating costs in long run, improving urban microclimate and urban aesthetics and overall QoL.

- District cooling constitutes only **4-8% construction cost** of an entire apartment complex and could act as a subsequent source of revenue generation during the occupancy phase of the housing complex for the **private developer** to invest in such community scale cooling infrastructures.

- However, district cooling technology comes with challenges of **high upfront investment costs** and the need for **high amount of cooling load** to be the feasible model for a ‘smart community’.
Future work..

Quantifying the housing density scale in which district cooling can be profitable in residential neighbourhoods and identifying break-even point for profitability.

CASE STUDY HOUSING
Sukhabrishti Mass Housing Complex
Middle Income Housing (MIG)
Total MIG – 3287
35% households having ACs
Summer monthly average cooling demand each household- 298196-320285kWh
(assuming COP range 2.7-2.9)
Special thanks to Prof. Forrest Meggers, my mentor and collaborator at the CHAOS lab at the Andlinger Center for Energy and Environment at Princeton University for introducing me in this area of low exergy community cooling during my Fulbright exchange program as a doctoral student from IIT Kharagpur India in 2017.
THANK YOU!