

FOCUS AREA 03

Smart Buildings

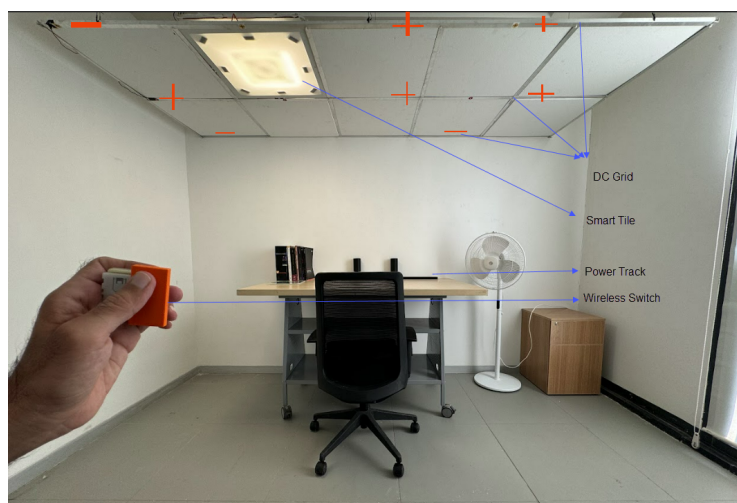
Integrated research on building technology, occupant behavior, energy demand and indoor environmental quality.

Research Context

Electricity demand from residential and commercial buildings is rising rapidly driven by increased device penetration and the adoption of new technologies. IVCCE aims to investigate the interaction between technology, occupant behavior, energy consumption, and indoor environmental quality to enable more efficient, healthy, and sustainable buildings. The long-term goal is to generate insights that contribute to the development of national standards for smart homes, enabling optimized building performance, reduced energy use, and more sustainable urban living.

Smart DC Ceiling

A facility has been created to investigate the integration of DC devices into ceiling tiles, powered by ceiling rails. As shown in image, this setup eliminates the need for traditional wiring and switches, allowing flexibility in installation. Bluetooth Low-Energy (BLE) switches are used to control the equipment mounted on the ceiling tiles. Accurate estimation of switch location is achieved using trilateration techniques and machine learning algorithms. This research seeks to enhance energy efficiency and integration with renewable power sources.

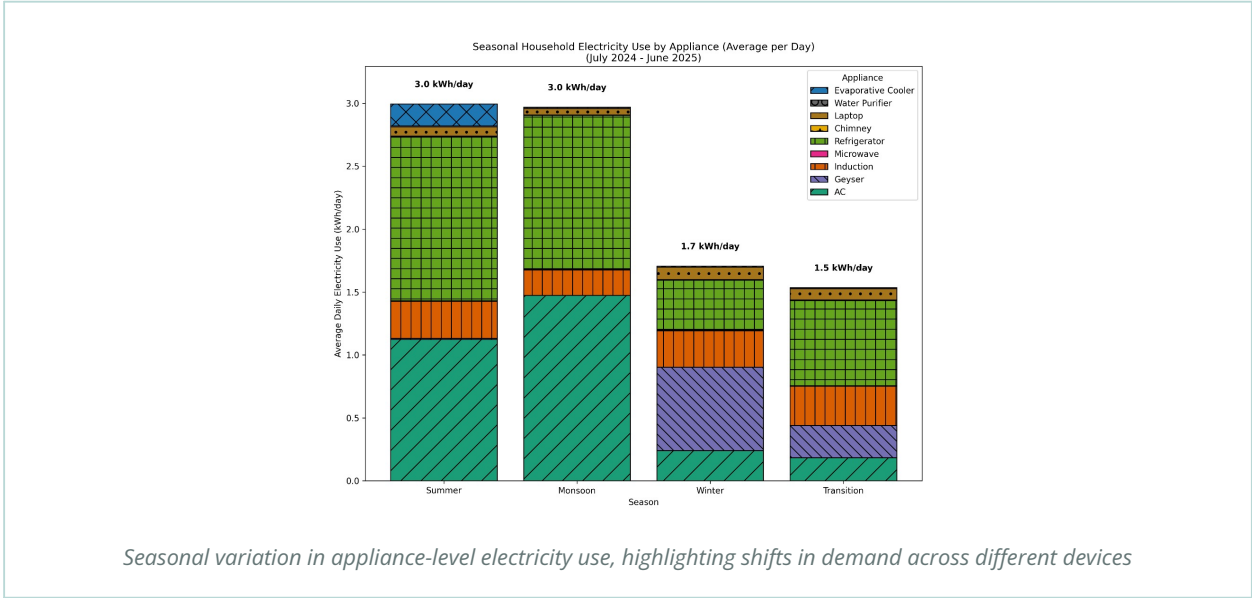


DC ceiling grid setup - DC LED powered by ceiling rails

Research Studies

1 Appliance-level Electricity Use in a Residential Household

This study examined a household in Mohali, India, over a 12-month period (July 2024 to June 2025) spanning diverse seasonal conditions. Using high-resolution data from smart plugs, a smart meter, and indoor temperature-humidity sensors, the analysis explores how appliance usage patterns reflect environmental sensitivity and behavior-driven efficiency.

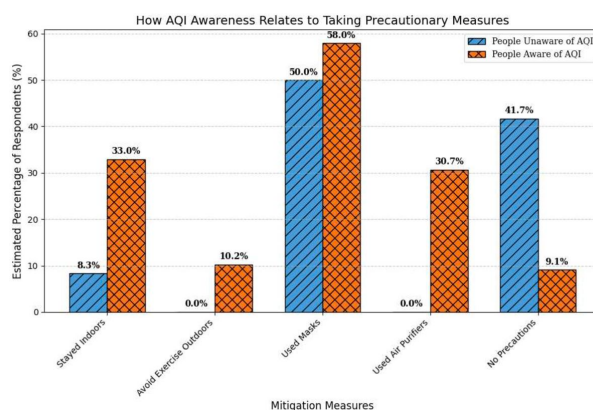


2 Energy Implications in a Mixed-Mode Building

A pollution-aware natural ventilation schedule was developed by combining hourly outdoor particulate levels (PM2.5 and PM10) with EnergyPlus simulations for a representative apartment in a polluted urban setting such as Delhi-NCR. Window-opening decisions observed in household interviews were also used to represent how natural ventilation is typically avoided during pollution seasons. Simulation comparisons between behavior-based window patterns, temperature-driven mixed-mode operation, and pollution-aware rules showed how aligning window use with measured outdoor conditions can change both cooling energy use and indoor exposure outcomes in mixed-mode buildings.

3 Behavioral and Socio-Economic Dimensions of Indoor Air Quality

This study explores public awareness of air pollution and the perceived effectiveness of strategies to improve Indoor Air Quality (IAQ). Insights were gathered through in-person interviews across Delhi-NCR, representing a range of socio-economic backgrounds. Findings reveal widespread awareness of the Air Quality Index (88% of total respondents), but limited understanding of PM2.5 and its health risks (33%). A clear behavior pattern was also observed: air purifier use was reported by respondents who were aware of AQI, whereas mask use was reported widely regardless of AQI awareness



Precautions taken by households in accordance with AQI awareness

4 Energy and Indoor Air Quality Trade-offs

This study examines the trade-offs between reducing particulate exposure and cooling energy use under outdoor particulate pollution. These trade-offs were quantified using a combination of ethnographic interviews and building performance simulations for a residential building in New Delhi. Two mitigation strategies were assessed: (1) pollution-aware natural ventilation, in which window operation was driven by outdoor PM_{2.5} thresholds, and (2) portable air cleaning combined with temperature-based window operation.

5 Residential Electricity Usage Simulation

This study addresses the scarcity of high-resolution residential electricity consumption data in India by developing a REUS to generate realistic synthetic datasets. Using hourly electricity consumption data collected over one year from 65 households across seven residential categories, along with 18 socio-technical features per home, the study employs a combination of probabilistic finite state modeling, feature selection, and machine learning techniques. Simulation models based on different Long Short-Term Memory (LSTM) networks and Transformer architectures were developed and benchmarked against traditional statistical approaches such as Markov Chains and ARIMA models.