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Benchmarking Buildings Based on Their Energy Performance in Kerala: A Case Study of Kochi

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Highlights

- Globally, countries are committing to decarbonizing their building stock. Achieving climate mitigation targets requires an understanding of the efficiency levels of existing buildings. Energy performance benchmarking helps establish baseline efficiencies and provides policymakers, building portfolio owners, and managers with the information they need to design and implement building efficiency programs.
- We tested a novel benchmarking methodology for offices in Kochi to understand the availability of data and practical challenges if benchmarking were to be scaled up.
- For each office, we derived a Building Performance Index (BPI) using statistical regression techniques. Twenty-two offices out of 50 had a BPI < 1 or were relatively more efficient than other offices. We also observed an average Energy Performance Index (EPI) of 130 kilowatt-hours per square meter per year (kWh/m^2/year) for sample office buildings, with EPI values ranging from 21.3 to 441.7 kWh/m^2/year.
- Through a qualitative survey, we documented perceptions of the importance of energy efficiency (EE) services in offices of varying ownership and management structures. There were no significant differences in the attitudes and perceptions of owner- and tenant-occupied offices.
- City-level benchmarking can be done in India with minimum data by supporting back-end statistical analysis resources and tools. The benchmarking methodology we have adopted in this study could guide such efforts at national and subnational levels. We recommend India take a more institutional approach to benchmark energy performance.

Abstract

Many developed countries regularly conduct building energy use benchmarking for continuous monitoring and evaluation of energy efficiency (EE) programs and policies to inform the design of new ones. Such activities also provide an opportunity to engage with building owners, tenants, and managers on RE and EE policies and programs. Our study was aimed at developing a methodology for citywide energy benchmarking exercises in India. We tested a novel benchmarking methodology for offices in Kochi to understand the availability of data and practical challenges if benchmarking were to be scaled up. The study was also aimed at documenting barriers to retrofits for different owner-tenant models.

Keywords: Buildings, energy efficiency, benchmarking, energy performance

Introduction

In 2021, the buildings and construction sector accounted for around 37% of energy- and process-related CO_2 emissions and over 34% of energy demand globally [1]. In India, buildings were responsible for 33 percent of total electricity consumption in 2018–19 [2], with more than 60 percent of India's electricity needs coming from thermal power [3]. During 2019-20, in Kerala, buildings with LT connections alone consume nearly 67% of the total electricity consumption in the state [4]. This share will further increase if we consider the data regarding commercial and residential buildings with HT connections, which are not available separately. These numbers highlight the importance of decarbonizing buildings in the state if it wants to achieve its goal of becoming a carbon neutral state by 2050 [5]. Achieving climate mitigation targets requires an understanding of the efficiency levels of existing buildings. Energy performance benchmarking helps establish baseline efficiencies and provides policymakers, building portfolio owners, and managers with the information they need to design and implement building efficiency programs. In this context, we tested a novel benchmarking methodology for offices in Kochi to understand the availability of data and practical challenges if benchmarking were to be scaled-up.

The status quo of building energy performance benchmarking

Many developed countries regularly conduct building energy use benchmarking for continuous monitoring and evaluation of EE programs and policies to inform the design of new ones. Benchmarking provides a baseline of energy use of existing buildings, compares their energy performance with others after homogenizing for physical and operational characteristics, and provides policymakers data on the relative efficiencies of buildings. While building codes and standards speak to new buildings, benchmarking programs specifically address the efficiency of existing buildings. Citywide benchmarking systems can be used by policymakers as a yardstick of energy performance in buildings when benchmarks are disclosed publicly [6]. A citywide benchmarking program where the information is shared publicly serves three purposes [7]: It informs and empowers the real estate market to pay attention to energy efficiency (EE); it motivates building owners to invest in EE services and retrofit projects; and it can help policymakers design better EE programs and policies. Consistent benchmarking efforts across a large sample of buildings can inform better building energy codes. Good performers can be rewarded (e.g., US Department of Energy's Sustainability Awards), while low performers can be penalized (e.g., the Minimum Energy Efficiency Standard [MEES] regulations in the United Kingdom).

Benchmarking activities also provide an opportunity to engage with building owners, tenants, and managers on RE and EE policies and programs. These activities provide information to market actors and allow building owners to prioritize measures for improvements. In India, the Bureau of Energy Efficiency (BEE) attempted to collect building energy performance data from 2007 to 2009 through primary and secondary surveys. These results were used to develop and launch a Star Labelling Program for office buildings in 2009. However, this program has not been revised since 2009.

In 2010, the USAID ECO-III project partnered with BEE to conduct a large-scale benchmarking effort involving data from 760 commercial buildings of various typologies [8]. In 2014, with support from the Shakti Sustainable Energy Foundation, BEE launched the EcoBench Tool [9] for benchmarking and rating the energy performance of hospitals using ECO-III Project survey results. No such national benchmarking exercise was repeated in India.

About This Paper

Our research began with the objective of developing a citywide energy benchmarking program. We reviewed the literature, consulted experts with previous experience in benchmarking studies in India, and developed the survey questionnaire. We surveyed 50 offices in Kochi to understand the data available for such a citywide program and to develop a Building Performance Index (BPI) for the offices using statistical regression techniques. Our findings may not be representative due to the small sample size of data fields used in the survey, which had implications on the interpretation of some of the findings (e.g., reasons that some offices performed better than others).

We also conducted a qualitative survey, where we spoke with the office managers to understand their perceptions of EE services and retrofits and their awareness of energy service companies (ESCOs). In several markets globally, ESCOs have been instrumental in driving building energy performance improvements, especially in cases where up-front investments in EE are high. We also asked questions to help assess the applicability of common barriers, like the split incentive and financing barriers facing EE retrofit projects. Split incentives refer to transactions where economic benefits of energy savings do not accrue to those who invest in energy efficiency, such as when building owners pay for investments in energy efficiency while occupants pay the energy bills [10].

Research Objectives

Our research objectives include the following:

1. Assess the feasibility of conducting a citywide benchmarking exercise for office buildings.
2. Develop a BPI for the offices.
3. Document barriers to retrofits for different owner-tenant models as well as enablers to seeking EE services.

Approach and Methodology

We collected data on 50 office spaces in Kochi city. We chose offices because they account for 27 percent of large commercial consumers in Kochi, the second largest category after retail spaces, as per the data we collected from the KSEB. We decided to focus on office buildings also because they are included in BEE's Star Labelling Program typology. Also, office spaces are more amenable to the initial landscape assessment due to more typical operational hours and building design. For defining large commercial consumers, we wanted to follow the threshold based on data on buildings within the Energy Conservation Building Code (ECBC). ECBC applies to commercial buildings with connected load ≥ 100kW or contract demand ≥ 120 kVA. However, since the number of such buildings in Kochi was low, we defined them as those with connected load ≥ 75kW or contract demand ≥ 100 kilovolt ampere (kVA). We adopted a two-part methodology—a quantitative survey to benchmark the energy performance of selected office spaces and a qualitative questionnaire (over the telephone) with managers of the offices.

Scope of Study

The scope of our study is office spaces and the electricity consumed and managed within these boundaries. We have not benchmarked office buildings, which would refer to additional energy services provided as "common services" to all offices within the building in the form of elevators, water pumping systems, and common area lighting. Hereafter, we will refer to the sample as "offices."

Sample Identification

After fixing the sample criteria as offices with connected load ≥ 75 kW, we sought their electricity consumption data from the electric utility, the KSEB. Since the KSEB used a different method to document this information, we had to work with it to clarify the consumer categories and shortlist 91 consumers. We contacted these consumers to seek their willingness to participate in the study. Based on the discussions, 62 joined the survey. Upon further analysis to ensure homogenization, we finalized 50 office spaces for the advanced analysis on benchmarking energy performance and qualitative research to ensure the homogeneity of the sample.

Primary Data Collection

According to Kumar et al. [11], in India, several efforts have been undertaken to collect energy use data of commercial buildings. These have seen only limited success for the following reasons: difficulties in standardizing questionnaire terms with the vocabulary used by office managers; challenges in ensuring data quality; addressing data confidentiality concerns of participating buildings; and inability to strike a balance between depth of data and the ease of collecting information. Keeping these lessons in mind, we developed our survey questionnaire.

This survey sought to collect data on basic energy use to enable comparisons of energy performance. Since this was a first-of-a-kind initiative at a city scale in India, we were also opportunistic and focused on datasets that the office manager could provide without much effort.

We had a letter of support from the Kochi Municipal Corporation (KMC), which immensely helped our data gathering efforts. Primary data was collected over a period of two months, starting in November 2019, by a trained survey agency that used in-person and remote data collection techniques. The survey agency's experience and expertise in data collection, measurement, and verification techniques have helped the researcher obtain quality data from offices. Some data fields were classified as mandatory to enable benchmarking; others were voluntary.

Benchmarking Approach

Energy performance of a building depends on various parameters, including its size, number of occupants, conditioned area, and so forth. While a building is to be compared with other buildings for its energy performance, it is important that we factor in these parameters to warrant a justifiable comparison. Using the Building Performance Index (BPI) as a yardstick to compare buildings for their energy performance allows us the flexibility to factor in these parameters. While the Energy Performance Index (EPI) is one of the most widely used metrics to indicate a building's energy performance, it only considers a building's annual energy consumption and its floor area to assess its performance. Our study was more focused on a detailed assessment that demanded the use of BPI over EPI for benchmarking buildings.

Our methodology for benchmarking is adapted from Sarraf et al. [12], where regression-based statistical methods were used to benchmark the energy performance of 760 commercial buildings. The approach was used to develop India's first national-level benchmarking platform (EcoBench), which we previously mentioned in the paper. Under this approach, a building's energy performance is compared with a "benchmark" building of similar characteristics using a scoring system. Statistical methods were used to estimate the energy consumption of the "benchmark" building and the scores or relative rankings of the buildings on the BPI. Under this approach, a building's energy performance is compared with a "benchmark" building of similar characteristics using a scoring system. Statistical methods were used to estimate the energy consumption of the "benchmark" building and the scores or relative rankings of the buildings on the BPI. The process we followed is delineated below.

Step 1: Homogenizing sample data

First, we looked at office spaces with a connected load ≥ 75 kW. We then collected data on physical characteristics (e.g., floor area, conditioned space) and operations and management (e.g., employee density, working days, and operating hours). We also analysed their impact on the dependent variable—the office's annual electricity consumption. Through this process, we identified 12 buildings that behaved significantly differently from others and decided to remove them from the sample. The parameters, along with the criteria used for the homogenizing sample, are listed in the below table.

Table 1: Independent Variables Considered and Their Contribution to Homogenizing Sample

Parameter	Criteria for removing buildings with heterogeneous behavior from sample
Operating hours	Only single-shift operations were considered. Data points with 24 x 7 operations were excluded.
Operation	Buildings that are not fully occupied/operational.
Year of operation	Buildings that only started operating in the last 6 months.
Additional facilities	Buildings that had additional facilities like laboratories, etc.

Step 2: Estimating energy consumption of benchmark building

Taking guidance from the methodology adopted by Sarraf et al. [11], we used multiple regression techniques to estimate the energy consumption of our "benchmark building." A benchmark building is a hypothetical building with the same characteristics as the building to be benchmarked. There is a standard equation that defines the energy use of a benchmark building.

Energy use of a benchmark building = Function (building type, construction, physical, operational, and location characteristics)

Using the data from the 50 offices, we used multiple regression to derive an equation that calculated the benchmark building's energy consumption, using the coefficients for values of independent variables that impact or drive energy use in a building. A multiple regression predicts a dependent variable's value based on the value of two or more independent variables. Comparing the actual consumption (actual performance) of the building to be benchmarked with that of the benchmark building (expected performance) gives the building's relative efficiency. The small sample dataset limited our choice of functional forms of the regression model. We explored different forms and confirmed through the scatterplots that there were nonlinear relationships between the dependent and independent variables.

This process also helped assess the significance of interactions between the different independent variables. By trying out different regression models and closely examining the coefficients of independent variables, we identified the following variables as significant in influencing the annual electricity consumption of the building: carpet area (m^2), employee density (number of employees/unit area), and conditioned area (percent). Some variables initially assumed to be significant were later removed from the regression analysis. For example, the p-value of the dummy variable for operating hours was not significant and required that we disregard it as a determinant variable for developing the regression model. However, it is likely that with a bigger sample size of buildings, operating hours will play a more significant role in determining the annual electricity consumption of a building. We disregarded it in our analysis because of its statistical insignificance in the regression analysis.

At various stages in our analysis, we tried regression models using different variables to explore their significance before establishing the final regression model. The final model was based on those variables' observed significance (p-value); we have included or disregarded these variables, as appropriate, in further analysis. The final regression model is based on a log-linear functional form in which the log of annual electricity consumption was the dependent variable and the log of carpet area, employee density, and the dummy variable to indicate whether the building is 50 percent air-conditioned or not (variable = 0 if < 50% area is conditioned by ACs; variable = 1 if ≥ 50% area is conditioned) are the independent variables. An R-squared (R^2) value of 0.75 was observed for this model with a residual standard error of 0.1712. The derived equation for predicting the log of the annual electricity consumption of a building is given below.

*Log (Annual electricity consumption) = 2.29532 + 0.83155*Log (Carpet area) + 2.30037*Employee density + 0.21033*dummy variable for conditioned area* (1)

Step 3: Estimating Energy Consumption of Benchmark Building

The results of the multivariate regression provided the equation to estimate the energy consumption of a benchmark building. The next step was to compare actual energy consumption to that of the benchmark office.

The Building Performance Index (BPI) was calculated for each office and used to compare offices with each other. The BPI is defined below.

BPI = Actual energy consumed by the office space / Estimated energy consumed by the benchmarked office space

A BPI of 1 indicates that the building's energy consumption is equivalent to the benchmarked building after normalizing construction and operational characteristics.

Buildings with BPI > 1 indicate that their energy consumption is higher than that of the benchmarked building; buildings with BPI < 1 indicate lower energy consumption. Buildings with a BPI of 2 suggest that they consume twice the energy of a comparable benchmarked building, while a BPI of 0.5 means that the building consumes half the energy of a benchmarked building. So, the lower the BPI, the better the building's energy performance relative to its peers.

Observations

Ownership and occupancy related observations

- Occupancy categories: For each office, we also collected ownership information. Of the 50 buildings, 17 were owned by the central government, 6 by the state government, and 27 by private companies.
- Premise ownership and facilities management: We further classified the buildings into five categories based on facilities management. The details of buildings based on their ownership and management types are given below.

Category	Definition	Number of Offices
Owner-occupied and managing facilities	The owner is also the occupant and manages the facilities in-house	23
Owner-occupied and private management of facilities	The owner is also the occupant of the office premises but has engaged a third party to maintain the facilities wholly or partially. This could include managing of electrical equipment and energy service systems.	9
Multitenant office space, management by owner	Multiple tenants occupy the building, and the owner manages the facilities for them. This owner can be government or private.	8
Multitenant office space, management of individual facilities by tenants	Multiple tenants occupy the building, and they manage their respective facilities. The tenants could be government or, private or both.	7
Single-tenant office space, Facilities management by tenant	A single tenant occupies the office and manages the facilities.	3

- Owners occupied most of the buildings surveyed (32 of the 50 buildings). Facilities in 23 offices were managed by in-house teams, and third parties managed the remaining 27.
- Tenants occupied 18 offices; 15 were present in buildings where there were other tenants as well. In 8, the owner managed the facilities, and in the remaining 10, tenants did.
- None of the leased facilities had third-party facilities managers.

Energy- and equipment-related characteristics

Connected load and annual consumption: Of the 50 offices, 21 had a connected load ranging between 75kW and 100 kW. The remaining 29 had a connected load above 100 kW. There were 11 offices with a load greater than 200 kW. The highest load recorded was 690 kW for a 21-floor office space. The 50 offices had a combined annual electricity consumption of 12 million units and a total connected load of 8.192 MW.

Air-conditioning: Three of the 50 buildings had centralized air-conditioning. The percentage area conditioned by ACs varied from 2 percent to 100 percent, indicating a mixed-mode ventilation practice in many offices.

Rooftop solar: Seven of the 50 offices have rooftop solar plants. Of these, 6 were in owner-occupied offices where the owner also managed the facilities. One multitenant building managed by the owner also had a rooftop solar installation.

Energy performance benchmarks: The benchmarking exercise aimed to collect empirical data to produce statistically robust BPI values and generate a simple ranking of buildings while normalizing for independent variables' impact on individual offices' energy performance. We allotted building IDs to the 50 buildings, calculated their BPIs, and converted them to ranks ranging from 1 to 50. BPI values ranged from 0.34 to 2.19 (Figure 1). Although we could not conduct more in-depth investigations into the reasons behind the different energy performance of the same type of buildings, we are presenting some observations:

The Top 22 ranks are for offices with BPI < 1

- 14 of the 32 owner-occupied offices (44 percent) are in the top 22. Of these, 11 are offices where the owner occupied and managed the facilities, and third parties managed the remaining three.
- There are also 6 office spaces occupied by tenants and managed by the owner (75 percent of this category) in the top 22.
- 2 of the 3 offices where a single tenant occupied the building and managed the facilities are in the top 22, with BPI scores of 0.48 and 0.60.
- 14 of the 22 offices were occupied by private companies (54 percent of private companies), 4 by central government (21 percent of central government buildings), and 4 by state government (80 percent of the state government buildings).

The bottom 28 ranks are for offices with BPI > 1

- Eighteen owner-occupied offices are in the bottom 28. There are 12 offices where the owners occupied and managed the facilities in-house, and third parties managed the remaining 6.

- All 7 offices where multiple tenants occupied and managed facilities are in the bottom 28.
- Fourteen of the 28 offices at the bottom are occupied by central government agencies, 12 by private companies, and the remaining 2 by state government bodies.

Qualitative Survey

We conducted a qualitative survey of the 50 offices over the telephone due to COVID-19 restrictions. The survey's primary respondents were office managers and building supervisors who had provided the quantitative survey data. The interviews focused on two questions:

What are the barriers to implementing EE retrofits in buildings?

Barriers to EE retrofits in buildings are an acknowledged knowledge gap [13]. We wanted to test the applicability of the "split incentives" and other barriers across different buildings.

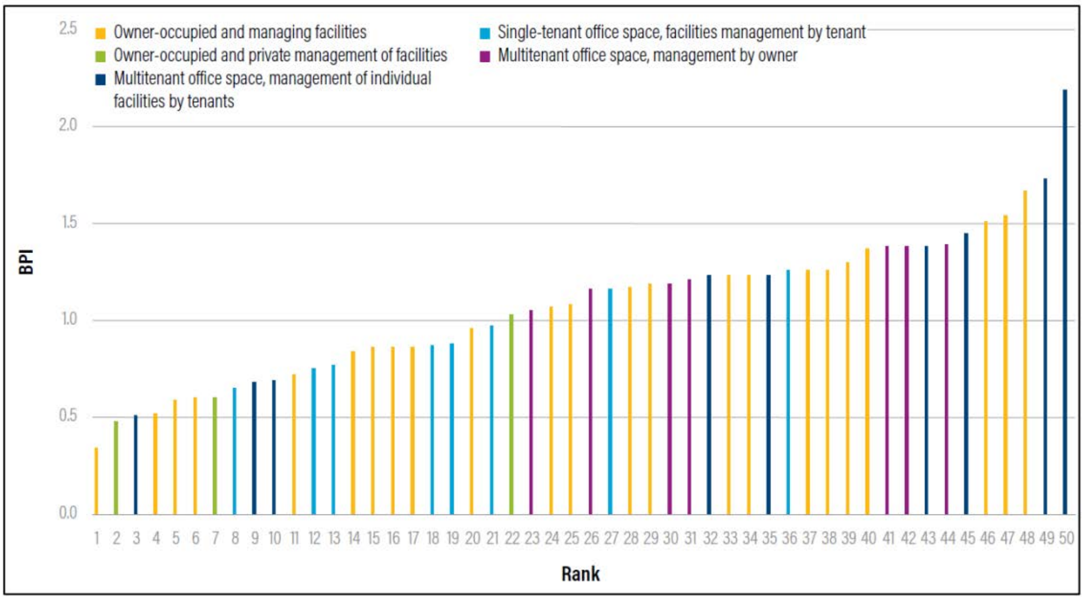

Figure 1: BPIs and Building Ranks by Building Categories

What are the enablers (or drivers) to EE services?

We wanted to document specific drivers of EE services, including retrofit projects. We wanted to see if the benchmarking survey results changed mindsets or receptivity toward EE services in existing offices.

Based on the survey, the findings and inferences are tabulated below.

Barrier Category	Findings from Kochi	Inferences
Split incentives	Most offices were bare when tenants moved in. The tenant had to invest and install cooling equipment (e.g., ACs) and lighting. Although tenants could have installed efficient equipment, most did not, except for Level 1 interventions (replacing broken bulbs with LED lights). [Based on the responses, we classified the replacements and retrofits into three levels: Level 1, referring to no changes or minor replacements (e.g., lights in case of a breakdown to LEDs); Level 2, referring to full-scale retrofits of the lighting system and fixtures to more efficient LEDs; and Level 3, referring to the replacement of higher-cost ACs with higher-efficiency equipment.	Tenants having to invest up-front in efficient equipment typically opt for low-cost equipment and appliances. EE considerations are unlikely to be prioritized unless they are readily available (e.g., LED lights). Also, though tenants could make their own decisions, the owners' management of services may have impacted their decision not to purchase and install more efficient equipment.
Financing	In offices where owners or tenants managed facilities, operations budgets paid for replacements or retrofits, even for new ACs. However, most offices, irrespective of who owns or occupies them, had only carried out Level 1 interventions. When asked, all except one identified financing as a challenge to installing new EE equipment. Interestingly, we found that there is no interest in taking loans to finance retrofits.	Upgrading and retrofitting HVAC systems is generally expensive and may need significant capital (especially in small offices). Given the limited presence of HVAC systems in the study, replacing split ACs with energy-efficient ones is important. ACs or retrofitting efficient fans appears to be easier to implement. However, these do not achieve scale (in terms of cost savings), and more expensive upgrades need

		management approval if they are financed from operational budgets.
Interest motivation saving energy and in	All the surveyed offices ranked energy saving as one of their top five priorities. But beyond stating this, they did not do much to achieve that goal. Their primary need was the presence of a reliable power backup.	Most electrical upgrades or replacements are postponed until there is a breakdown of equipment. Even then, EE is not the first consideration for replacement. Alternatives that are readily available and affordable are prioritized.
Broader information and awareness on the energy services market	Most offices surveyed were aware of energy-saving measures. However, knowledge and awareness of ESCOs were limited across the board.	In mature markets, ESCOs can aggregate smaller projects on behalf of office owners to lower project management and implementation costs [14]. In India, while ESCOs operate in the building sector, awareness of their existence and utility is limited.

Discussion

Findings and Critical Observations

- Benchmarking building energy use is possible in Indian cities with minimal data. We used readily available or collectable data for establishing relative energy efficiency levels of buildings. However, statistical applications for data analysis would require training and capacity-building of program officials.
- Interest and involvement of ULBs are very important. ULBs play a critical role in supporting the data collection exercise.
- There was little evidence of the split incentive barrier. Most tenants moved into offices where the owner provided only basic lighting and core services. Though tenants had the choice of installing efficient equipment and appliances, they preferred purchasing lower-cost and more readily available average efficiency alternatives in the market, except light-emitting diode (LED) lights, because of their ubiquitousness.
- There is no demand for financing high-cost upgrades. None of the offices expressed interest in taking loans or accessing other finance for more expensive retrofits or replacements. They were satisfied with their operations budget for upgrades and replacements.
- Saving energy is considered important to offices even though their actions suggest otherwise. Offices ranked energy savings as one of their top five priorities, but their actions, for example, on energy audits or purchase of high-efficiency equipment, do not back this up.
- Awareness of ESCO models is low. Offices were not aware of energy service companies (ESCOs) and their business models. Those who had heard of ESCOs perceived the business model to be more suited to industries.

Conclusion and Recommendations

- City-level benchmarking exercises are the starting point for evaluating the performance of buildings and identifying opportunities to improve operational performance.
- Regular benchmarking can support the development of outcome-based building codes, elevating India's building efficiency policy efforts.
- Availability of tools and approaches for benchmarking at local levels is necessary to ensure regular improvements.
- Kerala Institute of Local Administration (KILA) can sensitize local bodies on the importance and benefits of energy benchmarking to track the performance of their buildings and encourage energy retrofits afterward.
- Energy Management Centre in Kerala can adopt the methodology attempted in this study to build a benchmarking tool for application throughout the state, thus informing the design of local EE programs and schemes on building stock efficiency improvements in cities.
- The success of EE policies and programs can vary due to local market factors. A deeper understanding of local variations in EE's perceived barriers and opportunities can inform better design and implementation of EE schemes in existing buildings.

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