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FROM CONSUMPTION TO CONSERVATION: EVALUATING BUILDING ENERGY PERFORMANCE IN THIRUVANANTHAPURAM

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ABSTRACT

In India, buildings account for approximately one-third of the total electricity consumption, with nearly two-thirds of this demand being met through thermal power sources. In Kerala, buildings with Low Tension (LT) and High Tension (HT) electricity connections represent a significant portion of the state's overall electricity usage. As part of climate change mitigation efforts, decarbonizing these buildings requires proactive energy performance benchmarking by Thiruvananthapuram Municipal Corporation. Encouragingly, benchmarking building energy consumption in Indian cities is feasible even with limited data. This article presents an innovative methodology for benchmarking energy use in office buildings in Thiruvananthapuram, aiming to assess data availability and identify the practical challenges that could emerge if such efforts were expanded. To support continuous improvements, it is crucial to develop tools and methods tailored for local-level benchmarking. Furthermore, the State

Government can play a pivotal role by utilizing training institutions to build awareness among local bodies about the value of energy benchmarking. This would help them monitor building performance effectively and promote subsequent energy retrofit initiatives.

Keywords: Benchmarking, Power consumption, Decarbonizing, Building energy consumption.

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1. Backdrop

Across the globe, nations are committing to decarbonizing their building stock as a critical step toward climate goals. The buildings and construction sector accounted for 36% of global final energy consumption (excluding embedded energy) and contributed 39% of energy and process-related CO_2 emissions in 2018 (UNEP 2019). In India, buildings were responsible for 33% of total electricity consumption during 2018–19 (MOSPI 2019), with over 60% of that electricity derived from thermal power sources (MOSPI 2019).

In Kerala, buildings with Low Tension (LT) electricity connections alone accounted for 62% of the state's total electricity use. This figure is likely even higher when High Tension (HT) connections used by commercial and residential buildings are considered, although such data is not available separately. These statistics underscore the critical role of building decarbonization in Kerala's efforts to achieve its target of becoming carbon neutral by 2050. Meeting climate mitigation goals requires a clear understanding of how efficiently current buildings use energy. Energy performance benchmarking serves as a tool to determine baseline efficiency levels and equips policymakers, building owners, and managers with insights necessary for planning and implementing energy-saving measures. In this context, piloted an innovative benchmarking approach for office buildings in Thiruvananthapuram to assess data availability and identify practical barriers that may arise if benchmarking is scaled across the region.

2. Global Practice and Indian Experience

In many developed countries, building energy performance benchmarking is routinely carried out to monitor and evaluate energy efficiency (EE) initiatives, as well as to support the development of new programs and policies. Benchmarking establishes a baseline for energy consumption in existing buildings, allowing comparisons of their efficiency with similar structures after adjusting for differences in physical and operational attributes. While building codes typically focus on new constructions, benchmarking provides insights into the performance of existing buildings.

Citywide benchmarking systems, when data is made publicly accessible, serve as an effective tool for assessing building energy efficiency. According to Chung (2011) and Hart (2015), such transparency helps achieve three key objectives: it empowers the real estate sector to value energy efficiency; it encourages building owners to invest in retrofitting and EE services; and it enables policymakers to craft more effective energy regulations. When benchmarking is applied consistently across a wide sample of buildings, it can lead to improvements in energy codes. High-performing buildings may be recognized with awards (such as the U.S. Department of Energy's Sustainability Awards), while low performers could face penalties, as in the UK's Minimum Energy Efficiency Standards (MEES).

Beyond performance tracking, benchmarking also opens avenues for engaging building owners, tenants, and managers in renewable energy (RE) and EE initiatives. It provides essential data to market stakeholders and helps owners identify and prioritize areas for energy improvement.

In the Indian context, the Bureau of Energy Efficiency (BEE) undertook a data collection initiative between 2007 and 2009 through both primary and secondary surveys. The findings led to the launch of the Star Labeling Program for office buildings in 2009, which has not been updated since. In 2010, the USAID ECO-III Project collaborated with BEE to carry out a large-scale benchmarking study covering 760 commercial buildings of various types (Kumar et al., 2010). Later, in 2014, with support from the Shakti Sustainable Energy Foundation, BEE introduced the EcoBench Tool (Sarraf, 2014) for benchmarking hospitals, based on earlier ECO-III survey data. However, since then, no nationwide benchmarking program has been conducted in India.

3. Energy Benchmarking: Insights from Thiruvananthapuram

This paper stems from our initial objective of designing a citywide energy benchmarking framework. To begin with, conducted an extensive review of existing literature, consulted experts familiar with benchmarking initiatives in India, and developed a comprehensive survey tool. Then surveyed 45 office buildings in Thiruvananthapuram to evaluate the availability of data needed for a citywide program and to construct a Building Performance Index (BPI) using statistical regression methods. While the limited sample size and scope of data fields used in the survey may affect the representativeness of the results—especially in explaining performance variations among offices—the exercise still provided valuable insights.

In addition to the quantitative survey, carried out qualitative interviews with office managers to explore their understanding of energy efficiency (EE) services, retrofitting, and awareness of energy service companies (ESCOs). Globally, ESCOs have played a significant role in enhancing building energy performance, particularly in contexts where EE upgrades require substantial upfront investment. The interviews also explored common barriers to EE adoption, including the "split incentive" issue—where those who bear the cost of EE improvements (typically building owners) do not directly benefit from the energy savings, which usually accrue to tenants (WRI 2016).

In March 2021, WRI India released a working paper titled *"Benchmarking Energy Performance of Offices in Thiruvananthapuram"* based on the findings from both quantitative and qualitative analyses. The paper introduced new benchmarking methodologies and offered preliminary policy recommendations. Given the relevance of these insights for Kerala and its local governments, this abridged version presents a more localized perspective, aimed at helping urban local bodies in Kerala explore benchmarking efforts at different scales.

4. Objectives of this study

The research objectives include the following:

- Evaluate the potential for implementing a comprehensive citywide energy benchmarking program for office buildings.
- Design and establish a Building Performance Index (BPI) tailored to the operational and energy use characteristics of office spaces.

- Identify key barriers and enabling factors influencing energy efficiency retrofits across various owner–tenant arrangements, with a focus on awareness, financing, and service access.

5. Approach and Methodology

Dara were collected from 45 office spaces in Thiruvananthapuram city, because they account for 25 percent of large commercial consumers in Thiruvananthapuram, the second largest category after retail spaces. The researcher decided to focus on office buildings since 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. As part of this work, defined large commercial consumers as those with connected load ≥ 75kW or contract demand ≥ 100 kilovolt ampere (kVA). The threshold is determined 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. The number of such buildings in Thiruvananthapuram was low. For this study 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.

6. Scope of Study

This study focuses exclusively on office spaces and the energy consumption managed within their operational boundaries. It does not include the energy use associated with shared or common services in multi-tenant buildings—such as elevators, water pumping systems, and lighting in common areas—which are typically managed at the building level and not individually metered for each office. For the purpose of this study, the term **"offices"** will refer solely to these independently functioning office units, excluding the aforementioned common energy services.

7. Sample Identification

After fixing the sample criteria as offices with connected load ≥ 75 kW, the researcher sought their electricity consumption data from the electric utility, the KSEB. Since the KSEB used a different method to document this information, work with it to clarify the consumer categories and short-list 91 consumers. Then these consumers were contacted to seek their willingness to participate in the study. Based on the discussions, 62 joined the survey. Upon further analysis, finalized 45 office spaces for the advanced analysis on benchmarking energy performance and qualitative research to ensure homogeneity of the sample.

8. Primary Data Collection

As noted by Kumar et al. (2010), multiple initiatives in India have attempted to collect energy consumption data from commercial buildings. However, these efforts have often faced limited success due to several key challenges: difficulties in aligning survey terminology with the language commonly used by office managers; issues related to data accuracy and quality; concerns over confidentiality of sensitive energy data; and the inherent trade-off between collecting detailed data and minimizing the reporting burden on respondents.

Taking these lessons into account, we carefully designed our survey questionnaire to focus on essential and easily accessible information related to energy consumption. The primary objective was to gather baseline data that would allow for meaningful comparisons of energy performance across office buildings. Given that this initiative represented one of the first city-level benchmarking exercises of its kind in India, the data collection strategy was pragmatic—prioritizing information that office managers could provide readily, without requiring extensive effort or specialized expertise.

The data collection process was significantly facilitated by a formal letter of support from the Thiruvananthapuram Municipal Corporation (TMC), which helped build credibility and encouraged participation. A trained survey agency conducted the primary data collection using both in-person visits and remote methods, depending on the availability and convenience of the respondents. To ensure consistency and reliability in benchmarking, certain key data fields were designated as mandatory, while others were considered optional.

9. Rationale for Using Building Performance Index (BPI) for Benchmarking

The energy performance of a building is influenced by a variety of factors, including but not limited to its total built-up area, number of occupants, proportion of conditioned spaces (such as air-conditioned areas), operational hours, and the nature of activities conducted within the premises. Therefore, when comparing the energy performance of one building to another, it is essential to normalize for these key parameters to ensure a fair and meaningful comparison.

Traditionally, the **Energy Performance Index (EPI)**—which calculates energy use per unit of floor area (typically measured in kWh/sq.m/year)—has been widely used as a metric for evaluating building performance. However, EPI considers only two variables: total annual energy consumption and floor area. While this offers a general overview, it does not sufficiently account for the operational diversity and contextual nuances of different buildings.

To address these limitations, our study adopts the **Building Performance Index (BPI)**, a more comprehensive and statistically robust metric that accommodates multiple building characteristics. The BPI allows for normalization across a broader set of influencing factors, providing a more accurate representation of energy efficiency across diverse office buildings.

Our benchmarking methodology is adapted from the work of **Sarraf et al. (2014)**, which utilized regression-based statistical techniques to assess the energy performance of 760 commercial buildings. This methodology laid the foundation for **EcoBench**, India's first national-level benchmarking platform for hospitals and other building typologies. Under this approach, a building's actual energy performance is compared with that of a statistically modeled "benchmark" building possessing similar physical and operational attributes. The relative performance is expressed as a BPI score, enabling a fair and data-driven ranking of buildings.

In our study, the same approach was tailored for application to office buildings in Thiruvananthapuram. Statistical modeling was used to estimate the expected energy use of each building based on a defined set of attributes, and BPI scores were assigned based on the deviation from this expected benchmark. Buildings that performed better than the modeled benchmark received higher scores, indicating greater energy efficiency.

While a full exposition of the statistical methodology falls outside the scope of this paper, readers interested in a deeper understanding of the modeling techniques and scoring system are encouraged to consult the original publication by Sarraf et al. (2014).

10. Findings from the benchmarking exercise

10.1. Occupancy categories: For each office, collected ownership information. Of the 45 buildings, 12 were owned by the central government, 6 by the state government, and 27 by private companies.

10.2. Premise ownership and facilities management: 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.

i. Owners occupied most of the buildings surveyed (32 of the 45 buildings). Facilities in 23 offices were managed by in-house teams, and third parties managed the remaining 22
ii. Tenants occupied 18 offices; 10 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.
iii. None of the leased facilities had third-party facilities managers

10.3. Size categorization of office spaces: Analysed data from the 45 offices to understand energy use characteristics, physical characteristics of the building, building management, and ownership information. Categorized them into small, medium, and large offices using statistical tests in the R program. To fix these categories, used segmented regression techniques to analyse the data for breakpoints. However, no breakpoints were identified, possibly because of the small sample size. The carpet area of offices ranged from 325 m2 to 11,600 m2.

10.4. Energy- and equipment-related characteristics

i. **Connected load and annual consumption:** Of the 45 offices, 21 had a connected load ranging between 75kW and 100 kW. The remaining 24 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 45 offices had a combined annual electricity consumption of 12 million units and a total connected load of 8.192 MW.
ii. **Air-conditioning:** Three of the 45 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.
iii. **Rooftop solar:** Seven of the 45 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.

10.5. 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. Then allotted building IDs to the 45 buildings, calculated their BPIs, and converted them to ranks ranging from 1 to 45. BPI values ranged from 0.34 to 2.19 (Figure 1). Although no in-depth investigations into the reasons behind the different energy performance of the same type of buildings, but presenting some observations:

A. The Top 22 ranks are for offices with BPI < 1

i. 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.

ii. There are also 6 office spaces occupied by tenants and managed by the owner (75 percent of this category) in the top 22.

iii. 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.

iv. 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).

B. The bottom 28 ranks are for offices with BPI > 1

i. 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.

ii. All 7 offices where multiple tenants occupied, and managed facilities are in the bottom 28.

ii. Fourteen of the 28 offices in the bottom are occupied by central government agencies, 12 by private companies, and the remaining 2 by state government bodies.

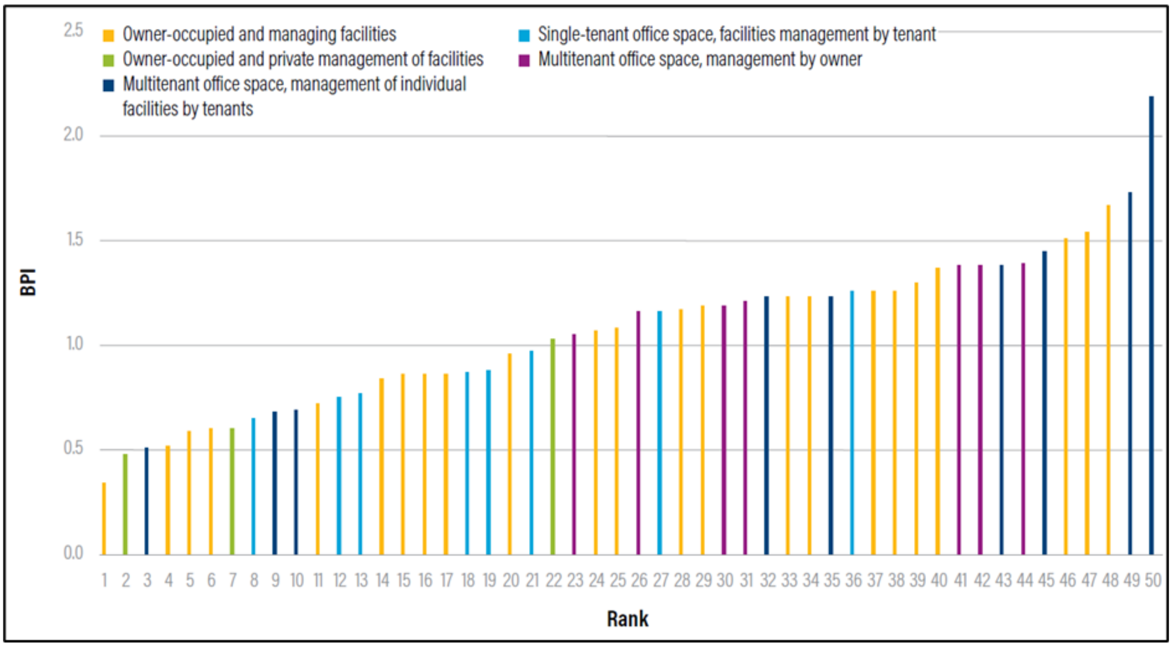

Figure 1: BPIs and Building Ranks by Building Categories

11. Qualitative Survey

Also conducted a qualitative survey of the 45 offices over the telephone due to entry 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 (Marquez et al. 2012). Also tested the applicability of the "split incentives" and other barriers across different buildings.

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

  It is required to document specific drivers of EE services, including retrofit projects. Also required 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	FINDINGS FROM THIRUVANANTHAPURAM	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).	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, it is 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. 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 and motivation in saving energy	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. But knowledge and awareness on ESCOs was limited across the board.	In mature markets, ESCOs can aggregate smaller projects on behalf of office owners to lower project management and implementation costs (Marquez et al. 2012). In India, while ESCOs operate in the building sector, awareness of their existence and utility is limited.

12. Findings and Critical Observations

This study presents several key insights into the feasibility, practical challenges, and institutional readiness for implementing energy benchmarking initiatives for office buildings in Indian cities, with specific observations from Thiruvananthapuram:

i. Feasibility of Benchmarking with Minimal Data Inputs:

The study demonstrates that energy benchmarking of buildings in Indian urban contexts is feasible using limited and readily available data. By leveraging basic information—such as energy bills, built-up area, occupancy, and equipment usage—the research was able to establish relative energy efficiency levels among office buildings. However, the application of statistical tools for deriving meaningful benchmarks and developing indices like the Building Performance Index (BPI) requires specialized analytical capabilities. Thus, capacity-building and technical training of Urban Local Body (ULB) personnel and program implementers are essential for scaling such initiatives (Rajan J. B., & Biju S. K., 2013).

ii. Critical Role of Urban Local Bodies (ULBs):

The support and engagement of ULBs are pivotal for the successful execution of benchmarking programs (Rajan J. B., & Biju S. K., 2015). In this study, the involvement of the Thiruvananthapuram Municipal Corporation facilitated data access and legitimized the data collection process, improving the willingness of office owners and managers to participate. This highlights the importance of institutional endorsement and governance support for citywide energy performance initiatives.

iii. Limited Impact of Split Incentive Barrier:

Contrary to common assumptions in energy efficiency literature, the study found limited evidence of the "split incentive" barrier, where landlords are responsible for energy efficiency investments while tenants benefit from the reduced utility bills. In most surveyed offices, tenants occupied spaces with only basic infrastructure (e.g., lighting and core services) provided by the owner. While tenants had the autonomy to procure energy-efficient equipment, they often opted for readily available and cost-effective options, primarily due to ease of access and upfront affordability. LED lighting emerged as the only widely adopted efficient technology, likely due to its low cost and market saturation.

iv. Low Demand for Financing High-Cost Retrofits:

The study found no indication of demand for financing mechanisms—such as loans or performance contracts—for major energy efficiency upgrades. Offices reported that their existing operational budgets were adequate for routine maintenance, minor replacements, and incremental upgrades. This suggests a gap in both the awareness and perceived necessity of capital-intensive retrofits, pointing to the need for targeted awareness programs and innovative financial products.

v. Perception–Action Gap in Energy Saving Priorities:

While many offices ranked energy conservation among their top five operational priorities, their actual practices did not align with this stated intention. Few had undertaken energy audits or proactively procured high-efficiency equipment beyond LEDs. This disconnect between perception and action underscores the need for behavioral interventions, institutional nudges, and improved access to credible technical advisory services.

vi. Low Awareness of Energy Service Companies (ESCOs):

Awareness and understanding of ESCO models among surveyed office managers were significantly low. Where awareness existed, ESCOs were largely perceived as entities relevant only to industrial or large-scale institutional energy users. There was limited recognition of ESCOs' potential role in the commercial office segment, suggesting an opportunity for outreach, education, and tailored service offerings by ESCOs in the urban commercial sector.

13. Recommendations

i. Initiate City-Level Benchmarking as a Foundation for Energy Efficiency Planning:-

Conducting energy benchmarking at the city level serves as a critical first step in evaluating the energy performance of buildings. Such exercises help establish baseline performance data, identify underperforming buildings, and uncover opportunities for operational improvements. Municipalities should integrate benchmarking into their routine urban governance practices to promote evidence-based energy management.

ii. Leverage Benchmarking to Inform Outcome-Based Building Codes:-

Periodic benchmarking exercises can provide empirical data to support the formulation of outcome-based building codes and energy performance standards. By transitioning from prescriptive codes to performance-driven regulations, India can significantly enhance its policy framework for building efficiency, ensuring that design and operation are aligned with long-term energy and climate goals.

iii. Develop and Deploy Localized Benchmarking Tools and Frameworks:-
The development and dissemination of simple, adaptable benchmarking tools at the local level

is essential to institutionalize energy performance assessments. These tools should be user-friendly, require minimal data inputs, and be integrated with existing urban management systems to enable continuous monitoring and periodic assessments.

iv. **Empower ULBs through Capacity-Building and Institutional Awareness**:- The Kerala Institute of Local Administration (KILA) can play a pivotal role in sensitizing Urban Local Bodies (ULBs) about the importance and benefits of energy benchmarking. Through dedicated training programs, workshops, and model guidelines, KILA can equip ULBs with the knowledge and skills needed to assess and track energy use in public buildings, paving the way for targeted retrofits and energy conservation measures.

v. **Adopt and Scale Statewide Benchmarking Initiatives via Energy Management Centre (EMC):-**

The Energy Management Centre (EMC), Kerala can adopt the methodology piloted in this study to develop a scalable, state-level benchmarking platform. This platform can serve as a decision-support tool for identifying high-impact interventions, prioritizing energy efficiency (EE) investments, and designing localized programs to improve building stock performance across urban areas in Kerala.

vi. **Incorporate Local Context in EE Program Design**:-

The effectiveness of energy efficiency policies and programs is highly influenced by local market conditions, stakeholder perceptions, and behavioral trends. A granular understanding of region-specific barriers—such as limited financing, low awareness, or institutional constraints—can enable the design of more responsive and adaptable EE schemes. Localized assessments should become a standard part of program development to ensure relevance and sustainability.

14. Conclusion

This study demonstrates the feasibility and relevance of implementing a citywide building energy benchmarking program in Indian urban contexts, using Thiruvananthapuram as a pilot case. Despite the limitations of sample size and data availability, the analysis shows that basic energy performance comparisons can be effectively conducted using minimal yet strategic data inputs. The development of a Building Performance Index (BPI) allowed for more contextual and equitable comparisons among office buildings, taking into account operational and physical variables often overlooked in simpler metrics like the Energy Performance Index (EPI).

The findings underscore the importance of institutional support, particularly from Urban Local Bodies (ULBs), in facilitating data collection and promoting energy efficiency (EE) practices. While energy saving is acknowledged as a priority by most offices, there remains a significant gap between intent and action—driven by low awareness of ESCO models, limited demand for financing retrofits, and persistent behavioral inertia.

The study also emphasizes the need for localized tools and frameworks, along with stakeholder engagement and capacity-building, to scale benchmarking initiatives. Establishing a state-level platform for benchmarking, led by agencies like the Energy Management Centre and KILA, can empower local governments to drive meaningful improvements in building energy performance. Ultimately, benchmarking is not only a technical exercise but a policy enabler that can guide smarter investments, improve accountability, and support India's broader climate and energy goals.

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