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# Cost-Effectiveness and Energy Efficiency Assessment of a Commercial Building Retrofit in Mbeya, Tanzania.

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***ABSTRACT:*** *Rapid urban expansion in Mbeya City has increased demand for commercial buildings that balance economic viability with sustainability. This study evaluates the cost-effectiveness and energy efficiency of retrofitting a mid-rise commercial building with measures such as LED lighting, inverter-based HVAC systems, and rooftop solar PV. Using building performance records, utility bills, and stakeholder interviews, the analysis applied cost-benefit and life-cycle methods to assess financial and operational impacts. Results show a 22% reduction in electricity consumption and energy use intensity, with retrofit investments representing 8-15% of capital costs and achieving payback within five years. The rooftop solar system contributed 7% of total demand, while lighting upgrades delivered the largest savings. These findings confirm that targeted retrofits are both technically feasible and financially attractive in Tanzania's commercial sector. Broader adoption, however, requires stronger regulatory enforcement and accessible green financing to scale energy-efficient practices across urban developments.*

***KEYWORDS:*** *Energy efficiency, Cost effectiveness, Commercial building design, Mbeya city(Tanzania)*

## I. INTRODUCTION

Tanzania is experiencing rapid urbanization, with cities such as Mbeya undergoing significant demographic and spatial growth. Urban expansion has been shown to reshape national development priorities and intensify demand for modern infrastructure [1]. Mbeya, with a population exceeding 500,000 according to the 2022 census, has emerged as one of the fastest-growing urban centers in the southern highlands. This growth has driven demand for commercial buildings, including offices, retail centers, and mixed-use developments, which in turn has increased energy consumption and placed pressure on the national grid [2].

The commercial building sector in Tanzania is characterized by high energy intensities and thermal inefficiencies. National energy balance data indicate that commercial buildings are among the highest consumers of electricity, largely due to extended operating hours and reliance on artificial lighting and cooling systems [3]. Most structures are constructed using conventional materials such as concrete blocks and corrugated roofing, which are affordable but thermally inefficient [4]. Energy audits reveal that typical commercial buildings consume more than 80 kWh/m²/year, nearly double the international benchmarks for energy efficiency. This technical performance gap results in high operating costs, unstable indoor comfort, and elevated greenhouse gas emissions. Addressing this challenge requires both passive design strategies-such as orientation, natural ventilation, and daylighting-and active measures, including efficient lighting, HVAC systems, and renewable energy integration [5].

Although the technical solutions are well established, adoption in Tanzania remains limited. Barriers include high upfront costs, lack of technical expertise, and weak regulatory enforcement. Developers often underestimate the long-term financial benefits of energy-efficient retrofits, while financial institutions rarely provide green financing products. Furthermore, architectural practices have not consistently integrated energy efficiency into design, despite global recognition of its importance in mitigating climate impacts [6]. While the National Energy Efficiency Strategy 2024-2034 outlines measures such as mandatory audits and performance standards, implementation remains slow, and enforcement mechanisms are weak [7]. As a result, most commercial buildings continue to operate with inefficient systems, locking in high energy demand and costs.

This study contributes to closing that gap by providing localized empirical evidence from a retrofitted mid-rise commercial building in Mbeya City. The novelty lies in combining technical performance evaluation with economic and policy analysis in a Tanzanian context, where such integrated case studies remain scarce. Specifically, the research investigates three questions: (1) What energy savings can be achieved through targeted retrofits in a typical Mbeya commercial building? (2) Are these measures


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financially viable under Tanzanian market conditions when assessed through life-cycle cost analysis? (3) How do the findings inform national energy efficiency strategies and building codes?

By sharpening the engineering problem, situating the case study within its local context, and explicitly stating its contribution, this paper demonstrates that energy-efficient retrofits are both technically feasible and economically attractive in Tanzania's commercial sector, and highlights the institutional reforms needed to scale their adoption.

## II. LITERATURE REVIEW

Energy efficiency in buildings has emerged as a global priority in response to climate change, rising energy costs, and rapid urbanization [8]. According to the International Energy Agency, buildings account for nearly 30% of global energy consumption and 28% of energy-related $CO_2$ emissions [9]. These figures underscore the critical role that the building sector must play in achieving climate targets. In response, countries have adopted building energy codes, green certification systems, and financial incentives to promote energy-efficient construction and retrofitting [10].

Energy efficiency strategies are typically categorized into passive and active measures. Passive strategies involve architectural decisions such as building orientation, natural ventilation, and thermal insulation. These are particularly effective in tropical and subtropical climates where cooling loads dominate energy use. Active strategies include efficient lighting, HVAC systems, and renewable energy technologies such as solar photovoltaic panels [11].

Cost-effectiveness is a major factor influencing the adoption of energy-efficient technologies, especially in developing countries [12]. Life-cycle cost analysis is widely used to evaluate the economic viability of energy-saving measures by comparing initial investment costs with long-term operational savings [13]. Studies have shown that energy-efficient buildings often achieve payback within five to ten years and deliver substantial savings over their lifespan [14].

In Sub-Saharan Africa, the adoption of energy-efficient building practices is still limited. Most buildings are constructed using conventional materials and methods that prioritize affordability over performance [15]. However, there are promising examples of green building initiatives in countries such as Kenya, Rwanda, and South Africa. These include the development of green building councils, the introduction of energy codes, and the implementation of pilot projects that demonstrate the feasibility of sustainable design [16].

Tanzania has made some progress in promoting energy efficiency. The Tanzania Energy Efficiency Action Plan outlines a roadmap for improving energy performance in buildings, industries, and public institutions. The plan includes measures such as mandatory energy audits, capacity building, and the development of minimum energy performance standards. However, implementation has been slow, and enforcement mechanisms remain weak [17]

Commercial buildings in Tanzania present a significant opportunity for energy savings. These buildings typically have high energy intensities due to extensive use of lighting, air conditioning, and electronic equipment [18]. A study by Kabanda and Mwakalinga found that most commercial buildings in urban Tanzania lack basic energy-saving features such as insulation, efficient lighting, or zoning controls. As a result, operational costs are high and indoor environmental quality is often poor.

Despite these challenges, there is growing interest in sustainable building practices among Tanzanian stakeholders. Universities are incorporating green design into their curricula, NGOs are conducting awareness campaigns, and some developers are experimenting with solar energy and efficient appliances. These efforts are supported by international organizations such as UN-Habitat, which has launched programs to promote energy efficiency in East African cities [19].

These literatures highlights both the potential and the barriers to energy-efficient building design in Tanzania. While the technical solutions are well understood, their adoption depends on local capacity, regulatory frameworks, and financial incentives. This paper contributes to the discourse by providing empirical evidence from a real-world case study in Mbeya.

## III. METHODOLOGY

This study employs a qualitative case study approach to evaluate the cost-effectiveness and energy efficiency of retrofitting strategies for a mid-rise commercial building in Mbeya City. The case-study method was chosen because it allows for in-depth analysis of real-world conditions and is particularly suited to exploring complex, context-dependent phenomena [20]. The selected building is a four-story, mixed-use commercial structure located in the central business district. It was chosen because it represents the typical construction typology in urban Tanzania-


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reinforced concrete, hollow blocks, corrugated roofing, and aluminum-framed windows-and because its high energy intensity made it a suitable candidate for retrofit evaluation. While this single case provides valuable insights, its generalizability is acknowledged as limited. Primary data were collected through structured interviews with building managers, engineers, and tenants. These interviews explored motivations for retrofitting, perceived benefits, and operational changes post-intervention [21]. On-site observations were conducted to assess the building's physical condition and the functionality of installed systems. Secondary data included architectural drawings, utility bills, and maintenance logs [22].

A life-cycle cost analysis was used to evaluate financial viability [23]. This method considers all costs associated with a building system over its expected life span, including capital, operation, maintenance, and replacement costs. The analysis used a 25-year time horizon and a 6% real discount rate. Key financial indicators included the net present value, the internal rate of return, and the payback period [24].

Energy efficiency was assessed using Energy Use Intensity (EUI), measured in kWh/m²/year. EUI was calculated as:

$$EUI = \frac{\text{Annual Electricity Consumption (kWh)}}{\text{Gross Floor Area } (\text{m}^2)}$$

Where annual electricity consumption represents the total energy used within one year, and gross floor area refers to the total conditioned building area. This metric normalizes energy consumption relative to building size, allowing meaningful comparisons across different buildings. The calculated EUI values were then compared to national and international benchmarks to assess relative performance [25].

Interview data were analyzed thematically to capture perceptions of the impacts of retrofitting. Tenants reported improved lighting quality, more stable indoor temperatures, and reduced noise from HVAC systems. These qualitative insights were integrated into the results to complement quantitative findings, highlighting non-financial benefits such as comfort and productivity [26].

Finally, the study reviewed relevant policy documents to understand the regulatory context. These included the Tanzania Energy Efficiency Action Plan and the National Building Code. This policy analysis helped identify institutional gaps and informed the recommendations presented later in the paper [27].

### A. OVERVIEW OF MBEYA CITY

Mbeya City is located in the southern highlands of Tanzania and serves as the administrative and economic center of the Mbeya Region. The city is strategically positioned along the Tanzania-Zambia Highway and the TAZARA railway, making it a key transit and trade hub for the Southern African Development Community (SADC) region [28]. According to the 2022 national census, Mbeya's population has exceeded 500,000, reflecting rapid urban growth over the past two decades [29].

Fig 1. Location of the Mbeya region [30]

The city's urban landscape is a mix of formal and informal development. While the central business district features multi-story commercial buildings, banks, and government offices, the outskirts are dominated by informal settlements and peri-urban agriculture [31]. Mbeya's master plan outlines zoning regulations and infrastructure development goals, but implementation has been inconsistent due to limited municipal capacity [32].

Mbeya's climate is classified as subtropical highland, with moderate temperatures and significant rainfall throughout the year. Average daytime temperatures range from 15°C to 25°C, and annual precipitation exceeds 1,000 mm [33]. These conditions reduce the need for mechanical cooling but require careful attention to moisture control and ventilation design [34]. The city's energy infrastructure is primarily dependent on the national grid, which is supplied by a mix of hydropower and thermal generation [35]. Despite recent investments in electrification, power outages and voltage fluctuations remain common, especially during the rainy season. Many commercial buildings rely on diesel generators for backup power, thereby increasing operational costs and contributing to air pollution [36].


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Commercial buildings in Mbeya vary widely in terms of design and energy performance. Most are constructed using concrete blocks, corrugated metal roofing, and aluminum-framed windows, which offer limited thermal insulation. Few buildings incorporate energy-saving features such as insulation, shading devices, or efficient lighting systems[37]. Despite these challenges, there is growing awareness of sustainable building practices in Mbeya. Local universities have introduced courses in green architecture and renewable energy, and NGOs are promoting energy efficiency through pilot projects and training programs [38]. These efforts are beginning to influence both the public and private sectors.

### B. CASE STUDY: A TYPICAL COMMERCIAL BUILDING IN MBEYA CITY

The case study focuses on a mid-rise commercial building located in Mbeya's central business district. Constructed in 2012, the building serves multiple functions, including office spaces, retail outlets, and conference facilities [39]. With a total floor area of approximately 2,500 square meters across four stories, it is representative of the mixed-use commercial typology common in Tanzanian cities [40].


Fig 2. A typical commercial building located at Soko Matola, Mbeya CBD

The building was originally constructed using reinforced concrete and hollow concrete blocks, with a corrugated metal roof and aluminum-framed windows [41]. These materials are affordable and widely used in Tanzania, but offer limited thermal insulation [42]. The original design lacked passive cooling features such as cross-ventilation, shading, or thermal massing. An energy audit conducted in 2021 revealed that the building consumed an average of 18,000 kWh per month, translating to an energy use intensity (EUI) of 86 kWh/m²/year. This figure is significantly higher than international benchmarks for energy-efficient commercial buildings. The building's monthly electricity bill averaged TZS 3.5 million, a substantial operational cost for the owner [43].

In response, the owner initiated a retrofitting project between 2021 and 2023 [44]. The interventions included replacing incandescent and fluorescent lighting with LED fixtures, installing motion sensors in common areas, and upgrading air conditioning units to inverter-based systems [45]. A 10 kW rooftop solar photovoltaic system was also installed to supplement grid electricity [46]. The retrofitting process was phased to minimize disruption to tenants. The lighting upgrade was completed first, followed by HVAC improvements and the solar installation. The total cost of the project was approximately TZS 45 million (USD 18,000), financed entirely by the building owner [47].

Post-retrofit monitoring showed a 22% reduction in monthly electricity consumption, lowering the EUI to 67 kWh/m²/year. The solar PV system generated about 1,200 kWh per month, covering 7% of the building's total energy demand. Tenants reported improved lighting quality, more stable indoor temperatures, and reduced noise from air conditioning units [48]. Despite these improvements, challenges remained. The building's orientation and window-to-wall ratio limited the effectiveness of natural ventilation and daylighting [49]. The lack of insulation in the roof and walls continued to contribute to thermal inefficiency [50]. Additionally, the absence of a building management system meant that energy use was not continuously monitored [51].

Nonetheless, the case study demonstrates that even modest retrofitting measures can yield significant energy and cost savings in Tanzanian commercial buildings [52]. It also highlights the importance of integrating energy efficiency into the design phase rather than relying solely on post-construction interventions [53].

### C. COST-EFFECTIVENESS ANALYSIS

Evaluating the cost-effectiveness of energy-efficient interventions is essential for understanding their financial viability and encouraging broader adoption in Tanzania's commercial building sector [54]. In the Mbeya case study, the total cost of retrofitting was approximately TZS 45 million, equivalent to around USD 18,000 at the time of implementation. This investment covered the purchase and installation of LED lighting, motion sensors, inverter-based air-conditioning units, and a 10-kW rooftop solar photovoltaic system. To assess financial viability, a life-cycle cost analysis (LCCA) was conducted over a 25-year period. This method accounts


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for all costs associated with a building system over its expected lifespan, including capital, operation, maintenance, and replacement costs [55]. A real discount rate of 6% was applied, consistent with international standards for building performance evaluation [56].

Post-retrofit data showed an average monthly energy cost reduction of TZS 770,000, translating to annual savings of over TZS 9.2 million. The annual savings were calculated as:

$$\text{Annual Savings} = \text{Monthly Savings} \times 12$$
$$= 770{,}000 \times 12 = 9{,}240{,}000 \text{ TZS/year}$$

When discounted over 25 years, the Net Present Value (NPV) of these savings was estimated using:

$$NPV = \sum_{t=1}^{25} \frac{\text{Annual Savings}}{(1+r)^t} - C_{initial}$$

where $r$ is the discount rate and $C_{initial}$ is the initial investment cost. The discounted value of savings was approximately TZS 104 million. This figure is more than double the initial investment, indicating a strong return on investment.

The Internal Rate of Return (IRR) was calculated as the discount rate that satisfies:

$$0 = \sum_{t=1}^{25} \frac{\text{Annual Savings}}{(1+IRR)^t} - C_{initial}$$

The IRR was 14%, indicating the project yields a 14% annual return over its lifecycle.

The simple payback period was determined using:

$$\text{Payback Period} = \frac{C_{initial}}{\text{Annual Savings}}$$

The payback period was just under five years [57]. These results are consistent with findings from other studies in Sub-Saharan Africa, which have shown that energy-efficient retrofitting can be economically viable even in low-income contexts [58]. Lighting and HVAC upgrades typically have payback periods of three to seven years, depending on building type and usage patterns [59].

In addition to direct financial benefits, the retrofitting measures yielded several indirect advantages. Improved lighting and thermal comfort contributed to higher tenant satisfaction, which can lead to increased occupancy rates and rental income. The building's enhanced energy performance also reduced its environmental footprint, aligning it with emerging green building standards and potentially increasing its market value [60]. However, the analysis also revealed some limitations. The lack of access to concessional financing or government incentives meant that the entire investment burden fell on the building owner. This is a common barrier in Tanzania, where green financing mechanisms are still underdeveloped [61]. Additionally, the absence of a building management system limited the ability to track and optimize energy use in real time [62].

Despite these challenges, the case study provides compelling evidence that energy-efficient retrofitting can be both technically feasible and financially attractive in the Tanzanian context. The key to maximizing cost-effectiveness lies in strategic planning, early integration of efficiency measures, and access to affordable financing [63].

### D. ENERGY EFFICIENCY EVALUATION

The evaluation of energy efficiency in the Mbeya commercial building was conducted using both quantitative and qualitative metrics. The primary quantitative indicator was energy use intensity (EUI), measured in kilowatt-hours per square meter per year (kWh/m²/year) [1], [64]. Before retrofitting, the building recorded an EUI of 86 kWh/m²/year, which is significantly higher than the international benchmark of 40-60 kWh/m²/year for energy-efficient commercial buildings. After implementing energy-saving measures, the EUI dropped to 67 kWh/m²/year, representing a 22% improvement in overall energy performance. The most impactful intervention was the replacement of traditional lighting systems with LED fixtures. Lighting accounted for nearly 40% of the building's total electricity consumption prior to retrofitting [65].

The installation of motion sensors in common areas, such as hallways and restrooms, further enhanced efficiency by ensuring that lights were active only when needed [66]. The building's HVAC system was another major contributor to energy consumption. The original air conditioning units were outdated and operated at fixed speeds, leading to frequent cycling and energy waste [67]. These were replaced with inverter-based systems that adjust compressor speed in response to cooling demand. This technology significantly reduces energy use under partial-load conditions, which are common in office environments


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[68]. A zoning strategy was also implemented, allowing different sections of the building to be cooled independently based on occupancy patterns [69].

Natural ventilation and daylighting were enhanced through architectural modifications. Operable windows were enlarged, and light shelves were installed to redirect sunlight deeper into interior spaces. These changes reduced reliance on artificial lighting during daylight hours and improved indoor air quality [70].

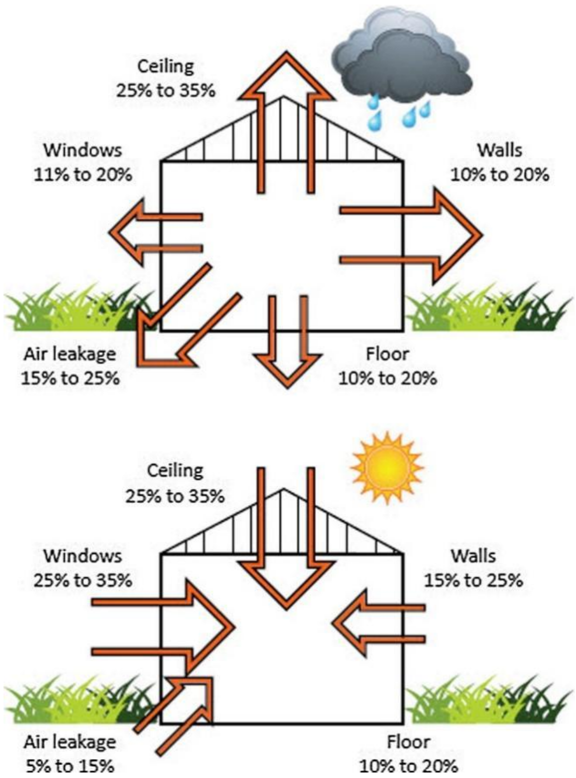


Fig 3. Natural ventilation and daylighting through architectural modifications[71]

The rooftop solar photovoltaic system contributed to the building's energy efficiency by generating approximately 1,200 kWh per month. This accounted for about 7% of the building's total energy demand and provided a reliable source of electricity during grid outages. The solar system also reduced the need for diesel generators, which are costly to operate and environmentally harmful [72], [73].

Qualitative assessments were conducted through interviews and surveys with building occupants. Tenants reported improved lighting quality, more stable indoor temperatures, and reduced noise from air conditioning units [73]. These improvements contributed to higher levels of comfort and productivity, which are important but often overlooked aspects of building performance.

Despite these gains, the evaluation revealed areas for further improvement. The building still lacks thermal insulation in its roof and walls, which limits the effectiveness of both passive and active cooling strategies [74]. Additionally, the absence of a building management system means that energy performance is not continuously monitored, reducing opportunities for real-time optimization and fault detection [75].

## IV. RESULTS AND DISCUSSION

The findings from the Mbeya case study highlight the complex relationship between design decisions, operational performance, and economic outcomes in commercial buildings. The retrofitting measures implemented, such as LED lighting, inverter-based HVAC systems, and rooftop solar, demonstrated clear benefits in terms of reduced energy consumption and improved occupant comfort [76]. These outcomes align with global evidence showing that energy-efficient buildings can achieve substantial operational savings when properly designed and maintained [77].

However, the case also revealed persistent barriers to widespread adoption. The initial capital outlay, although modest by international standards, was a significant burden for the building owner. This reflects a broader challenge in Tanzania, where access to affordable financing for green building projects remains limited. Without targeted financial instruments such as green bonds or concessional loans, many developers are unlikely to prioritize energy efficiency [78].

Another key issue is the lack of technical expertise and institutional support. Many professionals in the construction sector are unfamiliar with energy modeling tools, passive design strategies, or green certification systems. This skills gap limits the ability to design and implement high-performance buildings. Moreover, Tanzania's building codes do not currently mandate energy efficiency standards, leaving compliance largely voluntary [79].

The case also underscores the importance of integrating energy efficiency from the earliest stages of building design [80]. Many of the retrofitting measures were constrained by the building's original layout and orientation, which were not optimized for passive strategies. Early integration enhances performance and reduces the cost of later modifications [81].

Policy and governance emerged as critical factors influencing adoption. While Tanzania has developed strategic documents such as the Energy Efficiency Action Plan, implementation remains uneven due to limited enforcement capacity [82]. Strengthening


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institutional frameworks and fostering public-private partnerships are essential to scaling up energy-efficient construction.

The case illustrates the potential for energy-efficient buildings to contribute to broader sustainability goals [83]. By reducing energy demand and emissions, such buildings support Tanzania's commitments under the Paris Agreement and its Nationally Determined Contributions [84]. They also enhance economic resilience and improve the quality of life for urban residents.

Tbl 1. Comparative Results

| Intervention | Pre-retrofit Performance | Post-retrofit Performance | Improvement (%) |
|---|---|---|---|
| Energy Use Intensity (EUI) | 86 kWh/m²/year | 67 kWh/m²/year | 22% |
| Monthly Electricity Use | 18,000 kWh | 14,040 kWh | 22% |
| Monthly Electricity Cost | TZS 3.5 million | TZS 2.73 million | 22% |
| Solar PV Contribution | 0 kWh | 1,200 kWh | +7% coverage |
| Payback Period | N/A | 5 years | - |
| Net Present Value (NPV) | N/A | TZS 104 million | - |
| Internal Rate of Return | N/A | 14% | - |

The quantitative results show that lighting upgrades had the greatest impact, cutting electricity use by nearly 40% in the lighting load alone. HVAC improvements further minimized energy waste at partial loads, while solar PV added resilience to grid instability [85].

The Energy Use Intensity (EUI) was calculated by dividing the building's annual electricity consumption by the total floor area (2,500 m²). Annual electricity consumption was obtained from monthly consumption multiplied by 12:

$$\text{Annual Electricity Consumption} = \text{Monthly Consumption} \times 12$$

$$EUI = \frac{\text{Annual Electricity Consumption (kWh)}}{2{,}500 \text{ m}^2}$$

Annual savings of TZS 9.2 million were discounted over a 25-year horizon using a 6% real discount rate. The Net Present Value (NPV) was calculated using the standard discounted cash flow formula:

$$NPV = \sum_{t=1}^{25} \frac{\text{Annual Savings}}{(1+r)^t}$$

where $r = 0.06$ and $t$ represents each year of the project life. The resulting NPV was estimated at TZS 104 million.

Qualitative feedback from tenants confirmed improvements in comfort, productivity, and satisfaction, which, in turn, enhance building value and occupancy rates. However, limitations such as a lack of insulation and the absence of a building management system constrained further efficiency gains [86]. Energy-efficient retrofits in commercial buildings can pay for themselves within 3-7 years, even in resource-limited settings[87].

The Mbeya case study demonstrates the tangible benefits of moderate retrofitting measures in commercial buildings, particularly in resource-constrained contexts such as Tanzania. The interventions implemented LED lighting, inverter-based HVAC systems, and rooftop solar PV, which produced a 22% reduction in electricity consumption and a favorable payback period of under five years [88]. These results confirm that targeted retrofits can be economically viable even without external financing, thereby offering a practical model for similar mid-rise commercial buildings across Tanzanian cities.

Beyond the immediate case, the findings highlight several broader lessons. First, the economic viability of efficiency measures suggests that replication is feasible across comparable building types, especially those with high lighting and cooling loads. However, the building owner's reliance on self-financing underscores a systemic barrier: without accessible green financing instruments, the scalability of such retrofits remains limited [89]. This case, therefore, illustrates both the


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potential and the constraints of adopting energy efficiency in Tanzania's commercial sector.

Second, the engineering significance of the interventions lies in their ability to reduce energy waste during partial loads and improve occupant comfort. Yet, the absence of insulation and the building's orientation limited the effectiveness of passive strategies. This reinforces the critical importance of integrating efficiency measures at the design stage rather than relying solely on post-construction retrofits [90]. The Mbeya case thus extends earlier studies by demonstrating that while retrofits can yield substantial savings, their impact is constrained by initial design decisions.

Third, the results align with regional evidence from Kenya and South Africa, where similar retrofits have achieved payback periods of three to seven years. By confirming these trends in the Tanzanian context, the study contributes localized empirical data that has been largely absent from the literature. At the same time, the findings differ from some international benchmarks, where energy use intensities of 40-60 kWh/m²/year are common. The Mbeya building's post-retrofit EUI of 67 kWh/m²/year, though improved, remains above these benchmarks, indicating that further efficiency gains are possible with more comprehensive interventions [91].

## V. CONCLUSION

This study has explored the cost-effectiveness and energy efficiency of retrofitting strategies in a typical commercial building in Mbeya City, Tanzania. Through a detailed case analysis, it has been demonstrated that even modest interventions such as upgrading lighting systems, improving HVAC efficiency, and integrating solar photovoltaic technology can lead to significant reductions in energy consumption and operational costs. The building's energy use intensity was reduced by 22%, and the investment achieved a favorable payback period of under five years. Beyond the quantitative savings, the retrofitting measures also enhanced indoor environmental quality, contributing to improved occupant comfort, satisfaction, and productivity. These qualitative benefits are essential for the long-term viability of commercial properties, especially in competitive urban markets like Mbeya. However, the study also revealed persistent challenges, including limited access to green financing, a lack of technical expertise, and weak enforcement of energy efficiency standards.

Addressing these barriers requires a coordinated effort among policymakers, financial institutions, developers, and educators. Strengthening regulatory frameworks, expanding access to affordable financing, and building technical capacity across the construction sector are critical steps toward mainstreaming energy-efficient design. Public awareness campaigns and data-driven monitoring systems can further support this transition by fostering a culture of sustainability and accountability. As Tanzania continues to urbanize, the demand for commercial space will grow. Ensuring that this growth is energy-efficient is not only economically prudent but also environmentally necessary. The insights from this case study offer a practical model for other cities in Tanzania and across Sub-Saharan Africa. Energy-efficient buildings are no longer optional; they are a strategic imperative for a resilient, low-carbon, and inclusive urban future

## VI. RECOMMENDATIONS

Based on the findings of this study, several strategic recommendations can be made to promote energy efficiency in Tanzania's commercial building sector.

a) Institutionalize Building Energy Standards and Certification. Tanzania should adopt mandatory Minimum Energy Performance Standards (MEPS) for commercial buildings and integrate them into planning permissions, occupancy permits, and utility approvals. A national energy code tailored to local climatic and market conditions must be developed. This should be reinforced by a government-backed Green Building Certification Scheme and Energy Performance Certificates (EPCs) to increase transparency and drive energy-conscious property investment.

b) Strengthen Technical Expertise in the Construction Sector. A major limitation identified is practitioners' lack of familiarity with energy modeling tools (e.g., DesignBuilder, eQUEST), passive design methods, and green certification systems. Reforming curricula in engineering, architecture, and building science programs and launching continuous professional development (CPD) initiatives will address this skills gap [84]. Establishing a network of Energy Efficiency Champions to mentor peers and share best practices can further promote market transformation.

c) Expand Access to Affordable Financing Instruments. The case study showed that even modest capital outlays can be prohibitive. Tanzania should introduce concessional loans for retrofitting through commercial banks such as CRDB and NMB, backed by government guarantees [92]. Green bonds and blended finance structures involving donor funds and institutional investors can reduce financial risk. Fiscal incentives like tax holidays or zero-rated VAT on retrofit technologies would further encourage uptake.


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d) Prioritize Design-Phase Integration of Efficiency Measures. Energy modeling should be mandatory during the concept and schematic design stages to identify cost-effective strategies such as passive solar gain, natural ventilation, and daylighting. Government-led incentives, including expedited approvals or bonus FAR for high-efficiency buildings, will encourage compliance. All public sector projects should adopt integrated design processes with lifecycle performance targets [93].

e) Deploy Building Management Systems for Real-Time Optimization. The lack of real-time monitoring was a barrier to the Mbeya retrofit. Commercial buildings should be encouraged to adopt Building Management Systems (BMS) to efficiently control HVAC, lighting, and plug loads. IoT-based platforms offer affordable entry points. Post-retrofit Measurement and Verification (M&V) protocols, aligned with standards such as IPMVP, should be institutionalized to quantify energy savings [94].

f) Align Building Sector Initiatives with Tanzania's Climate Goals. Energy-efficient construction supports Tanzania's Nationally Determined Contributions (NDCs), particularly the target of a 30-35% reduction in GHG emissions by 2030 [95]. These measures contribute to SDG 7 (Clean Energy), SDG 13 (Climate Action), and Vision 2025. A national low-carbon building roadmap should be developed to help translate climate targets into building-sector outcomes, supported by international climate funds such as GCF and CIF[96]

g) Foster Public-Private Partnerships and Stakeholder Engagement. Scaling retrofits will require coordinated effort. PPP platforms should be formed to connect government ministries, developers, tech providers, and financiers [97]. A nationwide Retrofit Readiness Campaign would build awareness and demand. Demonstration projects in high-visibility urban areas (e.g., Dar es Salaam, Arusha, Mbeya) can showcase feasibility and impact [98].

h) Establish Data Infrastructure for Energy Planning. Reliable performance data underpins effective policy and investment decisions. A centralized Building Energy Database should be developed by the Ministry of Energy or EWURA to capture Energy Use Intensity (EUI), retrofit outcomes, and financial indicators. Utilities and local governments should be authorized to collect building-level data.

i) Position Retrofitting within Broader Urban Sustainability Frameworks. Retrofitting supports inclusive growth, health, and climate resilience. Policies should link energy upgrades with urban planning, disaster risk reduction, and circular economy strategies. Energy-efficient retrofits can help reduce energy poverty, improve productivity, and support green job creation. Interventions should be mapped across sectors, including buildings, transport, industry, and utilities, for integrated SDG delivery [99].

j) The applications of renewable energy in energy efficient building. To boost energy efficiency in Mbeya's commercial buildings, renewable technologies should be prioritized. Rooftop PV systems combined with net metering reduce grid reliance, while solar water heaters lower electricity use for heating [100]. Biogas from organic waste provides clean thermal energy, and hybrid PV-battery systems enhance power reliability. Passive solar design promotes daylighting and ventilation, further minimizing energy needs [101]. These approaches align with Tanzania's Energy Efficiency Action Plan and support resilient urban growth. Implementing financial incentives, streamlining permitting processes, and coordinating among institutions can accelerate adoption, making renewables central to sustainable infrastructure across Mbeya's expanding commercial sector [102].

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