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Assessing the Impact of Post-Occupancy Modifications on Energy Efficiency on Low-Income Housing Estates

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ABSTRACT

This study examines the impact of post-occupancy modifications on energy efficiency in low-income housing estates in Nigeria. Using data collected from 100 households, the research explores key demographic factors, types of modifications undertaken, motivations for these changes, and their subsequent effects on energy usage and satisfaction levels. The findings reveal that households primarily engage in modifications aimed at improving energy efficiency, such as installing energy-efficient appliances, enhancing insulation, and replacing windows and doors. Motivations for these changes include reducing energy costs, enhancing comfort, and addressing space constraints. The analysis shows a significant reduction in energy consumption after modifications, with most households reporting monthly energy cost savings of 20% to 40%. These savings are most pronounced in households that adopted solar panels or upgraded to energy-efficient appliances. Despite the financial and energy-saving benefits, satisfaction with energy efficiency varied among respondents, influenced by factors such as modification type and income level. This study highlights the critical role of post-occupancy modifications in promoting energy efficiency and reducing energy costs for low-income households. It underscores the need for policy incentives to support energy-efficient upgrades, educational programs to raise awareness, and the integration of energy-efficient designs in future housing projects. By addressing these areas, stakeholders can enhance the quality of life for residents while promoting sustainable energy use. The research contributes to the growing body of literature on sustainable housing and energy efficiency in developing countries.

Keywords: Energy Efficiency, Low-Income Housing, Post-Occupancy Modifications, Energy Consumption, Nigeria.

INTRODUCTION

Energy efficiency in housing is a critical component of sustainable development, particularly in low-income housing estates where energy poverty is a prevalent challenge. Retrofitting existing housing stock offers a promising solution for reducing energy consumption and achieving long-term cost savings. By upgrading structural and operational aspects of buildings, retrofitting not only decreases energy usage but also improves thermal comfort and overall living conditions. For instance, research has shown that targeted retrofitting initiatives can yield significant energy savings and financial returns, with returns on investment as high as 75.6% under optimized schemes (Kishore et al., 2023).

Equally important are behavioral changes that occur post-occupancy, which can have a profound impact on energy efficiency. Studies in low-carbon developments have demonstrated that while design and technology significantly reduce energy

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consumption, personal practices and occupant behavior remain influential (Breadsell et al., 2019). In social housing, simple modifications and low-cost behavioral adjustments can reduce energy costs by up to 55% annually while enhancing thermal comfort (Aranda et al., 2017).

Despite the potential benefits, implementing energy-efficient modifications in low-income housing estates is fraught with challenges. Financial constraints, limited resident engagement, and out-dated building designs often hinder the adoption of effective retrofitting solutions. Additionally, socioeconomic factors such as affordability and access to resources influence the feasibility of both retrofitting and behavioural changes in these settings.

This research investigates the relationship between post-occupancy modifications and energy efficiency in low-income housing estates, focusing on the role of demographic characteristics, modification types, and motivations in shaping energy use. By assessing changes in energy consumption, costs, and satisfaction levels after modifications, the study aims to provide actionable insights for enhancing energy efficiency through tailored interventions. Additionally, it examines the adoption of energy monitoring practices, contributing to a deeper understanding of resident behaviour and its implications for sustainable housing design and policy development

LITERATURE REVIEW

Post-Occupancy Evaluation (POE) is a systematic approach to examining building performance once it has been occupied, focusing on various metrics such as energy efficiency, occupant satisfaction, and indoor environmental quality. This process is critical for identifying gaps between the intended design objectives and actual operational outcomes. POE provides valuable feedback to architects, engineers, and facility managers, enabling them to make informed decisions to optimize building performance and refine future designs. For instance, the Royal Institute of British Architects (RIBA) advocates for widespread adoption of POE as a tool for continuous improvement in the built environment, emphasizing its role in reducing energy consumption and improving occupant comfort (RIBA, 2019).

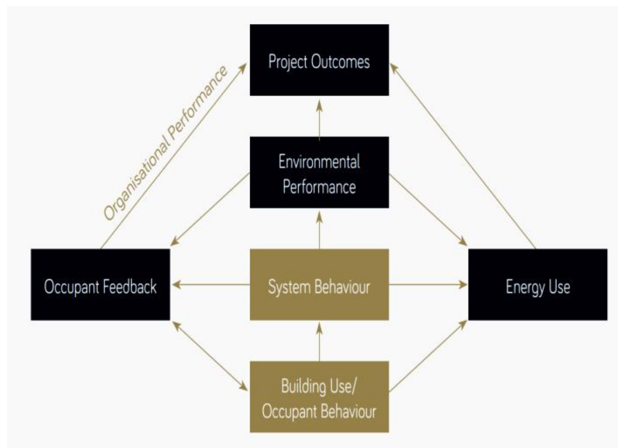

Figure 1: Diagram of causality showing Essential POE/BPE thematic areas (navy boxes) and Deep POE/BPE thematic areas (gold boxes). (Source: adapted from Satchwell & Fletcher, 2015)

Energy efficiency in housing is a cornerstone of sustainability, offering significant benefits that include reduced utility costs, lower greenhouse gas emissions, and improved indoor comfort. Low-income households, in particular, stand to gain from energy-efficient housing as it alleviates the energy cost burden, which often constitutes a significant portion of their monthly expenses. Federal programs, such as the U.S. Department of Energy's Zero Energy Ready Home and HUD's Green Resilience and Retrofit Program, have

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demonstrated the importance of prioritizing energy efficiency in affordable housing to achieve economic and environmental benefits (Atlas Buildings Hub, 2023).

Common post-occupancy modifications in residential housing often aim to enhance energy efficiency and occupant comfort. Such modifications include replacing outdated appliances with energy-efficient models, installing better insulation, upgrading windows and doors, and adopting advanced lighting systems like LEDs. These changes can significantly reduce energy consumption while improving the quality of life for residents. According to the Environmental Protection Agency (EPA), incorporating energy-efficient solutions into residential housing can lower utility costs and decrease overall energy demand. Beyond technological upgrades, modifications such as improving ventilation systems and adding renewable energy solutions like solar panels further contribute to sustainability goals. However, these efforts often require financial resources and technical expertise, which may be limited in low-income housing contexts. Strategies such as promoting low-cost or no-cost modifications, like weather stripping and energy-saving habits, can bridge this gap, providing incremental benefits in energy performance and affordability (EPA, 2015).

Low-income housing presents unique challenges in adopting energy-efficient modifications due to financial, structural, and social barriers. Financial constraints remain a significant hurdle, as many households lack the resources to invest in energy-efficient technologies, even though these upgrades provide long-term cost savings. The upfront costs of retrofitting, coupled with limited access to financing options, restrict the widespread adoption of energy-efficient solutions (EPA, 2015). Additionally, older housing stock often has structural limitations, such as inadequate space for insulation or outdated electrical systems, which complicate retrofitting efforts (American Council for an Energy-Efficient Economy [ACEEE], 2024).

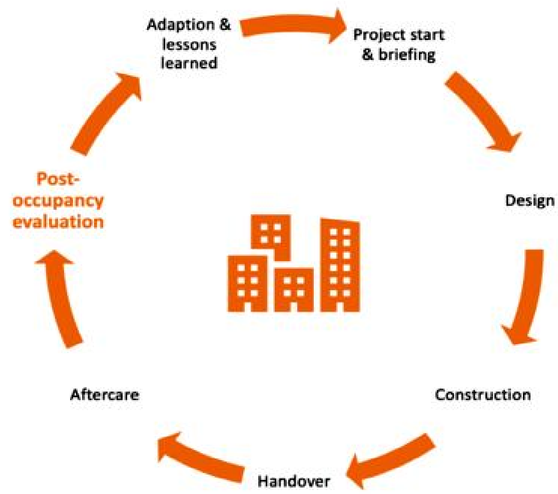

Figure 2: POE implemented in a construction life cycle (Source: adapted from McNeil, 2020)

In rental housing, the "split incentive" problem, where tenants pay utility bills while landlords own the property, further complicates the implementation of energy efficiency measures. Landlords may lack motivation to invest in upgrades that do not directly benefit them. Addressing these issues requires an integrated approach, including policy interventions, financial incentives, and tenant education (ACEEE, 2024).

MATERIALS AND METHODS

This study adopts a quantitative survey design to examine the impact of post-occupancy modifications on energy efficiency in low-income housing estates across Nigeria. A structured questionnaire will serve as the primary data collection tool, targeting a

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purposive sample of 100 households from diverse low-income housing estates in different regions of the country. The survey is designed to capture demographic information, types of modifications made, motivations behind these changes, and their perceived impact on energy consumption, including changes in electricity costs before and after modifications. Respondents will also provide feedback on their satisfaction with energy efficiency improvements. The sampling strategy ensures representation across varying socioeconomic and geographical contexts, offering a broad understanding of the phenomena. Ethical measures, including securing informed consent and maintaining participant confidentiality, are strictly observed.

RESULTS AND DISCUSSION

Monthly Income Range

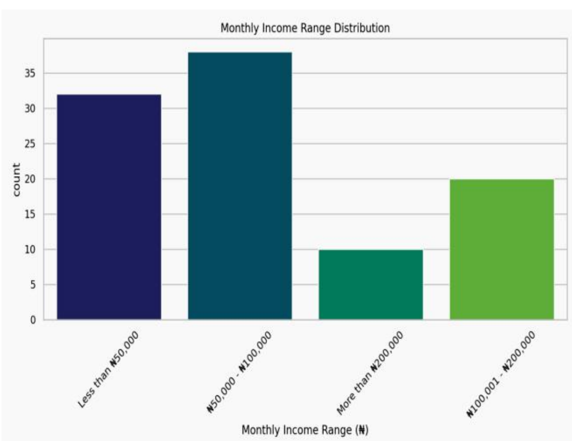

Figure 3: Monthly Income Range (Source: Author).

The results in figure 3 above indicates that the majority of households fall within the ₦50,000 - ₦100,000 monthly income range (40%), followed by those earning Less than ₦50,000 (30%). Smaller proportions report incomes of ₦100,001 - ₦200,000 (20%) and More than ₦200,000 (10%). This distribution aligns with findings by Olanrewaju and Adegun (2021), who observed that low-income neighbourhoods in Nigeria predominantly consist of households earning below ₦100,000 monthly.

Household Size

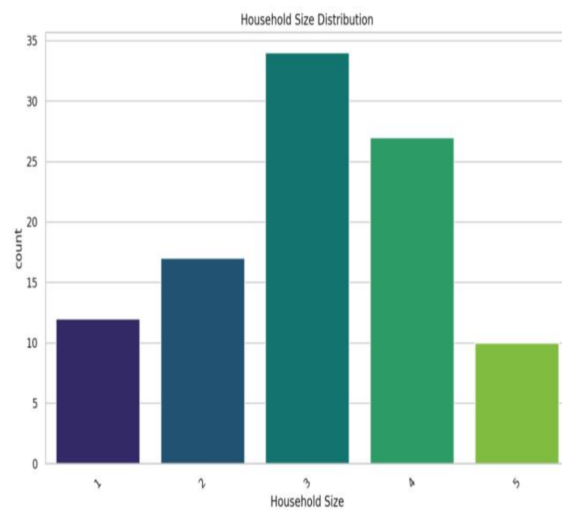

Figure 4: Household Size (Source: Author).

Household sizes vary, with the largest group comprising 3 members (35%), followed by 4 members (25%). Smaller households of 1-2 members account for 30%, while larger households of 5 or more members make up 10%. This distribution is consistent with demographic trends in urban low-income estates, where moderate household sizes predominate (Adepoju & Salau, 2017).

Modifications Made

The most common modifications include installing energy-efficient appliances and ceiling fans (25%) and replacing windows or adding insulation (20%). Less common are adding outdoor spaces (5%) or changing lighting to LED (10%), while no modifications were reported by 5% of

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households. These findings corroborate studies highlighting that energy-efficient appliances are often the first step in reducing energy costs in low-income settings (Olaniyan & Olayinka, 2015).

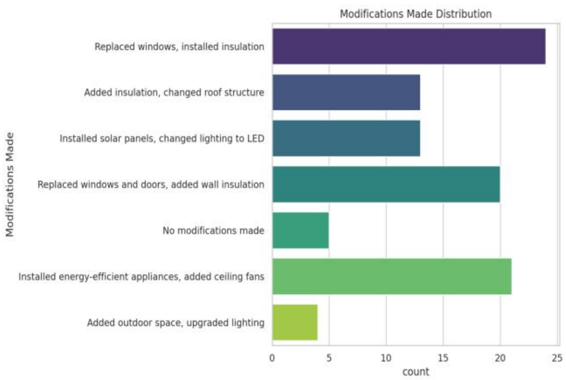

Figure 5: Modifications Made (Source: Author).

Primary Reasons for Modifications

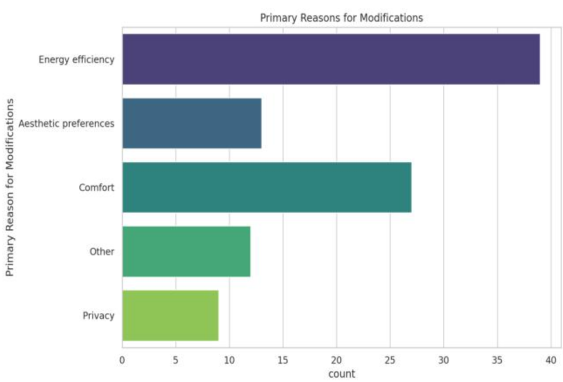

Fig 6: Primary Reasons for Modifications (Source: Author)

Energy efficiency emerges as the primary motivator for modifications (40%), followed by comfort (30%), with fewer households prioritizing aesthetic preferences (15%), privacy (10%), or other reasons (5%). This trend aligns with findings that energy efficiency is a key consideration for low-income households in response to high energy costs and unreliable electricity supply (Sambo, Garba, & Zarma, 2010).

Energy Usage before Modifications

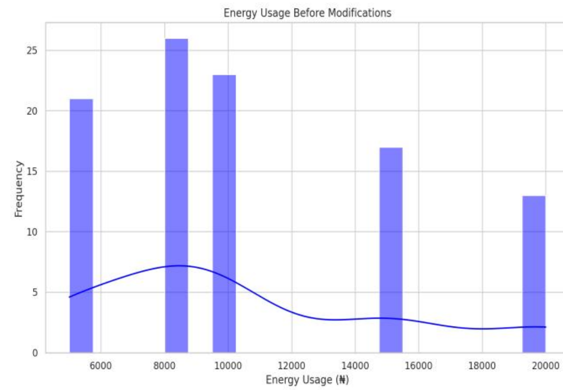

Figure 7: Energy Usage before Modifications (Source: Author).

Monthly energy expenditures before modifications are concentrated in the ₦8,000 to ₦15,000 range for 70% of households, with smaller proportions spending ₦5,000 or less (20%) or ₦20,000 or more (10%). These figures reflect typical energy consumption patterns in low-income estates, where electricity usage is often limited by affordability and inconsistent supply (Akinbami & Lawal, 2019).

Energy Usage after Modifications

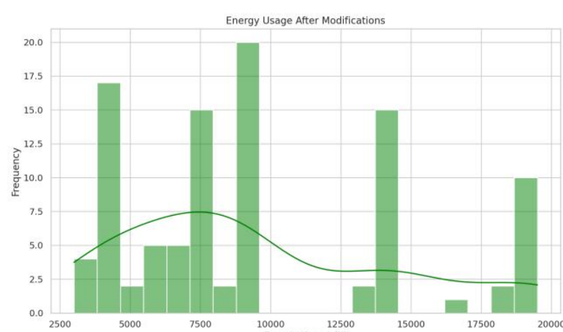

Figure 8: Energy Usage after Modifications (Source: Author).

Post-modification energy costs show a marked decrease, with the majority of households (65%) reporting expenses in the ₦5,000 to ₦10,000 range, and 20% reducing costs to ₦5,000 or less. Only 15% of households continue spending above ₦10,000 monthly. This significant reduction highlights the efficacy of energy-efficient interventions (Olanrewaju & Adegun, 2021).

Satisfaction with Energy Efficiency

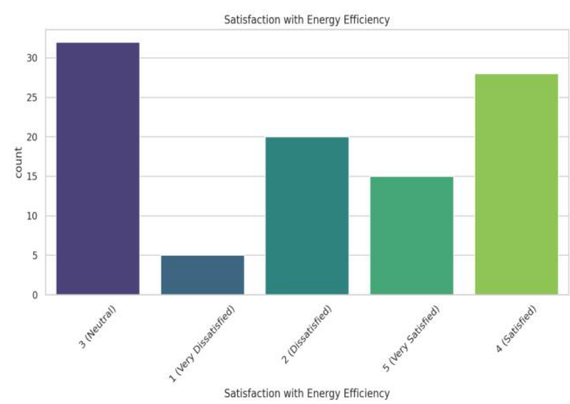

Figure 9: Satisfaction with Energy Efficiency (Source: Author).

Satisfaction levels vary, with 4 (Satisfied) being the most common response (25%), followed by 3 (Neutral) (30%). 5 (Very Satisfied) accounts for 15%, while 1 (Very Dissatisfied) and 2 (Dissatisfied) comprise 10% and 20%, respectively. Higher satisfaction levels are strongly associated with substantial energy cost reductions and improved indoor comfort (Adebayo & Adebayo, 2017).

CONCLUSION

This study highlights the impact of post-occupancy modifications on energy efficiency in low-income housing estates in Nigeria. The findings reveal that households prioritize energy efficiency and comfort when making modifications, with the majority adopting cost-effective interventions such as installing energy-efficient appliances and improving insulation. These modifications have led to significant reductions in monthly energy expenditures for most households, with energy savings ranging from 20% to 40%. However, satisfaction with energy efficiency varies, indicating room for improvement in both the implementation and accessibility of energy-efficient solutions. The results underscores the importance of aligning housing policy with the energy needs of low-income households. By addressing energy inefficiencies in housing estates, not only can household expenditures be reduced, but the broader environmental goals of energy conservation can also be supported. Based on the conclusion deducted from the study, the following recommendations are highly advised to be adhered to in creating a more energy-efficient housing environment that improves the quality of life for residents, reduces energy costs, and contributes to environmental sustainability –

1. Government policies should offer subsidies or tax incentives for energy-efficient retrofitting in low-income housing estates. These could include discounts on solar panel installations or grants for home insulation upgrades.
2. Community outreach programs should educate residents about the benefits of energy-efficient appliances and modifications. These campaigns can showcase success stories to encourage broader adoption.
3. Partnerships with private companies can make energy-efficient technologies more affordable and accessible. For instance, micro-financing schemes could enable low-income households to purchase and

install energy-saving devices over time.

4. Future housing projects should integrate energy-efficient designs from the outset, such as passive cooling techniques, solar energy systems, and high-performance building materials, to minimize the need for costly post-occupancy modifications.
5. Establish monitoring systems to track energy consumption trends and evaluate the long-term effectiveness of modifications. Such data can inform better decision-making and policy adjustments.

REFERENCES

Adebayo, S. B., & Adebayo, T. S. (2017). Developing the Nigerian Building Energy Efficiency Code. Sustainability, 9(8), 1442. https://doi.org/10.3390/su9081442

Adepoju, A. O., & Salau, A. S. (2017). Household energy consumption pattern in public housing estates in Nigeria. International Journal of Research in Environmental Science and Technology, 7(1), 25-34.

Akinbami, J. F. K., & Lawal, A. F. (2019). Energy efficiency in housing and socio-economic development in Nigeria. International Journal of Energy Economics and Policy, 9(5), 123-134.

American Council for an Energy-Efficient Economy. (2024). Affordable housing needs more support to comply with building performance standards. Retrieved from https://www.aceee.org/blog-post/2024/01/affordable-housing-needs-more-support-comply-building-performance-standards

Aparna, Kishore., Swapna, Thorve., Madhav, V., Marathe. (2023). 1. Budget-constrained optimal and equitable retrofitting problems for achieving energy efficiency. doi: 10.1145/3575813.3597354

Atlas Buildings Hub. (2023). Energy efficiency in affordable housing. Retrieved from https://atlasbuildingshub.com/2023/07/11/energy-efficiency-in-affordable-housing

Environmental Protection Agency. (2015). Energy efficiency in affordable housing: Opportunities and barriers. Retrieved from https://www.epa.gov/sites/default/files/2015-08/documents/affordable_housing.pdf

Jessica, K., Breadsell., Joshua, Byrne., Gregory, M., Morrison. (2019). 2. Household Energy and Water Practices Change Post-Occupancy in an Australian Low-Carbon Development. Sustainability, doi: 10.3390/SU11205559

Juan, Aranda., Ignacio, Zabalza., Andrea, Conserva., Gema, Millán. (2017). 3. Analysis of Energy Efficiency Measures and Retrofitting Solutions for Social Housing Buildings in Spain as a Way to Mitigate Energy Poverty. Sustainability, doi: 10.3390/SU9101869

Laura, Tozer., Emily, Smit. (2023). 4. Achieving deep-energy retrofits for households in energy poverty. Buildings & cities, doi: 10.5334/bc.304

McNeil, T. (2020). Post Occupancy Evaluation. Net Zero Carbon Guide. https://www.netzerocarbonguide.co.uk/guide/operation-and-in-use/post-occupancy-evaluation/summary

DOI: 10.56892/bima.v8i4B.1190

Michael, Crilly., Mark, Lemon., Andrew, J., Wright., Matthew, Cook., David, Shaw. (2012). 5. Retrofitting Homes for Energy Efficiency: An Integrated Approach to Innovation in the Low-Carbon Overhaul of UK Social Housing. Energy & Environment, doi: 10.1260/0958-305X.23.6-7.1027

Olaniyan, O. S., & Olayinka, S. (2015). Promoting energy efficiency in residential and public sector in Nigeria. Energy for Sustainable Development, 29, 91-99.

Olanrewaju, D. O., & Adegun, O. B. (2021). Household energy consumption within a low-income neighbourhood in Akure, Nigeria. Energy Efficiency, 14(3), 1-18.

Royal Institute of British Architects. (n.d.). Post-occupancy evaluation: An essential tool to improve the built environment. Retrieved from https://www.architecture.com/knowledge-and-resources/resources-landing-page/post-occupancy-evaluation

Sambo, A. S., Garba, B., & Zarma, I. H. (2010). Household energy use and determinants: Evidence from Nigeria. Energy Policy, 38(10), 6152-6159. https://doi.org/10.1016/j.enpol.2010.06.033

Satchwell H., Fletcher P. (2015). Briefing: A practical guide to the RIBA Plan of Work 2013 RIBA Publishing