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CONSTRUCTING THE ENERGY POVERTY INDEX FOR RESIDENTIAL BUILDINGS IN SUB-SAHARAN AFRICA: A SYSTEMATIC REVIEW OF BUILT ENVIRONMENT INDICATORS

Henry Asuquo Okpo[1], Samuel Ekung[2], and Israel Udoka[3]

[1]Department of Building Technology, Akwa Ibom State Polytechnic, Ikot Ekpene, Akwa Ibom State, Nigeria

[2]Department of Quantity Surveying, University of Uyo, Uyo, Akwa Ibom State, Nigeria

[3]Department of Estate Management, School of Environmental Studies, Akwa Ibom State Polytechnic, Ikot Ekpene, Nigeria

ABSTRACT

Purpose: The Multidimensional Energy Poverty Index (MEPI), the dominant framework for measuring household energy deprivation in Sub-Saharan Africa (SSA), systematically excludes residential built environment variables, construction quality, thermal envelope performance, building code compliance, and informal settlement classification. This paper constructs a Built Environment Multidimensional Energy Poverty Index (BE-MEPI) integrating physical dwelling characteristics as structural determinants of energy poverty.

Design/Methodology/Approach: A PRISMA 2020 systematic review across four databases, Scopus, Web of Science, ScienceDirect, and Google Scholar, yielded 27 peer-reviewed studies (2011–2026). Thematic synthesis and framework-building methodology were applied to identify indicator gaps and construct the proposed index.

Findings: Five built environment dimensions are absent from existing MEPI applications: building material durability; thermal envelope performance; daylighting and ventilation adequacy; building code compliance; and informal settlement spatial classification. The BE-MEPI comprises 13 indicators across five pillars, compatible with Demographic and Health Survey infrastructure and the Alkire-Foster dual-cutoff protocol.

Originality/Value: This paper makes the first systematic attempt to construct a built-environment-sensitive MEPI extension for SSA, enabling critical policy distinctions between income-driven and built-environment-driven energy poverty, and implicating construction professionals, architects, and housing regulators as essential actors in energy poverty alleviation.

Research limitations/Implications: Key limitations include the resource-intensive nature of the thermal comfort indicator, the absence of a standardised structural integrity assessment protocol in SSA, and a baseline weighting scheme requiring empirical validation. Pilot application across diverse SSA urban morphologies is needed to establish benchmark scores and k-cutoffs.

Practical implications: The BE-MEPI offers direct policy relevance for SSA energy ministries, urban planners, and international development partners by linking construction quality to energy outcomes, enabling cross-ministerial data integration, and supporting SDG7-aligned monitoring beyond binary energy access metrics.

Keywords: Built environment indicators; Energy poverty index; Multidimensional energy poverty index (MEPI); Systematic review; Sub-Saharan Africa.

[1]Email: henryokpo24@gmail.com

1. INTRODUCTION

Measuring energy poverty is a precondition for addressing it. Since the early work of Boardman (1991) in the United Kingdom, the energy poverty measurement literature has evolved from single expenditure-based thresholds toward composite, multidimensional frameworks capable of capturing the diverse and intersecting deprivations that constitute energy poverty across different cultural and climatic contexts. The most influential instrument applied in developing country contexts is the Multidimensional Energy Poverty Index (MEPI), pioneered by Nussbaumer *et al.* (2012) using the Alkire-Foster (AF) dual-cutoff counting methodology, and subsequently applied across numerous Sub-Saharan African (SSA) and Asian contexts. The MEPI assesses household energy deprivation across five dimensions: cooking energy, lighting, electricity access, household appliances and services, and entertainment and communication. It produces both an incidence measure, the proportion of households identified as multidimensionally energy poor, and an intensity measure, the share of weighted deprivations experienced by energy-poor households.

The application of the MEPI across SSA has generated significant empirical insights. In Nigeria, Ashagidigbi *et al.* (2020) found a national average MEPI of 0.38, with substantially higher rates in rural compared to urban areas. Compaore *et al.* (2024), applying the Alkire-Foster MEPI to West African Economic and Monetary Union (WAEMU) countries, found that over 90% of households were multidimensionally energy poor, with deprivation of modern cooking fuels constituting the single largest contributor to the index at 0.398%. In Rwanda, Ntawuruhunga *et al.* (2021) documented significant rural-urban disparities in MEPI scores, with rural households consistently recording higher deprivation intensities. Alnour *et al.* (2026) extended the spatial dimension of energy poverty analysis in SSA, demonstrating significant spatial spillover effects of energy poverty on health, education, and labour market outcomes across 25 SSA countries.

Despite these contributions, a fundamental and underappreciated limitation constrains existing MEPI applications in SSA: the near-total exclusion of the physical built environment as a measurement domain. The MEPI, as conventionally operationalised, treats energy poverty as a function of the type of fuel used, the presence of electrical appliances, and grid connectivity, but does not account for the physical characteristics of the dwelling within which energy services are consumed or denied. This is analytically consequential for at least three reasons.

Firstly, residential construction quality operates as a gatekeeping mechanism for formal energy access in SSA. As documented across multiple SSA countries, utility providers systematically avoid extending grid infrastructure to non-permanent structures, thereby making the physical durability of a dwelling a prerequisite, rather than a correlate of electricity access (Tusting *et al.*, 2019). A household living in a non-durable informal structure may be coded as lacking electricity in the MEPI without the measurement framework capturing why: not because the grid is geographically distant, but because the built form of the dwelling disqualifies it from connection. This distinction matters profoundly for policy design.

Secondly, the thermal performance of a residential building directly determines the magnitude of energy demand for space comfort, one of the most significant household energy needs in SSA's predominantly tropical climates. A household living in a dwelling with a corrugated iron roof, uninsulated thin walls, inadequate natural ventilation, and minimal daylighting will experience thermal discomfort that the standard MEPI does not capture, yet which translates into either health deprivation (if mechanical cooling is unaffordable) or disproportionate energy expenditure (if it is purchased). Robles-Bonilla *et al.* (2021) made this argument precisely in proposing a thermal-comfort-extended MEPI, finding that inclusion of thermal comfort as an energy service dimension significantly increased measured energy poverty rates. Kajjoba *et al.* (2025) similarly demonstrated that the diversity of SSA construction practices complicates thermal performance predictions, with energy-intensive buildings failing to meet occupant comfort requirements.

Thirdly, the rapid growth of informal settlements across SSA cities, which now house more than 56% of the urban population (Chisola *et al.*, 2023; Mwansa *et al.*, 2025), is producing a residential stock characterised simultaneously by construction informality, thermal inadequacy, and energy access exclusion. Standard MEPI instruments, relying primarily on Demographic and Health Survey (DHS) data that categorise households by energy source type, are poorly equipped to capture these spatially embedded, architecturally determined forms of energy deprivation.

This paper responds to these gaps by conducting a systematic review of the literature on energy poverty measurement frameworks and built environment indicators in SSA, intending to construct a conceptually coherent, empirically tractable, and policy-relevant extension of the MEPI that integrates residential built environment variables. The proposed framework, designated the Built Environment Multidimensional Energy Poverty Index (BE-MEPI), retains compatibility with the Alkire-Foster methodology and existing DHS data infrastructure while adding five built environment pillars comprising 13 operationally defined indicators. The succeeding sections of the paper are structured as follows: Section 2 describes the systematic review methodology; Section 3 reviews the existing MEPI literature and its built environment gaps; Section 4 examines the built environment indicators identified through the review; Section 5 presents and operationalises the BE-MEPI framework; and Section 6 discusses implications for research, policy, and professional practice in SSA.

2. RESEARCH METHODOLOGY

2.1 Review Design

This study employs a systematic review methodology following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. The systematic review design was chosen for its capacity to provide a replicable, transparent, and audit-able synthesis of evidence across a heterogeneous body of literature spanning energy economics, building science, urban planning, and development studies. The central research question guiding the review is: What built environment indicators are absent from or inadequately operationalised in existing energy poverty measurement frameworks applied in Sub-Saharan Africa, and how should they be incorporated into an extended MEPI for residential buildings?

2.2 Search Strategy and Databases

Searches were conducted in February 2026 across four databases: Scopus, Web of Science, ScienceDirect, and Google Scholar, as shown in Table 1. Three search clusters were developed and combined using Boolean operators. The first cluster targeted energy poverty measurement: ("energy poverty index" OR "MEPI" OR "multidimensional energy poverty" OR "fuel poverty indicator" OR "energy deprivation index"). The second cluster addressed the built environment: ("built environment" OR "residential building" OR "housing quality" OR "construction materials" OR "building thermal performance" OR "building codes"). The third cluster specified the geographical context: ("Sub-Saharan Africa" OR "West Africa" OR "East Africa" OR "Southern Africa" OR "Nigeria" OR "South Africa" OR "Uganda" OR "Rwanda" OR "Mozambique" OR "Ethiopia"). Date limits of 2019 to 2026 were applied, except for foundational MEPI studies pre-dating this window (Nussbaumer *et al.*, 2012; Alkire and Foster, 2011), which were included for theoretical grounding. All searches were restricted to English-language publications.

Table 1: PRISMA Search Results by Database

Database	Search Terms Applied	Records Retrieved	After Title Screen	After Abstract Screen	Final Included
Scopus	("energy poverty index" OR "MEPI") AND ("built environment" OR "residential building") AND "Sub-Saharan Africa"	287	71	34	9
Web of Science	("multidimensional energy poverty") AND ("housing" OR "construction quality") AND "Africa"	214	58	26	8
ScienceDirect	("energy poverty indicator") AND ("building design" OR "thermal comfort") AND "Africa"	198	49	22	6
Google Scholar	MEPI Africa residential construction indicator framework	152	41	18	4
TOTAL	—	851	219	100	27

Source: Authors' compilation (2026).

2.3 Inclusion and Exclusion Criteria

Studies were included if they: (i) proposed, applied, critiqued, or extended an energy poverty index or measurement framework; (ii) engaged explicitly with built environment variables in relation to household energy outcomes; (iii) were geographically focused on SSA or provided sub-analyses applicable to SSA contexts; and (iv) were published in Scopus-indexed journals, indexed institutional reports, or peer-reviewed conference proceedings. Studies focusing exclusively on industrial or commercial energy systems without residential application, purely theoretical treatments without empirical grounding, and commentaries or editorials without primary data or synthesis were excluded. Grey literature was included only when produced by major international agencies (IEA, OPHI, UNDP, IOP) with transparent methodologies.

2.4 Screening and Data Extraction

Initial database queries returned 851 records. Following automated deduplication, 683 unique records were assessed by title. Of these, 219 were retained for abstract screening, and 100 were retrieved for full-text review. After applying inclusion and exclusion criteria, 27 studies were retained for synthesis (see Table 2). Data extraction captured: author(s) and year; journal; DOI; geographical scope; methodological approach; MEPI dimensions addressed; built environment variables included or excluded; and key findings relevant to index construction. Quality appraisal was conducted using the Mixed Methods Appraisal Tool (MMAT), with all 27 included studies meeting the minimum quality threshold for their respective designs.

Table 2: Summary of Included Studies (n = 27)

Author(s) and Year	Journal / Source	Country Focus	Method	EPI Dimension Addressed
Compaore *et al.* (2024)	Oxford Open Energy	WAEMU/West Africa	Alkire-Foster MEPI	Electricity, cooking, lighting, appliances
Alnour *et al.* (2026)	Sustainable Development (Wiley)	25 SSA countries	Spatial panel regression	Multidimensional energy poverty spatial spillovers
Robles-Bonilla *et al.* (2021)	Sustainability (MDPI)	Mexico / transferable to Africa	MEPI + thermal comfort extension	Thermal comfort as MEPI dimension
Ashagidigbi *et al.* (2020)	Sustainability (MDPI)	Nigeria	MEPI, Tobit regression	Cooking, lighting, appliances, electricity
Ssennono *et al.* (2021)	Energy Economics	Uganda	Multidimensional MEPI	Electricity, cooking, lighting, assets
Kajjoba *et al.* (2025)	Sustainable Energy Research	SSA (multi-country)	Systematic review	Thermal comfort; building design
Olawale-Johnson *et al.* (2025)	Energies (MDPI)	Nigeria	Simulation (DesignBuilder)	Thermal comfort; building envelope
Benayed *et al.* (2024)	Journal of Cleaner Production	28 SSA countries	Infrastructure index regression	Electricity access and infrastructure
Tusting *et al.* (2019)	Nature	Sub-Saharan Africa	Geostatistical framework	Housing quality; durable materials
Ibrahim *et al.* (2026)	IOP Environmental Research	Somalia/SSA	Multidimensional analysis	Housing quality → electricity access
Mwansa *et al.* (2025)	Nature	Sub-Saharan Africa	Geospatial block mapping	Infrastructure deficits; informality
Chisola *et al.* (2023)	Energies (MDPI)	SSA (multi-country)	Qualitative comparison	Off-grid energy; informal construction
Mahumane and Mulder (2022)	Renewable and Sustainable Energy Reviews	Mozambique	Econometric	Urbanisation of energy poverty
Pondie (2025)	Natural Resources Forum (Wiley)	43 SSA countries	Panel data FE + GMM	Energy poverty and environment
Wang *et al.* (2022)	IJERPH (MDPI)	Global (incl. Africa)	PRISMA review	Building energy use; health; IAQ
Ndagijimana *et al.* (2025)	Architecture (MDPI)	Rwanda	Case study / GIS	Green building in informal settlements
Santos *et al.* (2024)	Springer Built Environment	Africa	Literature review	Vernacular architecture; thermal comfort
Siksnelyte-Butkiene *et al.* (2021)	Sustainable Cities and Society	Europe/global	Systematic review of 71 indices	EPI indicator taxonomy; composite indices
Sujar-Cost *et al.* (2024)	Buildings (MDPI)	Spain (transferable)	Geospatial + EPC data	Building EPC → energy poverty mapping

Author(s) and Year	Journal / Source	Country Focus	Method	EPI Dimension Addressed
Ntawuruhunga *et al.* (2021)	PMC / Energies	Rwanda	Inter-indicator analysis	MEPI dimensions; rural-urban gap
Alnour *et al.* (2024)	Natural Resources Forum (Wiley)	SSA countries	MMQR	Energy poverty and environmental sustainability
IEA *et al.* (2025)	Tracking SDG7 Report	Africa/Global	Multi-agency synthesis	Electricity access; cooking; tier framework
OPHI (2024)	Global MPI Report	112 countries incl. SSA	Alkire-Foster MPI	Housing deprivation; electricity; cooking
Garba and Bellingham (2021)	Energy	SSA	Econometric	Cooking fuel poverty; GDP nexus
Abdulkareem and Al-Maiyah (2025)	Sustainability (MDPI)	Nigeria	Building simulation	Building codes; passive design; low-income housing
Gregory and Sovacool (2019)	Renewable and Sustainable Energy Reviews	Sub-Saharan Africa	Governance review	Energy poverty governance; infrastructure
Compaore *et al.* MEPIext (2024)	Oxford Open Energy	WAEMU	Probit + MEPI	MEPI determinants; rural-urban; gender

Source: Authors' compilation (2026).

2.5 Analytical Approach: Thematic Synthesis and Framework Construction

Given the purpose-oriented nature of the review to construct a measurement framework rather than merely synthesise findings, the analytical approach combined thematic synthesis (Thomas and Harden, 2008) with framework-building methodology derived from the indicator construction literature (Siksnelyte-Butkiene *et al.*, 2021). Following free-line coding of built environment variables mentioned, excluded, or recommended across the included studies, emergent indicator domains were organised into pillars and operationally defined with reference to data availability, measurability using existing survey instruments (DHS, MICS, housing censuses), and theoretical alignment with the Alkire-Foster dual-cutoff framework.

3. THE MEPI IN SUB-SAHARAN AFRICA: ACHIEVEMENTS AND BUILT ENVIRONMENT GAPS

3.1 The Alkire-Foster Foundation and MEPI Architecture

The Alkire-Foster (AF) counting methodology, formalised by Alkire and Foster (2011), provides the mathematical foundation for the MEPI. The AF method identifies a household as multidimensionally deprived if its weighted deprivation score across all dimensions exceeds a second cutoff k—typically set at one-third of possible weighted deprivations. The MEPI thus produces two statistics: H, the incidence or headcount ratio of multidimensionally energy-poor households; and A, the average intensity of deprivation among the poor. The composite MEPI score is $M = H \times A$, ranging from 0 (no energy poverty) to 1 (complete deprivation on all weighted dimensions). Nussbaumer *et al.* (2012) applied this architecture to five dimensions in African and Asian household data, weighting cooking, lighting, and electricity access most heavily.

The MEPI framework has been applied and adapted across a growing number of SSA country studies. Ssennono *et al.* (2021) applied a multidimensional MEPI to Ugandan household data, documenting significant energy poverty incidence across cooking, lighting, and asset dimensions. Ashagidigbi *et al.* (2020) applied an adapted MEPI to Nigeria using National Demographic Health Survey (NDHS) data, finding a national average MEPI of 0.38 and substantially higher deprivation in rural zones. Compaore *et al.* (2024) constructed an MEPI for WAEMU countries, finding that 90.5% of households were energy poor with an average intensity of 75.1%, driven primarily by dependence on solid biomass for cooking. The Oxford Poverty and Human Development Initiative (OPHI, 2024) incorporates energy-related indicators, electricity access and cooking fuel type into the Global Multidimensional Poverty Index (MPI), noting that approximately half of all poor people in SSA lack electricity.

Despite the methodological rigour of the AF-MEPI architecture, several systematic limitations have been identified in the literature. Siksnelyte-Butkiene *et al.* (2021), in a comprehensive systematic review of 71 composite energy poverty indicators, found that existing instruments systematically under-represent thermal comfort as an energy service dimension, tend to rely on binary rather than graduated indicators, and rarely incorporate built environment variables despite theoretical arguments for their relevance. The Energy Poverty Advisory Hub (EPAH) framework for the European Union similarly identified dwelling energy efficiency, encompassing building envelope performance, heating system efficiency, and construction quality, as a core measurement object that national energy poverty indicators must incorporate. While these critiques have been most developed in the European context, their logic applies with equal force, if not greater urgency to SSA, where construction informality is more prevalent and climate-induced thermal discomfort more severe.

3.2 The Thermal Comfort Gap

Thermal comfort is a state in which a building occupant expresses satisfaction with the thermal environment, which is recognised in the energy poverty literature as a foundational energy service: households unable to achieve acceptable indoor temperatures are, by any functional definition, energy poor in a critical dimension. However, the standard MEPI does not include a thermal comfort indicator, an omission that Robles-Bonilla *et al.* (2021) directly addressed. Their study extended the Nussbaumer MEPI framework by incorporating thermal comfort, assessed through adaptive comfort models, as an additional weighted dimension. They found that inclusion of thermal comfort significantly increased measured energy poverty rates in their study context, and argued that this omission in the standard MEPI produces a systematic underestimation of energy deprivation, particularly in climates where building thermal performance is the primary mechanism through which thermal comfort or discomfort is produced.

In SSA residential contexts, this gap is structurally significant. Kajjoba *et al.* (2025), reviewing thermal comfort and energy performance in low-income tropical buildings across SSA, established that the diversity of SSA construction practices, ranging from mud-brick vernacular to corrugated iron informal structures to modern concrete blocks, produces highly heterogeneous thermal performance profiles that are invisible to the standard MEPI. Olawale-Johnson *et al.* (2025), simulating residential thermal performance in Kaduna, Nigeria, demonstrated that passive design interventions, insulated roofs, reflective surfaces, optimised cross-ventilation, can reduce indoor temperatures by 3°C and cooling loads by 30–50%, yet the households that would benefit most from these interventions are precisely those whose buildings are thermally poorest and whose energy poverty would remain unmeasured under standard MEPI criteria.

3.3 The Construction Quality and Formal Classification Gap

A second major gap in existing MEPI applications concerns the formal classification of building construction and its relationship to energy access eligibility. Tusting *et al.* (2019), in a landmark geostatistical study of housing change across SSA from 2000 to 2015 published in Nature, documented that the prevalence of improved housing, defined as structures with durable construction materials, adequate living space, and access to improved water and sanitation, doubled from 11% to 23% between 2000 and 2015. Yet 47% of the urban African population analysed still lived in non-durable or unimproved housing in 2015. The study's construction material classification schema (roof, wall, and floor materials rated on durability scales) provides a directly usable template for building a construction quality indicator within an extended MEPI.

Ibrahim *et al.* (2026) and the geospatial analysis by Mwansa *et al.* (2025) both establish empirically that informal settlement classification and building material non-durability are systematically associated with electricity access exclusion across SSA. Utility providers prioritise connections to permanent structures with durable materials, meaning that the physical built form of a dwelling operates as a binary access gate. Standard MEPI applications code these households as lacking electricity access without attributing the causal mechanism to the built environment, a distinction that is essential for targeted policy intervention. Benayed *et al.* (2024), constructing an Africa Infrastructure Development Index (AIDI) and regressing it against household energy poverty across 28 SSA countries, similarly found that the relationship between infrastructure development and energy poverty alleviation is mediated by settlement type and construction quality.

3.4 The Building Code and Regulatory Gap

Existing MEPI frameworks contain no indicator related to building code compliance or the regulatory quality of residential construction. This gap is significant because building codes represent the institutional mechanism through which states mandate minimum thermal performance, structural safety, and infrastructure connectivity in new residential construction. Abdulkareem and Al-Maiyah (2025) document that national building codes and energy efficiency regulations in Nigeria reveal an alarming gap regarding the abandonment of basic sustainable design practices in low-income housing. Gregory and Sovacool (2019) similarly document that weak governance of energy infrastructure investment in SSA, including the regulatory oversight of building and construction standards, constitutes a structural driver of persistent energy poverty that aggregate access statistics fail to capture.

The absence of a building code compliance indicator from the MEPI means that the index cannot differentiate between a household that lacks electricity because of financial constraints and one that lacks it because its dwelling is structurally ineligible for connection under utility safety regulations. This distinction is policy-critical: the former requires a financing solution; the latter requires a construction upgrading intervention. An energy poverty index that cannot make this distinction cannot effectively guide targeted investment.

4. Built Environment Indicators for Energy Poverty Measurement in SSA

4.1 Building Material Durability as an Energy Poverty Indicator

The construction material durability of SSA residential buildings is not merely a housing quality variable, it is a direct determinant of energy access, thermal performance, and household energy burden. Wall, roof, and floor materials determine the thermal mass and insulating capacity of a dwelling, its structural eligibility for grid connection and load-bearing of solar panels, and its classification as permanent or informal by utility providers. Tusting *et al.* (2019) provide the most spatially comprehensive evidence base, using a composite improved housing indicator that includes durable construction as one of four components, mapped geostatistically across SSA at subnational resolution.

The DHS housing module, which is available for nearly all SSA countries and is the primary data source for MEPI computation, classifies wall materials (natural/rudimentary/finished), roof materials, and floor materials on categorical scales that can be readily converted into durability scores for MEPI indicator purposes. Santos *et al.* (2024) document the thermal implications of this material gradient: traditional mud-brick and thatch vernacular structures, despite their thermal mass advantages, are categorised as non-durable by housing quality frameworks, while thermally inferior corrugated iron roofs are more prevalent in semi-formal and urban informal structures. The built environment dimension of energy poverty is thus not simply about material quality in the abstract, but about the alignment or misalignment between durability classifications and thermal performance outcomes.

4.2 Thermal Envelope Performance as an Energy Service Dimension

Thermal envelope performance, the capacity of a building's walls, roof, floor, windows, and air infiltration characteristics to moderate indoor temperatures and reduce the mechanical energy required for thermal comfort, constitutes a fundamental energy service dimension that is absent from existing MEPI frameworks. The theoretical case for including thermal comfort as a dimension of energy poverty is well established. Thermal discomfort in residential buildings produces either direct health deprivation (respiratory and cardiovascular effects of excessive heat or cold exposure) or energy burden (excessive expenditure on mechanical cooling or heating). In both cases, the household is energy poor in a meaningful sense, yet standard MEPI instruments do not capture this deprivation.

Robles-Bonilla *et al.* (2021) proposed an operational approach: using adaptive comfort models (ASHRAE 55 or ISO 7730 thermal comfort standards) calibrated to local climate data, a deprivation threshold can be set at households where predicted indoor operative temperatures exceed the adaptive comfort upper bound for more than a specified proportion of occupied hours. Wang *et al.* (2022), in a PRISMA-compliant systematic review, found consistent evidence that energy-inefficient residential buildings are associated with poor indoor air quality, respiratory disease, and adverse health outcomes, establishing the health cost of the thermal envelope performance gap in residential buildings and reinforcing the case for its inclusion as an energy service indicator.

4.3 Daylighting and Natural Ventilation as Architectural Energy Indicators

Daylighting and natural ventilation, achieved through window placement, window-to-wall ratio (WWR), building orientation, and spatial configuration are architectural mechanisms through which buildings either reduce or increase household energy demands for lighting and cooling. In tropical SSA climates, inadequate natural ventilation forces households to rely on mechanical fans or air conditioning, creating energy burdens that standard MEPI indicators do not capture. Inadequate daylighting similarly forces daytime use of electric lighting, increasing both household energy costs and carbon emissions.

The passive design literature provides clear, quantifiable indicators for these dimensions. Olawale-Johnson *et al.* (2025) demonstrate through simulation that optimised natural ventilation combined with insulation reduces residential cooling loads substantially in Nigerian contexts. The review of building forms and orientation by Abdulkareem and Al-Maiyah (2025) found that passive design strategies, including optimal building orientation and cross-ventilation, can reduce cooling loads by up to 35.9% and improve daylighting by 69%, benchmarks that can be converted into deprivation thresholds for MEPI indicator purposes. WWR ratio of glazed area to total facade area are measurable from housing survey data or remote sensing, and provides a proxy for both daylighting and ventilation adequacy that is compatible with MEPI data collection protocols.

4.4 Informal Settlement Classification as a Spatial Energy Poverty Indicator

The spatial classification of a household's location within a formal or informal settlement operates as a structural determinant of energy access that is largely invisible to standard MEPI instruments relying on household survey data. Mwansa *et al.* (2025), using block-level building footprint data across all of SSA, established that physical measures of informality are systematically associated with indicators of human deprivation, including energy access, at granular spatial scales. Their analysis confirms that informality is not a uniform characteristic but exhibits consistent statistical distributions that reflect development gradients from city centres to peri-urban informal zones.

For MEPI construction purposes, the relevant indicator is not informality per se but energy access eligibility as determined by settlement classification. A household in a mapped informal settlement in most SSA cities is structurally ineligible for subsidised grid extension under prevailing utility policies, regardless of its absolute distance from the grid. Chisola *et al.* (2023) document that legal obstacles around mini-grid licensing create additional barriers for informal settlement households, while Ndagijimana *et al.* (2025) demonstrate from Rwanda that green building design integrated into informal settlement upgrading can simultaneously address construction quality and energy access, but only when built environment intervention is explicitly included in the upgrading framework.

4.5 Building Code Compliance as an Institutional Energy Poverty Indicator

Building code compliance, whether a residential structure was constructed with a permit, in accordance with planning regulations, and meeting minimum structural and fire safety standards, constitutes an institutional dimension of energy poverty that current measurement frameworks do not capture. Abdulkareem and Al-Maiyah (2025), reviewing Nigeria's Building Energy Efficiency Guidelines, document the regulatory gap between code intent and construction practice in low-income housing. Mahumane and Mulder (2022), examining the urbanisation of energy poverty in Mozambique, found that rapid urban growth without regulatory oversight produces large quantities of non-compliant, thermally inadequate residential stock that concentrates energy deprivation in peri-urban zones.

A building code compliance indicator, binary (formal permit/no permit) or categorical (formal/semi-formal/informal), is directly derivable from housing census data, municipal permit records, or rapid building assessment surveys. Its inclusion in the MEPI would enable differentiation between energy poverty driven by income constraints (which requires subsidy solutions) and energy poverty driven by regulatory non-compliance and construction informality (which requires upgrading, tenure formalisation, and construction assistance solutions). This distinction is essential for the alignment of energy policy with housing policy in SSA.

5. The BE-MEPI: A Proposed Built Environment Extension of the MEPI

5.1 Framework Overview and Theoretical Grounding

The Built Environment Multidimensional Energy Poverty Index (BE-MEPI) proposed in this paper extends the Nussbaumer *et al.* (2012) MEPI architecture by adding a fifth class of indicators: built environment characteristics of the residential dwelling. The framework retains the Alkire-Foster dual-cutoff counting methodology, meaning that BE-MEPI scores remain directly comparable with existing MEPI estimates and are computable from survey and census instruments already deployed across SSA. The theoretical basis for including built environment indicators is grounded in three converging arguments: (i) the capability approach (Sen, 1993, as cited in Alnour *et al.*, 2026), which defines energy poverty as the deprivation of capabilities for thermal comfort, clean cooking, adequate lighting, and productive energy services, capabilities that are partly produced by and partly constrained by the physical built environment; (ii) the energy ladder hypothesis, which conceptualises households as progressing from solid biomass through transitional fuels to modern energy as income and infrastructure access improve, a progression that is gated by the physical quality of the dwelling; and (iii) the spatial energy poverty literature (Alnour *et al.*, 2026), which demonstrates that energy deprivation exhibits significant spatial clustering driven by built environment characteristics of neighbourhood and settlement type.

5.2 Dimensions, Indicators, and Deprivation Thresholds

The BE-MEPI comprises five pillars and 13 indicators. Pillars I through III correspond to extended versions of existing MEPI dimensions (energy service access, thermal performance, and construction quality), while Pillars IV and V introduce new dimensions (indoor environment quality and spatial-infrastructure classification) not present in any existing MEPI application in SSA. Table 3 maps the conventional MEPI dimensions against the BE-MEPI extensions to illustrate the conceptual additions. Table 4 presents the full BE-MEPI indicator framework with operational definitions, data sources, measurement units, and deprivation thresholds.

Table 3: Mapping Conventional MEPI Dimensions to BE-MEPI Built Environment Extensions

Dimension	Conventional MEPI Indicator	Built Environment Extension (this review)	Deprivation Threshold	Weight
Electricity Access	Household connection to grid electricity	Construction quality as grid connection prerequisite; wiring safety; structural eligibility	No electricity access OR unsafe connection	0.20
Cooking Energy	Use of modern fuels (LPG, gas, electricity)	Kitchen design; indoor ventilation; cooking space separation from living areas	Use of solid biomass without ventilation	0.20
Thermal Comfort	Not included in original MEPI	Building envelope performance: wall materials, roof type, insulation, orientation, window-to-wall ratio	Predicted indoor temp. >30°C (tropics) or <18°C	0.20
Lighting	Electric lighting source	Glazing area, daylighting ratio, window placement; building density blocking daylight	No electric lighting; <1% glazing ratio	0.15
Appliances and Services	Ownership of refrigerator, radio, TV	Electrical load capacity of building; availability of safe sockets; load-bearing structural integrity	No refrigerator and no fan/AC capacity	0.15
Building Material Quality	Not included	Wall/roof/floor material durability score; formal vs informal construction classification	Non-durable walls AND non-durable roof	0.10

Source: Authors' synthesis based on Nussbaumer *et al.* (2012), Tusting *et al.* (2019), Robles-Bonilla *et al.* (2021), Kajjoba *et al.* (2025).

Pillar I (Energy Service Access) retains the three conventional MEPI indicators, electricity connection, cooking fuel modernity, and lighting quality, but extends each with a built environment sub-dimension. For electricity, the extension captures whether the absence of connection is attributable to structural non-eligibility of the dwelling. For cooking, the extension captures whether kitchen spatial design and ventilation adequacy compound the health burden of solid fuel use. For lighting, the extension captures whether architectural configuration, specifically glazing area and building density, limits daylighting independently of electric light availability.

Pillar II (Building Thermal Performance) introduces three new indicators that operationalise the thermal envelope performance of the dwelling. Wall material classification (BE-MEPI-2.1) uses the DHS material durability score already collected in SSA household surveys, with a deprivation threshold set at materials scoring ≤ 2 on the standard 5-point scale (mud, thatch, non-fired brick). Roof material and insulation (BE-MEPI-2.2) similarly uses the DHS roof classification, with deprivation defined as corrugated iron or thatch without supplementary insulation, the most thermally inadequate combination in tropical climates. Window-to-wall ratio (BE-MEPI-2.3) provides an architectural indicator of daylighting and natural ventilation adequacy, with a deprivation threshold of less than 10% glazed area, consistent with WHO guidance on minimum daylight and ventilation in residential buildings.

Pillar III (Construction Quality) introduces three indicators targeting the formal quality and structural integrity of the building itself. Building material durability score (BE-MEPI-3.1) uses the composite DHS housing quality indicator, with deprivation defined as households with non-durable wall and floor materials simultaneously. Building code compliance (BE-MEPI-3.2) is operationalised as a binary indicator derived from municipal permit records or household survey responses about dwelling construction history. The structural integrity index (BE-MEPI-3.3) is a composite score derivable from rapid building assessment surveys, with deprivation defined as scores below 4 on a 10-point scale.

Pillar IV (Indoor Environment Quality) introduces two indicators that capture the indoor consequence of combined energy source and built environment characteristics. Indoor air quality proxy (BE-MEPI-4.1) is constructed from cooking fuel type and ventilation characteristics jointly, operationalising the compound deprivation of solid fuel use in poorly ventilated spaces documented by Wang *et al.* (2022). Thermal comfort status (BE-MEPI-4.2) implements the Robles-Bonilla *et al.* (2021) thermal comfort extension, using either field measurements or adaptive comfort modelling calibrated to local climate data.

Pillar V (Spatial-Infrastructure) introduces two spatial indicators that locate the household within the built environment at neighbourhood and settlement scales. Grid proximity and service eligibility (BE-MEPI-5.1) operationalises the finding of IOP Somalia (2026) and Mwansa *et al.* (2025) that geographic and regulatory ineligibility for grid connection compounds household energy poverty. Informal settlement classification (BE-MEPI-5.2) provides a binary indicator of whether a household is located in a mapped informal settlement, consistent with the settlement-level energy access literature reviewed in Section 4.4.

Table 4: The BE-MEPI: Built Environment Multidimensional Energy Poverty Index

Pillar	Indicator Code	Indicator Description	Data Source	Measurement Unit	Deprivation Threshold
I. ENERGY SERVICE ACCESS	BE-MEPI-1.1	Electricity connection status	DHS / MICS surveys	Binary: 0/1	No formal connection
I. ENERGY SERVICE ACCESS	BE-MEPI-1.2	Cooking fuel modernity	DHS energy module	Categorical (biomass/LPG/gas)	Solid biomass without ventilation
I. ENERGY SERVICE ACCESS	BE-MEPI-1.3	Lighting quality	Household survey	Lux equivalent / source type	No electric or solar lighting
II. BUILDING THERMAL PERFORMANCE	BE-MEPI-2.1	Wall construction material	DHS housing module	Material classification score 1–5	Score ≤ 2 (mud/thatch/non-fired brick)
II. BUILDING THERMAL PERFORMANCE	BE-MEPI-2.2	Roof material and insulation	DHS / field survey	Material classification score 1–5	Score ≤ 2 (corrugated iron without insulation)
II. BUILDING THERMAL PERFORMANCE	BE-MEPI-2.3	Window-to-wall ratio (WWR)	Architectural survey / RS	% glazed area	WWR < 10% (inadequate daylighting and ventilation)

Pillar	Indicator Code	Indicator Description	Data Source	Measurement Unit	Deprivation Threshold
III. CONSTRUCTION QUALITY	BE-MEPI-3.1	Building material durability score	Housing census / DHS	Composite score	Non-durable wall AND floor material
III. CONSTRUCTION QUALITY	BE-MEPI-3.2	Building code compliance	Municipal records	Binary formal/informal classification	Informal; no permit
III. CONSTRUCTION QUALITY	BE-MEPI-3.3	Structural integrity index	Field survey / rapid assessment	Score 0–10	Score < 4
IV. INDOOR ENVIRONMENT	BE-MEPI-4.1	Indoor air quality proxy	Household survey (cooking + ventilation)	Composite proxy	Solid fuel + no ventilation
IV. INDOOR ENVIRONMENT	BE-MEPI-4.2	Thermal comfort status	Field measurement / adaptive model	PMV/PPD or adaptive comfort	> 90% hours outside adaptive comfort zone
V. SPATIAL–INFRASTRUCTURE	BE-MEPI-5.1	Grid proximity and service eligibility	GIS/utility data	Distance to nearest grid (km)	> 5 km OR ineligible due to informal status
V. SPATIAL–INFRASTRUCTURE	BE-MEPI-5.2	Informal settlement classification	Urban planning records/satellite	Binary	Located in a mapped informal settlement

Source: Authors' framework construction (2026). Material classification scales adapted from DHS housing quality modules and Tusting *et al.* (2019).

5.3 Weighting and the Dual-Cutoff Computation

Consistent with the Alkire-Foster methodology, each BE-MEPI indicator is assigned a weight that reflects its relative contribution to the total weighted deprivation score. In the proposed framework, the five pillars are given equal weight (0.20 each), with indicator weights within each pillar distributed equally unless contextual evidence justifies differential weighting. The total weight of the built-environment extensions (Pillars II, III, IV, and V) is thus 0.80, reflecting the paper's argument that conventional energy service access indicators (Pillar I) represent only one-fifth of the total energy poverty experience relevant to SSA residential contexts. This weighting is presented as a baseline specification; empirical validation studies should conduct sensitivity analyses across alternative weighting schemes, consistent with standard practice in the multidimensional poverty measurement literature (Siksnelyte-Butkiene *et al.*, 2021).

The dual-cutoff computation proceeds as in the standard MEPI. A household is identified as deprived on any indicator if its score falls below the indicator-specific deprivation threshold defined in Table 4. A weighted deprivation score c is computed for each household as the sum of weights of dimensions in which it is deprived. The household is classified as multidimensionally energy poor if $c \geq k$, where k is set at one-third of total possible weighted deprivations ($k = 0.33$) as a baseline, with sensitivity analysis across $k = 0.20$ and $k = 0.50$ recommended. Incidence H, intensity A, and composite score $M = H \times A$ are then computed at the household, community, and national levels. The BE-MEPI is thus fully compatible with existing MEPI computation protocols and software, requiring only the addition of new indicator variables to existing survey data collection instruments.

5.4 Data Requirements and Compatibility

A critical consideration for any proposed extension of the MEPI is data feasibility: whether the proposed indicators are measurable using existing or readily extendable survey instruments in SSA. The BE-MEPI is designed with this constraint explicitly in mind. All Pillar I indicators are already collected in DHS surveys. Pillar II indicators (wall material, roof material) are already collected in DHS housing modules and can be converted to durability scores without additional data collection; the window-to-wall ratio requires a single architectural measurement that can be added to standard DHS household listing forms. Pillar III indicators require additions to either housing census instruments or purpose-designed rapid building assessment tools, with building code compliance derivable from a single household survey question. Pillar IV indicators are constructable from existing DHS cooking and ventilation data for BE-MEPI-4.1, while thermal comfort (BE-MEPI-4.2) requires field measurement or modelling that is best suited to sample-based validation studies rather than national census enumeration. Pillar V indicators are derivable from GIS analysis of utility service maps and urban planning settlement classifications, both of which are increasingly available through open-source geospatial platforms, including the data compiled by Mwansa *et al.* (2025).

6. DISCUSSION

The BE-MEPI framework advances the energy poverty measurement literature in three theoretically significant ways. First, it extends the conceptual domain of energy poverty beyond energy source type and appliance ownership to encompass the physical conditions under which energy services are produced, consumed, and denied. In doing so, it aligns energy poverty measurement with the capability approach framework that Alkire and Foster (2011) invoked in designing the original AF methodology: poverty is a deprivation of substantive freedoms and capabilities, not merely an income shortfall or a resource gap. The capability to achieve thermal comfort, adequate daylighting, and safe indoor air quality is partly a function of the physical built environment; an index that ignores the built environment is therefore incomplete as a capability-based poverty measure.

Second, the BE-MEPI operationalises the distinction between energy poverty driven by income and price constraints (amenable to subsidy and tariff solutions) and energy poverty driven by built environment inadequacy (amenable to construction upgrading, passive design, and tenure formalisation solutions). This distinction, which existing MEPI applications cannot make, has direct implications for the design of energy access programmes and housing policies in SSA. Alnour *et al.* (2026) demonstrate through spatial panel analysis that energy poverty in SSA has significant neighbourhood-level clustering that cannot be explained by household-level socioeconomic variables alone; the BE-MEPI's built environment indicators provide the measurement instruments needed to identify and target the built environment drivers of this spatial clustering.

Third, the BE-MEPI contributes to the indicator construction literature (Siksnelyte-Butkiene *et al.*, 2021) by demonstrating how the Alkire-Foster methodology can accommodate built environment variables without departing from its dual-cutoff architecture. The framework is modular: individual pillars can be added or removed, and weights adjusted, to suit specific research questions or data environments, while remaining computationally compatible with the MEPI software infrastructure developed at OPHI.

The adoption of the BE-MEPI in SSA energy poverty monitoring and policy would carry several significant implications. For national energy ministries, it would require the integration of housing and construction quality data into energy poverty monitoring systems, a cross-ministerial coordination that is currently rare in SSA governance structures. The evidence reviewed, particularly from Gregory and Sovacool (2019) and the EPAH institutional literature, confirms that this integration is precisely what is needed: energy access is not solely an energy sector problem, and its measurement cannot remain confined to energy sector data alone.

For urban planning and housing authorities, the BE-MEPI provides a measurement instrument that links construction quality standards to energy outcomes, creating an evidence base for requiring minimum thermal performance standards in affordable housing programmes. Abdulkareem and Al-Maiyah (2025) identify an alarming regulatory gap in Nigeria's low-income housing sector that produces thermally inadequate buildings at scale; the BE-MEPI would quantify the energy poverty consequences of this gap and thereby create the evidence base for regulatory reform. The Rwanda case documented by Ndagijimana *et al.* (2025) demonstrates that green building design in informal settlement upgrading can simultaneously address construction quality and energy outcomes, the BE-MEPI would enable systematic evaluation of such programmes.

For international development partners funding SDG7 implementation in SSA, the BE-MEPI offers a measurement tool aligned with the multi-tier framework (MTF) promoted in the Tracking SDG7 2025 report (IEA *et al.*, 2025), which recognises that energy access is not binary but tiered across quality, reliability, quantity, and affordability dimensions. The built environment indicators in the BE-MEPI map directly onto the MTF's higher tiers, providing the diagnostic granularity needed to design Tier 3+ electrification programmes that account for dwelling eligibility constraints.

The BE-MEPI framework, as proposed, faces several limitations that future research must address. The thermal comfort indicator (BE-MEPI-4.2) requires field measurement or building energy simulation that is resource-intensive at the national scale; proxy approaches using building material combinations and climate data may be needed for large-sample applications. The structural integrity index (BE-MEPI-3.3) requires a standardised rapid assessment protocol that does not yet exist as a widely accepted instrument in SSA housing surveys. The weighting scheme proposed is a baseline specification requiring empirical validation through robustness and sensitivity analysis. Finally, the BE-MEPI as a whole requires pilot application in one or more SSA country contexts to validate its operationalisation, establish appropriate k-cutoffs, and assess its added explanatory value over the standard MEPI.

Future research should pursue several directions. First, a pilot application of the BE-MEPI using existing DHS data supplemented by architectural field surveys in one or more SSA countries, ideally spanning different urban morphologies (formal city, informal urban, rural), is needed to validate the framework empirically and establish benchmark scores. Second, the relationship between BE-MEPI scores and established measures of household wellbeing (income poverty, health outcomes, educational attainment) should be examined using regression analysis to establish the index's external validity. Third, the framework should be extended to incorporate climate change projections, as increasing ambient temperatures in SSA will amplify the thermal comfort dimension of energy poverty over the coming decades, potentially making it the dominant driver of residential energy demand in the region by 2050.

7. CONCLUSIONS

This paper has argued, through a systematic review of 27 peer-reviewed and institutional studies, that existing energy poverty measurement frameworks applied in Sub-Saharan Africa, most centrally, the Multidimensional Energy Poverty Index (MEPI), contain a structural blind spot: the physical built environment of the residential dwelling. Construction material durability, thermal envelope performance, building code compliance, daylighting and ventilation adequacy, and informal settlement classification are all demonstrably associated with household energy poverty outcomes in SSA, yet none are captured in the dominant MEPI instruments currently deployed. The BE-MEPI framework proposed in this paper addresses this gap by extending the Alkire-Foster MEPI architecture with five built environment pillars and 13 operationally defined indicators, each grounded in reviewed empirical evidence and compatible with existing DHS and housing census data collection infrastructure. The framework is theoretically grounded in the capability approach, empirically motivated by the built environment evidence synthesised in this review, and methodologically compatible with the OPHI MEPI computation protocols used across SSA.

Three conclusions merit particular emphasis. First, energy poverty in SSA is not only a function of what energy source a household uses, but it is also a function of what kind of building it inhabits. A household using kerosene for lighting in a thermally adequate, well-ventilated, formally constructed dwelling is differently energy poor from one using the same kerosene in a tin-roofed, unventilated, non-durable informal structure in a peri-urban settlement ineligible for grid connection. The standard MEPI treats both households identically on the lighting dimension; the BE-MEPI distinguishes them. Second, the integration of built environment variables into energy poverty measurement would enable more targeted, cost-effective, and durable policy interventions by revealing the built environment drivers of energy deprivation. Construction upgrading, passive design adoption, tenure formalisation, and building code reform are all potential policy levers that the standard MEPI cannot identify as relevant; the BE-MEPI makes them visible. Third, the collaboration between building technologists, architects, urban planners, energy economists, and housing policy specialists is essential for the development, validation, and operationalisation of the BE-MEPI. The energy poverty challenge in SSA is fundamentally interdisciplinary, and its measurement frameworks must reflect this reality. The construction and building professions in SSA have an important, currently underutilised role to play in resolving one of the region's most persistent development challenges.

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