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THERMAL COMFORT IN INDONESIAN VERNACULAR HOUSES

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ABSTRACT

Thermal comfort in Indonesian housing is increasingly challenged by hot-humid climates, urban densification, material changes, and rising cooling demand. This study employed a narrative literature review with thematic synthesis. Literature was identified through a Scopus search conducted on 10 May 2026 using thermal-comfort and vernacular-architecture keywords, then supplemented by Indonesian case studies, classic comfort theories, thermal-comfort standards, and policy reports. The selected sources were screened based on relevance to thermal comfort, vernacular or naturally ventilated dwellings, and architectural design, and were appraised according to evidence type, including field measurements, occupant surveys, simulations, reviews, and architectural interpretations. A total of 45 cited sources formed the basis of the thematic synthesis. The review finds that Indonesian vernacular houses do not provide automatic comfort; their performance depends on climate exposure, material integrity, ventilation potential, roof design, shaded transition spaces, and occupant control. Evidence from Acehnese, Banjar, Minangkabau, Bugis, Javanese, Balinese, Palembang, and East Nusa Tenggara houses indicates recurring mechanisms: raised floors, ventilated roof voids, porous but shaded envelopes, semi-outdoor spaces, and climate-specific materials. The article proposes a performance-based translation framework for contemporary low-energy housing. Vernacular principles are most useful when evaluated through measured air movement, radiant heat, humidity, occupant votes, and future climate resilience.

KEYWORDS: adaptive thermal comfort, Indonesian vernacular architecture, passive cooling, traditional houses, tropical housing

Kenyamanan termal pada hunian di Indonesia semakin menghadapi tantangan akibat iklim panas-lembap, densifikasi perkotaan, perubahan material bangunan, dan meningkatnya kebutuhan pendinginan. Tinjauan naratif ini mensintesis berbagai bukti mengenai bagaimana rumah vernakular Indonesia mendukung pendinginan pasif dan kenyamanan termal adaptif. Penelusuran Scopus yang dilakukan pada 10 Mei 2026 mengidentifikasi 487 dokumen menggunakan kata kunci terkait kenyamanan termal dan arsitektur vernakular; pembatasan pada periode 2020–2026 serta jenis artikel/review menghasilkan 178 dokumen terbaru. Setelah proses penyaringan relevansi dan seleksi sumber tambahan, sebanyak 45 sumber terpilih membentuk sintesis tematik yang mencakup kasus-kasus Indonesia, teori klasik kenyamanan termal, standar, dan laporan kebijakan. Tinjauan ini menunjukkan bahwa rumah vernakular Indonesia tidak secara otomatis memberikan kenyamanan; performanya bergantung pada paparan iklim, integritas material, potensi ventilasi, desain atap, ruang transisi yang terlindungi bayangan, dan kontrol penghuni. Bukti dari rumah Aceh, Banjar, Minangkabau, Bugis, Jawa, Bali, Palembang, dan Nusa Tenggara Timur menunjukkan mekanisme yang berulang berupa lantai panggung, rongga atap berventilasi, selubung bangunan berpori namun teduh, ruang semi-terbuka, serta material yang sesuai dengan kondisi iklim. Artikel ini mengusulkan kerangka translasi berbasis performa untuk perancangan hunian rendah energi kontemporer. Prinsip-prinsip vernakular paling efektif ketika dievaluasi melalui pengukuran pergerakan udara, panas radiasi, kelembapan, penilaian kenyamanan penghuni, dan ketahanan terhadap perubahan iklim di masa depan.

KATA KUNCI: *kenyamanan termal adaptif, arsitektur vernakular Indonesia, pendinginan pasif, rumah tradisional, hunian tropis*

INTRODUCTION

Thermal comfort is a central issue in Indonesian housing because many regions experience high air temperatures, high relative humidity, intense solar radiation, and seasonal monsoon variation. In naturally ventilated Indonesian houses, Feriadi and Wong (2004) analysed 525 field observation datasets and found that the predicted mean vote (PMV) model tended to predict warmer thermal sensations than occupants actually reported. This finding indicates that thermal comfort in tropical dwellings is not only a matter of lowering air temperature, but also of providing adequate air movement, shading, and opportunities for adaptive behaviour.

Cooling demand is also a contemporary architectural and environmental concern. The International Energy Agency (2024) identifies Southeast Asia as a region where space cooling is becoming increasingly important for electricity demand, while Indonesia's National Cooling Action Plan frames cooling as an issue of health, climate resilience, and emissions reduction (UNESCAP, 2024). In this context, passive cooling and mixed-mode strategies are receiving greater attention, particularly in housing where continuous air-conditioning may be economically or environmentally unsustainable. Evidence from an air-conditioned residential room in Makassar further shows that mechanical cooling can maintain indoor temperature near comfort levels, it may also produce uneven air distribution and elevated CO_2 concentrations when occupancy increases and openings remain closed (Latif et al., 2023).

Indonesian vernacular represent a substantial body of climate-responsive design knowledge. Features such as roofs, raised floors, permeable envelopes, shaded verandas, courtyard-like compounds, and adaptive patterns of occupation emerged through long-term interaction between local culture and environmental conditions. However, vernacular houses should be understood as climate-responsive systems rather than inherently comfortable forms, as their performance depends on factors including site condition, material properties, ventilation pathways, maintenance, and occupant behaviour. Previous studies on tropical vernacular architecture have warned that comfort and practicability cannot be assumed from tradition alone (Foruzanmehr & Vellinga, 2011; Nguyen et al., 2019).

Existing studies on Indonesian traditional houses have largely focused on individual house types, specific regions, or isolated passive design features. As a result, a cross-typological synthesis linking vernacular form, passive cooling mechanisms, adaptive comfort, and contemporary low-energy housing design remains limited. Recent reviews also note that discussions of passive cooling in Indonesian traditional dwellings are not always explicitly connected to geographical conditions and climatic variation (Angkasa & Kamil, 2024).

This study contributes to architectural knowledge in three ways. First, it synthesizes dispersed evidence on thermal comfort in Indonesian vernacular houses across diverse climatic contexts. Second, it differentiates the strength of evidence across field measurements, occupant surveys, simulations, and architectural interpretations. Third, it proposes a performance-based translation framework for contemporary housing, in which vernacular principles are evaluated through thermal mechanisms rather than replicated as stylistic forms.

Adaptive Thermal Comfort and Hot-Humid Housing

The PMV/PPD model remains an important heat-balance approach for evaluating thermal environments, but its assumptions are most applicable under relatively controlled indoor conditions (Fanger, 1970; ASHRAE, 2023; ISO, 2025). In naturally ventilated buildings, adaptive comfort theory proposes that occupants respond to thermal condition through behavioural, physiological, and psychological adjustments (Brager & de Dear, 1998; Nicol & Humphreys, 2002). The adaptive approach was incorporated into thermal-comfort standards because field studies repeatedly showed differences between predicted and actual comfort in free-running buildings (de Dear & Brager, 2002; Humphreys et al., 2007).

This distinction becomes particularly important in hot-humid housing environments. Air movement increases convective and evaporative heat loss, which can make warm indoor conditions more acceptable when occupants have control over openings, fans, and room use (Cândido et al., 2010; Toe & Kubota, 2013). Indonesian studies support this position. Karyono (2015) suggested comfort temperatures around 27-28 °C for Indonesian conditions, while Feriadi and Wong (2004) found that occupants of naturally ventilated house often preferred higher air movement rather than simply lower air temperature. Similarly, Uno et al. (2018) also emphasized that thermal sensation in Indonesia should be interpreted within the context of everyday living in hot-humid environments.

Vernacular Architecture as Climatic Adaptation

Vernacular architecture can be understood as the outcome of long-term adjustment among culture, resource availability, construction knowledge, and climate (Rapoport, 1969). Climatic design literature has long emphasized orientation, shading, ventilation, material selection, and settlement form as passive strategies for comfort (Olgyay, 1963; Koenigsberger et al., 1973; Givoni, 1992). In tropical regions, passive design often relies on shaded openings, light envelopes, roof ventilation, and semi-outdoor spaces rather than sealed and highly insulated interiors (Mallick, 1996; Kubota et al., 2018).

Recent research on vernacular dwellings shows that their environmental value is not uniform. Some studies find strong passive performance, while others find discomfort, seasonal limitations, or loss of performance after modernization. A meta-analysis of vernacular thermal-comfort research highlights challenges in applying conventional comfort standards, modelling irregular envelopes, and interpreting occupant expectations (Costa-Carrapiço et al., 2022). A systematic review of vernacular dwelling climate responsiveness similarly calls for more explicit links between local climate, architectural strategy, and measured indoor environment (Yang et al., 2022).

Indonesian Vernacular Houses as Environmental Systems

Indonesian traditional houses exhibit substantial variation across hot-humid coastal zones, riverine lowlands, monsoon regions, highlands, and savanna-like environments. This diversity indicates that Indonesian vernacular architecture cannot be understood through to a single tropical design formula. In regions such as Aceh, South Sulawesi, South Kalimantan, West Sumatra, and South Sumatra, stilt houses commonly combine raised floors with timber envelopes and expansive roof forms to support environmental adaption. Balinese compounds distribute daily activities across multiple pavilions and shaded open spaces, while Javanese houses rely on large roof volumes and transitional verandas to moderate indoor conditions. In contrast, houses in East Nusa Tenggara may prioritize heat buffering and protection from cooler nighttime temperatures rather than maximizing ventilation (Karyono et al., 2012; Hildegardis et al., 2019).

METHODS

Review Design

This study uses a narrative literature review with thematic synthesis. The approach was selected because the available evidence is heterogeneous and includes field surveys, short-term enviromental measurements, building simulations, CFD models, machine-learning studies, standards, policy reports, and architectural interpretations. The review does not pool effect sizes. Instead, it compares thermal mechanisms, evidence types, and their implications for architectural design.

Search Record and Source Selection

The primary literature search was conducted in the Scopus database on 10 May 2026 using the following query: ("thermal comfort" OR "indoor thermal environment" OR "thermal sensation" OR "thermal acceptability") AND ("vernacular architecture" OR "traditional architecture" OR "traditional house" OR "vernacular dwelling" OR "indigenous house"). The search returned 487 documents. Restricting the publication period to 2020-2026 reduced the results to 267 records, and limiting document types to articles and reviews yielded 178 records. These records formed the recent literature search universe.

The Scopus search was supplemented with core Indonesian studies, thermal-comfort standards, policy documents, and classic thermal-comfort references published before 2020. Older sources were retained when they provided foundational theory or Indonesian empirical evidence that had not been superceded by more recent studies. The 178 recent records were screened by title, abstract, and architectural relevance. The final synthesis included 43 sources that directly addressed Indonesian vernacular houses, tropical naturally ventilated dwellings, adaptive comfort theory, or passive-cooling mechanisms.

Inclusion criteria comprised: (1) relevance to thermal comfort or indoor thermal environment; (2) an explicit connection to vernacular, traditional, or naturally ventilated dwellings; and (3) usefulness for interpreting Indonesian house typologies or comparable tropical passive strategies. Exclusion criteria included: (1) purely visual or descriptive discussions without climatic interpretation; (2) unverifiable bibliographic data, and (3) sources unrelated to housing or architectural design.

Synthesis and Evidence Appraisal

Sources were coded according to house type, climate context, passive strategy, thermal mechanism, quantitative evidence, and design implications. To avoid treating all sources as equally reliable, the review also classified the strength of evidence. Field studies that combined occupant feedback with environmental measurements were considered stronger indicators of thermal comfort than simulation-based studies alone. Simulations, CFD, and machine-learning approaches were valuable for testing and explaining mechanisms, but their findings were interpreted cautiously when not supported by occupant data. Architectural interpretations and policy reports were used to establish design relevance rather than to demonstrate thermal performance directly.

The two figures and four tables presented in this article were developed from this thematic coding process. Figure 1 about outlines the search and synthesis framework. Table 1 summarizes the review protocol and the evidence appraisal criteria used in this study.

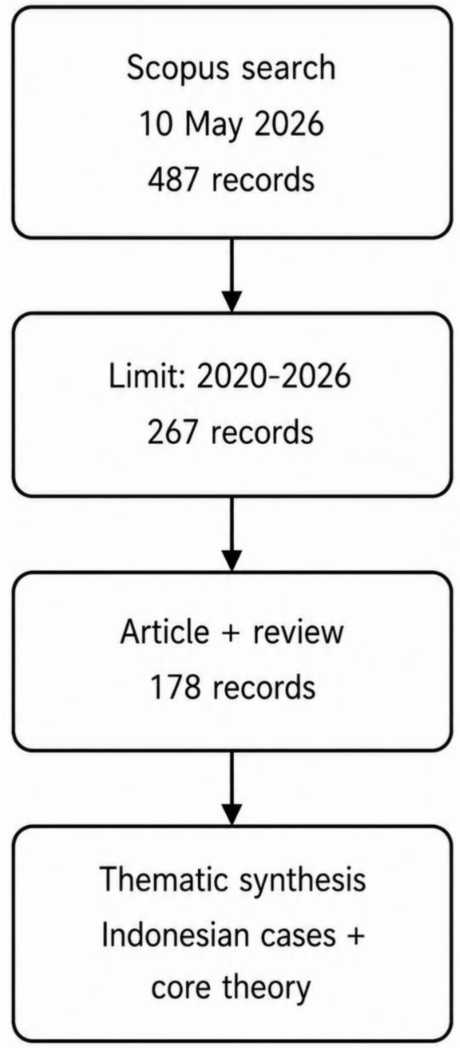


Figure 1. Review flow and synthesis framework derived from the Scopus search, thematic screening, and the final narrative synthesis of 43 included sources.
(Source: Author's Document, 2026)

Table 1. Review protocol and evidence appraisal

Element	Specification	Purpose
Database search	Scopus; accessed 10 May 2026; thermal-comfort and vernacular-architecture query; 487 records.	Establishes the recent evidence universe.
Limits	2020-2026 = 267 records; article/review types = 178 records.	Focuses the recent review while keeping relevant classic works.
Supplementary sources	Indonesian case studies, standards, policy reports, and classic comfort theory.	Retains foundational and Indonesia-specific evidence.
Screening criteria	Thermal comfort/indoor environment; vernacular or naturally ventilated dwellings; architectural relevance.	Avoids purely descriptive or non-architectural sources.
Appraisal	Evidence ranked as field survey, measurement, simulation/model, review, or interpretation.	Prevents treating all claims as equal evidence.
Final synthesis	43 cited sources retained after thematic relevance screening and supplementary source selection.	Defines the evidence base used for the narrative synthesis.

(Source: Author's Analysis, 2026)

RESULTS AND DISCUSSION

Typological Diversity and Climate Context

The reviewed Indonesian cases indicate four broad thermal typologies. First, stilt houses such as Rumoh Aceh, Bugis houses, Banjar houses, Rumah Gadang, and Palembang Limas houses elevate the living floor above ground level. This strategy can enhance under-floor airflow, support flood adaptation, and reduce exposure to ground moisture, although these benefits depend on maintaining adequate ventilation beneath the structure.

Second, pavilion or compound-based houses, especially Balinese examples, create shaded gradients between outdoor and indoor spaces and allow activities to shift across different thermal conditions, as shown in recent work of Bale Paon and Bale Dangin in Penglipuran demonstrate how this spatial flexibility contributes to thermal adaption (Aritama et al., 2025).

Third, Javanese Joglo and Limasan houses rely primaly on high roof volumes, deep overhangs, and spatial hierarchy to moderate indoor condition. Fourth, highland and savanna-related houses such as Mbaru Niang and Uma Kbubu demonstrate that Indonesian tropical design does not always prioritize openness and maximum ventilation; in some contexts, thermal comfort depends instead on heat retention and controlled air exchange.

This differentiation supports the argument of Hermawan and Švajlenka (2021) that thermal comfort outcomes vary according to location, seasonal conditions, and envelope characteristics.

Table 2. Indonesian vernacular house types, passive mechanisms, and design implications

House type	Climate context	Main passive mechanisms	Evidence and design implication
Rumoh Aceh	Hot-humid coastal/lowland	Raised floor, roof ventilation, porous envelope, orientation	ANN and CFD studies indicate orientation and air movement effects; retain under-floor and roof airflow.
Bugis house	South Sulawesi coastal/lowland	Stilted floor, light walls, verandas, overhangs, attic ventilation	Bioclimatic assessment supports raised and shaded ventilation strategies for flood-prone housing. CFD-based attic-chimney evidence also supports roof-cavity ventilation as a heat-removal and airflow strategy in Bugis houses (Latif et al., 2019).
Banjar houses	Riverine hot-humid	Timber structure, veranda, landscape, floor insulation	Measured Banjar studies report comfortable-warm conditions; combine passive ventilation with fans and roof upgrades.
Rumah Gadang	High-rainfall West Sumatra	Large roof volume, open interior, orientation, openings	Roof voids and open spatial organization support air distribution and heat buffering.
Palembang Limas	Riverine lowland	Tiered floors, large roof, partitionless hierarchy	Reported stratification up to 4.6 °C shows thermal and social zoning can coincide.
Balinese compound	Tropical monsoon	Separated pavilions, courtyard/natah, shaded circulation	Mass layout and orientation create outdoor-indoor gradients and support activity shifting.
Joglo/Limasan	Java monsoon lowland	High central roof, deep eaves, transitional spaces	Roof geometry and shaded porosity support ventilation but depend on modern occupancy patterns.
Mbaru Niang/Uma Kbubu	Highland/savanna variation	Compact form, thatch, controlled openings	Demonstrates that some Indonesian contexts require heat buffering rather than maximum openness.

(Source: Author's Analysis, 2026)

Passive Cooling Mechanisms and Trade-offs

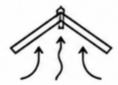
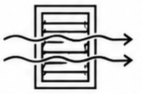
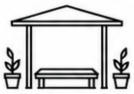
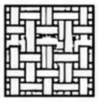
Raised floors are among the most recurrent mechanisms in riverine and coastal traditions. They can reduce exposure to humid ground, create shaded airflow beneath the living space, and support flood resilience. Yet this strategy may lose effectiveness when the under-floor space is enclosed for storage, commercial use, or parking without preserving its airflow function. Therefore, thermal performance issue is not simply on the presence of stilts, but on maintaining continuous airflow beneath and through the dwelling.

Large roof volumes and roof cavities represent another important thermal mechanism. In Minangkabau houses, Nugroho (2021) associated orientation, opening placement, expansive roof volume, and partitionless space with improve bioclimatic performance. In Acehnese houses, Muslimsyah et al. (2024) showed that orientation influences indoor temperature, humidity, and air movement, while Husin (2025) reported indoor air-speed variations up to approximately 2.7 m/s in CFD and measurement analysis. In Buginese houses, CFD analysis of an inclined attic chimney integrated with a triangular roof indicates that roof-cavity ventilation can enhance air movement and remove trapped heat, especially when the chimney channel is sufficiently deep and connected to horizontal roof outlets (Latif et al., 2019). Nevertheless, large roof volumes without adequate ventilation or radiant heat control may function as heat reservoirs rather than cooling devices.

Porous envelopes, verandas, and shaded transitional spaces are also central to adaptation in hot-humid environments. Timber boards, louvres, bamboo, wall openings, and operable windows can increase air movement, while verandas and semi-outdoor rooms create cooler zones for daily activities. The Banjar Gajah Baliku study recorded an average main-room temperature of 25.45 °C and identified orientation, verandas, walls construction, landscape, passive shading, and floor insulation as key bioclimatic criteria (Hafizha & Jairina, 2023). Alkausar and Riyani (2023) likewise reported a comfortably warm thermal-humidity index range in Banjar housing. However, the effectiveness of these strategies may be constrained by security concerns, rain exposure, privacy needs, and dense urban surroundings.

Material transformation represents a major challenge for maintaining vernacular thermal performance. Traditional assemblies of timber, bamboo, thatch, palm fibre, and clay tiles often functioned in combination with natural ventilation and shading. Replacing these materials with thin metal roofs, concrete walls, or sealed ceilings may increase radiant heat gain and reduce night-time cooling unless compensatory measures such as insulation, ventilation gaps, or reflective layers are added. This concern is consistent with broader evidence that vernacular performance depends on the interaction of material system, building envelopes, urban morphology, and occupant practices rather than from any single architectural feature alone (Zhai & Previtali, 2010; Santamouris, 2016).

Table 3. Passive cooling mechanisms, thermal functions, and critical trade-offs in Indonesian vernacular houses

Vernacular mechanism		Thermal function	Critical trade-off
	**Raised floor**	Separates living zone from humid ground	Undercroft enclosure
	**Roof voids**	Buffers radiant heat and releases hot air	Decorative roof without ventilation
	**Porous envelope**	Improves cross-flow and air movement	Rain/security constraints and unshaded openings
	**Transition space**	Creates shaded thermal gradients	Loss in compact urban housing
	**Local materials**	Moderates heat gain and moisture response	Metal/concrete substitution
	**Occupant control**	Enables adaptive comfort actions	Sealed rooms and fixed cooling

(Source: Author's Analysis, 2026)

Quantitative Evidence and Interpretation

The quantitative evidence in this review should be interpreted as reference points rather than directly comparable effect sizes. The data include field-observation counts, comfort-temperature estimates, thermal-humidity indices, simulated air speeds, orientation optimization, and temperature stratification, each generated through different methods and intended to answer different research questions. For this reason, Table 4 identifies both the quantitative findings and the corresponding evidence type.

Several patterns nevertheless emerge consistently across the literature. Air movement repeatedly appears as a critical factor in naturally ventilated Indonesian dwellings. Feriadi and Wong (2004) demonstrated that PMV may overestimate warmth relative to actual votes, while Karyono (2015) suggested that Indonesian comfort temperatures can be higher than conventional cooling setpoints. Evidence from the Palembang Limas house adds another dimension: Angkasa et al. (2025) reported vertical temperature stratification up to 4.6 °C, indicating that social and spatial hierarchy may also contribute to thermal zoning. These data support a design approach based on air movement, shading, spatial flexibility, and occupant control.

Design Translation for Contemporary Housing

The evidence supports translation rather than direct imitation of vernacular forms. Contemporary housing can adopt strategies such as ventilated roof cavities, ridge or gable vents, shaded openings, secure cross-ventilation, semi-outdoor buffer spaces, and low-conductivity or ventilated material assemblies. Ceiling fans and mixed-mode operation should be treated as adaptive mechanisms that reduce dependence on compressor-based cooling when paired with effective natural ventilation. In contemporary bedrooms and study spaces that continue to rely on air conditioning, mixed-mode operation should also address indoor air quality. Field measurements in Makassar showed that CO_2 concentrations may exceed 1000 ppm under conditions of higher occupancy and closed openings, whereas opening windows or doors helped restore air circulation (Latif et al., 2023). Indonesian ventilation and energy standards also provide a regulatory context for integrating passive and mechanical systems (Standar Nasional Indonesia, 2001, 2011).

Design translation must remain climate-specific rather than universally applied. Coastal and riverine houses benefit from ventilation, shading, and moisture control, whereas dense urban housing requires secure ventilation strategies and protection from radiant heat gain. Highland and savanna environments may depend more on controlled porosity and night-time heat retention. Studies of modernized Javanese houses also show that lifestyle changes and room-use patterns influence whether vernacular forms remain environmentally effective (Xian et al., 2024). Thus, passive cooling should be evaluated through use patterns as well as architectural components.

Table 4. Quantitative anchors and evidence interpretation

Source	Evidence type	Quantitative anchor	Interpretation
Feriadi & Wong (2004)	Field survey + measurement	525 field-observation data sets	PMV tended to predict warmer sensation than actual votes.
Karyono (2015)	Indonesian comfort synthesis	Comfort temperature about 27-28 °C	Supports higher setpoints when adaptive opportunity exists.
Hafizha & Jairina (2023)	Field measurement	Mean main-room temperature 25.45 °C	Banjar bioclimatic criteria were associated with acceptable indoor conditions.
Muslimsyah et al. (2024)	ANN modelling	Optimum orientation near 292.19° in one scenario	Orientation should be tested with wind and solar geometry.
Husin (2025)	CFD + measurement	Indoor air speed up to about 2.7 m/s	Acehnese passive design can support meaningful air movement.
Angkasa et al. (2025)	Multi-case thermal study	Stratification up to 4.6 °C	Palembang Limas spatial hierarchy can produce thermal zoning.
Hermawan & Švajlenka (2021)	Comparative field/simulation study	Comfort percentages from 0% to 39%	Comfort varies by season, location, and envelope type.
Latif et al. (2019)	CFD simulation	Solar chimney depth tested from 0.10 to 0.35 m; average airflow velocity increased with channel depth, with interior airflow reaching above 0.25 m/s	Roof-cavity ventilation and inclined chimney design can strengthen passive airflow in Buginese houses, although validation with occupant data remains needed.

(Source: Author's Analysis, 2026)

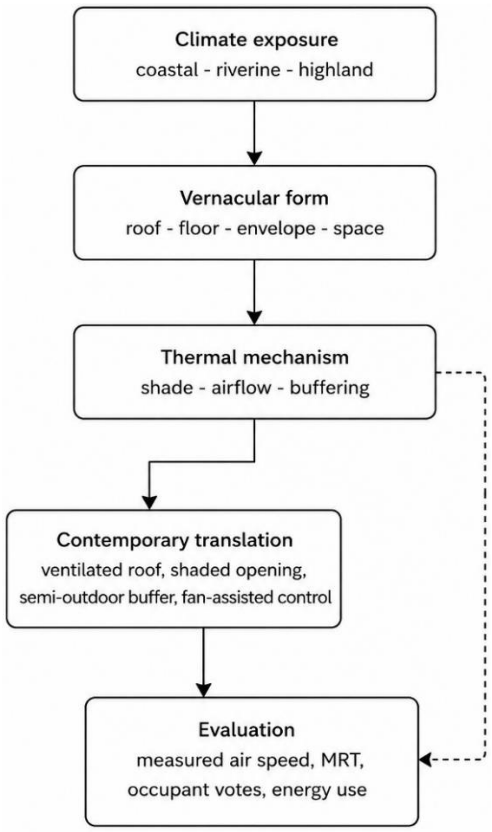


Figure 2. Performance-based translation framework from vernacular principles to contemporary low-energy housing (Source: Author's Document, 2026)

Figure 2 shows that vernacular knowledge should be translated through performance logic rather than reproduced through formal imitation. Climate exposure first determines which vernacular forms are thermally relevant, including roof volume, raised floors, porous envelopes, or shaded transitional spaces. These forms should then be interpreted as underlying thermal mechanisms, including shading, airflow enhancement, radiant buffering, and adaptive spatial use.

In contemporary housing, the mechanisms can be translated into design strategies including ventilated roof assemblies, shaded and secure openings, semi-outdoor buffer spaces, and fan-assisted mixed-mode operation. The final step is evaluation through measurable indicators, including air speed, mean radiant temperature, occupant feedback, and energy use.

Research Gaps

The most significant gap identified in this review is the lack of long-term, occupant-centred monitoring across Indonesian house typologies. Future research should combine environmental measurements with behavioural observation, including air temperature, relative humidity, mean radiant temperature, air velocity, occupant votes, clothing adaption, activity patterns, window operation, fan use, and room migration.

Comparative studies should examine original and modified houses to identify which changes degrade or improve performance. Simulations should be validated with field data, especially for porous envelopes and roof voids. Climate-change scenarios are also needed because historically adequate passive systems may not remain sufficient under more frequent heat extremes. Future research should also include indoor air-quality indicators, especially CO2 concentration, because contemporary low-energy housing increasingly combines passive ventilation, intermittent air-conditioning, and varying occupancy density (Latif et al., 2023).

Limitations And Recommendations

This review has three limitations. First, although Scopus records were used to define the recent evidence universe, but the final 43-source synthesis was narrative rather than systematic review approach. Consequently, this study does not claim exhaustive coverage of all Indonesian house traditions or all 178 recent Scopus records. Instead, its purpose is to clarify thermal mechanisms, distinguish evidence strength, and derive design implications from representative cases.

Second, the reviewed literature applies diverse methods and comfort indicators. Field surveys, environmental measurements, CFD simulations, ANN models, architectural descriptions, and policy documents cannot be treated as equivalent evidence. For that reason, this article interprets numerical data as contextual anchors rather than pooled effect sizes. Claims about design translation should therefore be tested again in specific locations and user groups.

Third, Indonesian regional evidence remains uneven. Case studies from Aceh, Java, Bali, South Sulawesi, South Kalimantan, West Sumatra, South Sumatra, and East Nusa Tenggara are more extensively represented than many other island and ethnic traditions. Future research should expand measured studies to eastern Indonesia, dense urban kampung environments, modified heritage houses, and low-income contemporary housing that incorporates vernacular elements.

Future studies should combine environmental monitoring with occupant surveys and design documentation. At minimum, studies should report air temperature, relative humidity, mean radiant temperature, air speed, clothing, activity, adaptive actions, and room-use patterns. Comparative work between original and modified houses is especially important because modernization may remove the ventilation and shading mechanisms that made vernacular systems climatically meaningful.

CONCLUSION

Indonesian vernacular houses provide valuable but heterogeneous thermal-comfort knowledge. Their value lies in the climatic logic of ventilation, shading, roof buffering, raised floors, semi-outdoor spaces, materials, and adaptive occupation. They should not be interpreted as automatically comfortable objects, but as environmental systems whose performance depends on climate, site exposure, material integrity, and occupant control.

The strongest evidence supports air movement, shaded porous envelopes, ventilated roof spaces, raised or ventilated floors, and spatial choice as key mechanisms in hot-humid naturally ventilated dwellings. At the same time, highland and savanna-related houses show that Indonesian passive design cannot be reduced to maximum openness. Thermal strategies must be matched to microclimate, daily rhythms, and seasonal variation.

For contemporary housing, vernacular principles should be translated into testable design strategies: ventilated and insulated roofs where needed, shaded secure openings, semi-outdoor thermal buffers, low-heat-gain materials, fan-assisted adaptive comfort, and mixed-mode cooling. For conservation, thermal mechanisms should be documented as part of heritage value, not treated as secondary to visual form. The review is limited by heterogeneous methods and uneven regional evidence, but it offers a framework for turning Indonesian vernacular knowledge into measurable, low-energy housing guidance.

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