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Title:
Climate-Resilient Housing Research in Australia: A Comprehensive Review

Date:
2025

Citation:
Ma, X., Yang, C., Fatourehchi, D. & Lu, D. (2025). Climate-Resilient Housing Research in Australia: A Comprehensive Review. Buildings, 15 (21), https://doi.org/10.3390/buildings15213885.

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Review

Climate-Resilient Housing Research in Australia: A Comprehensive Review

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Abstract

Australia's residential sector faces mounting climate adaptation challenges. Residential buildings contribute over 10% of national carbon emissions and are increasingly exposed to intensifying extreme weather events, including bushfires, floods, and heatwaves. While previous reviews have examined specific mitigation strategies or impacts of individual hazards, no synthesis has traced how climate-resilient housing research has evolved across multiple hazard types and design approaches in the Australian context. This study addresses this gap through a longitudinal analysis of 36 peer-reviewed articles (2009–2025) identified via Scopus and analyzed thematically. The findings reveal a significant paradigm shift: early research (2009–2018) focused predominantly on energy efficiency and carbon mitigation through passive design and building performance optimization, whereas the recent literature (2019–2025) emphasizes comprehensive adaptation frameworks integrating hazard-specific resilience strategies, technological innovations, and socio-political considerations. This synthesis identifies emerging priorities, informing future research agendas and evidence-based policymaking for climate adaptation in Australia's residential sector.

Keywords: climate-resilience; housing; Australia; review

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Academic Editor: Francesco Nocera

Received: 15 September 2025
Revised: 21 October 2025
Accepted: 24 October 2025
Published: 27 October 2025

Citation: Ma, X.; Yang, C.; Fatourehchi, D.; Lu, D. Climate-Resilient Housing Research in Australia: A Comprehensive Review. *Buildings* **2025**, *15*, 3885. https://doi.org/10.3390/buildings15213885

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1. Introduction

Australia is facing unprecedented climate pressures, with intensifying extreme weather events including record-breaking bushfires [1], severe flooding [2], prolonged droughts [3], and increasingly frequent heatwaves [4]. These climate risks have collectively underscored the vulnerability of the housing sector, which contributes over 10% of Australia's total carbon emissions [5] while serving as the first line of defense in protecting occupants from escalating environmental hazards [6]. This dual imperative of reducing emissions while enhancing resilience has reshaped housing research and practice over the past decade [7].

Climate-resilient housing refers to the design, construction, and operation of dwellings that both mitigate climate change and adapt to unavoidable climate impacts. In the Australian context, early research placed strong emphasis on reducing energy consumption, highlighting the housing sector as one of the significant contributors to climate change due to domestic appliances, lighting, and HVAC systems [7,8]. As such, a broad spectrum of solutions has since been investigated in the literature, ranging from energy efficiency and passive design strategies to more technological solutions of renewable energy storage systems and energy management platforms [8].

More recently, researchers have increasingly focused on occupants' health and well-being, examining factors such as indoor environment quality [9], occupant satisfaction [10], and inclusive design strategies that address diverse user needs [11]. Meanwhile, interventions promoting affordable housing supply have gained traction, progressively linking climate adaptation with human-centered outcomes [12,13].

There remains a lack of systematic synthesis that has traced the temporal evolution of climate-resilient housing research across comprehensive dimensions. This fragmented understanding limits the capacity of policymakers, practitioners, and researchers to identify emerging trends, assess the maturity of different research streams, or recognize critical knowledge gaps requiring future attention.

This review seeks to address this gap by conducting the comprehensive longitudinal analysis of Australian climate-resilient housing research from 2009 to 2025, mapping not only what strategies exist but how research focus has evolved across technological, social, and policy dimensions. Specifically, this study examines:

RQ (1): How have research priorities and conceptual approaches to climate-resilient housing evolved in Australia from 2009 to 2025?

RQ (2): What are the emerging research priorities in this field?

This study provides an evidence base to inform future research agendas, guide policy development, and support strategic investment decisions in Australia's residential climate resilience.

Theoretical Basis

This review is grounded in climate resilience theory, which conceptualizes responses to climate change through three interconnected dimensions: mitigation, adaptation, and transformation [14,15], as illustrated in Figure 1.

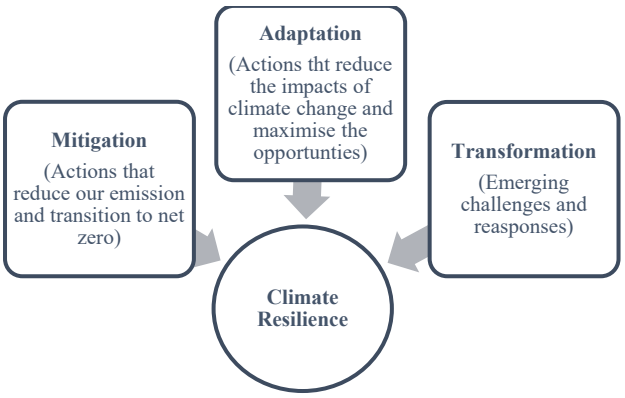


Figure 1. Climate resilience theoretical framework. Source: Adapted from [14,15].

Mitigation refers to strategies that reduce greenhouse gas emissions and limit the magnitude of climate change. Mitigation approaches focus on reducing the housing sector's contribution to climate change through technological and design interventions. In Australia, mitigation research has prominently featured passive design principles such as leveraging natural ventilation, thermal mass, and solar orientation etc.

Adaptation involves adjustments to natural or human systems in response to actual or expected climatic stimuli, aimed at moderating harm or exploiting beneficial opportunities [14,16]. For housing, adaptation strategies include designing for extreme weather events, improving thermal comfort during heatwaves, flood-resistant construction, and bushfire-resilient building materials and siting. In the Australian context, adaptation research has intensified following major climate disasters. For example, there was an

increase in studies examining bushfire-resistant construction materials since 2019/20 (e.g., ember-proof building envelopes) [17].

Transformation represents changes in the attributes of a system, often involving shifts in values, governance structures, and social-technical configurations [18]. Within the Australian housing research, transformation is evidenced by evolving conceptualizations of climate-resilient housing itself, which will be discussed in the following sections.

The climate resilience framework (Figure 1) is particularly relevant for Australian housing research synthesis. It provides an analytical structure for tracking research evolution over the decade studied, enabling the identification of temporal shifts from mitigation-focused to adaptation-oriented and potentially transformative approaches. In this way, the framework not only captures the trajectory of research over the past decade but also highlights opportunities for aligning housing strategies with broader societal transitions toward climate-resilient futures.

2. Methodology

2.1. Literature Search Strategy

A comprehensive literature search was conducted to explore the body of research related to climate-resilient housing in Australian cities from 2009 to 2025. The search was conducted in July 2025. Scopus was selected as the primary database for its comprehensive coverage of built environment and climate research journals, advanced search functionality allowing for complex Boolean queries and its established use in systematic reviews within housing and sustainability fields [19].

The search terms were aimed to capture papers addressing mitigation (e.g., energy efficiency, green buildings), adaptation (e.g., climate change), and transformation (e.g., design innovations) within the Australian housing context. Table 1 presents the reproducible search string executed in Scopus and their thematic rationale. The housing-related terms captured the residential building focus, while climate and resilience terms ensured relevance to climate challenges. Australian context terms maintained geographical specificity, and technological terms captured both incremental improvements and systemic innovations.

Table 1. Keyword search based on the thematic area.

Thematic Area	Keywords	Year	Rationale
Housing-related Terms	TITLE-ABS-KEY ((housing OR architecture OR 'resilient housing' OR 'sustainable housing' OR 'green building' OR 'energy-efficient housing' OR 'climate resilient' OR 'adaptive housing' OR 'resilient architecture') AND (climate OR 'climate change' OR 'climate resilience' OR 'climate adaptation' OR 'urban resilience' OR 'climate risk' OR 'disaster resilient housing') AND (Australia OR 'Australian cities' OR Sydney OR Melbourne OR Brisbane OR Perth OR Adelaide OR Canberra OR Hobart OR Darwin) AND ('sustainable design' OR 'building materials' OR 'green infrastructure' OR 'energy efficiency' OR 'carbon footprint' OR 'passive design'))	(PUBYEAR > 2009 AND PUBYEAR < 2026)	Captures residential building focus across multiple housing typologies
Climate Change & Resilience-related Terms			Ensures focus on climate-related challenges and resilience approaches
Australian Context			Maintains geographical specificity to Australian contexts
Technological & Design Innovations			Captures design strategy development for climate resilience

The trend in the number of papers found is illustrated in Figure 2. While there was a noticeable increase in publication volume up to 2022, a gradual decline has been observed in the most recent years. This recent decline likely reflects two factors: (1) COVID-19 impacts on research workflows and publication timeline. Publication and indexing lag, as research conducted in 2023–2024 may still be progressing through peer review and indexing processes; and (2) this search was conducted in July 2025, providing only partial coverage of 2025 publications. Therefore, the decline should be interpreted cautiously

as a methodological artifact rather than evidence of diminishing scholarly interest. The substantive upward trend from 2009 to 2022 demonstrates growing research attention to climate-resilient housing in Australia.

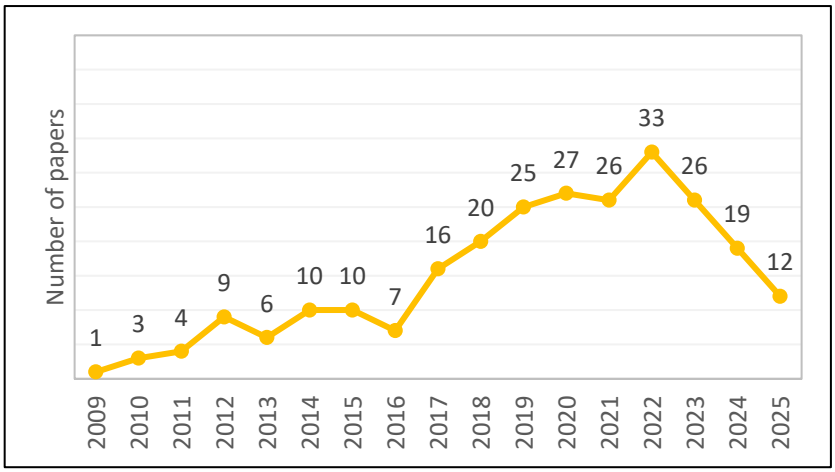


Figure 2. Number of papers published in Australian housing context. Source: Authors.

2.2. Screening and Eligibility Criteria

The initial search strategy retrieved 158 records, which then underwent a systematic two-stage screening process (Figure 3).

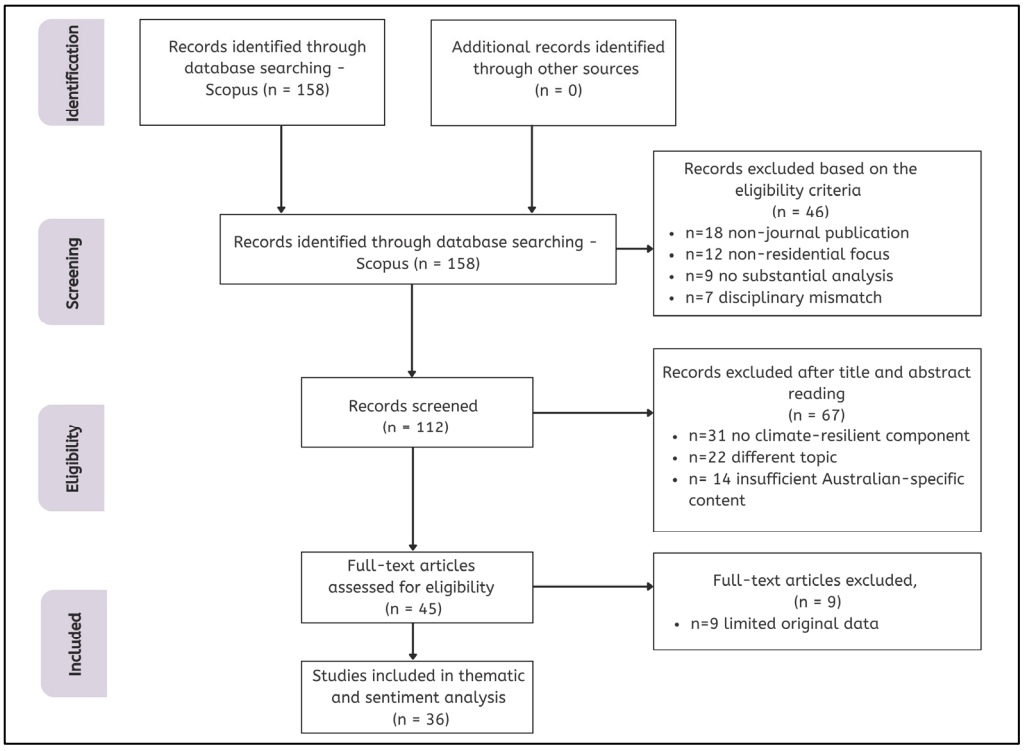


Figure 3. Paper Selection Process. Source: Authors.

The first stage involved screening titles, abstracts, and keywords of all retrieved articles against the inclusion criteria (Table 2). Articles were retained if they were peer-reviewed journal publications, written in English, published between 2009 and 2025, and focused on residential buildings within Australian contexts.

Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal articles	Non-journal formats (dissertations, conference proceedings, editorials, book chapters, correspondence, grey literature)
Original research (empirical or theoretical)	Non-original research (commentaries, brief notes without substantive analysis)
Australian residential building focus	Non-residential buildings or non-Australian contexts
Explicit climate resilience content	General sustainability without climate resilience focus
English language	Non-English publications
Published 2009–2025	Publications outside temporal scope
Substantive housing analysis	Housing discussed only tangentially

During this initial screening, studies were excluded if they were non-journal publications (conference papers, book chapters and editorials) (n = 18); non-residential focus (commercial, industrial or mixed-use buildings) (n = 12); Australia mentioned peripherally without substantial analysis (n = 9) and disciplinary mismatch (medical, biological, or nursing studies with minimal housing relevance) (n = 7). This preliminary screening reduced the corpus to 112 articles deemed potentially relevant for detailed examination.

The second stage involved a comprehensive full-text review of the remaining 112 articles. Articles were retained if they presented original empirical or theoretical research; directly addressed mitigation, adaptation or transformation approaches to climate changes in residential contexts and demonstrated engagement with climate resilience concepts. During stage two, 76 articles were excluded for the reasons including general sustainability focus without explicit climate resilience components (n = 31), housing discussed tangentially within broader urban planning contexts (n = 22), insufficient Australian-specific content (n = 14) and limited original data (n = 9).

This selection process ultimately identified 36 articles that met all inclusion criteria and provided insights into climate-resilient housing research evolution in Australia over the study period (Figure 3).

2.3. Thematic Analysis

The final corpus of 36 articles was imported into NVivo 15 software for qualitative analysis. The analysis employed a hybrid inductive-deductive approach combining theoretical framework application with emergent theme identification.

Articles were categorized according to the climate resilience framework's three dimensions using the following operational criteria,

Mitigation-focused studies: Research primarily addressing greenhouse gas emission reduction through housing design, construction, or operation. Indicators included focus on energy efficiency, renewable energy integration, carbon footprint reduction, low-carbon materials, or passive design for reduced HVAC demand.

Adaptation-focused studies: Research primarily addressing adjustments to housing in response to climate impacts. Indicators included focus on extreme weather resilience (flood, heatwave, drought), thermal comfort under changing conditions, hazard-resistant materials or construction, or climate-responsive design modifications.

Transformation-focused studies: Research addressing system changes in housing provision, governance, or conceptualization. Indicators included shifts in policymaking,

alternative housing models, integration of social equity considerations, or reconceptualization of climate-resilient housing definitions.

The coding process involved four iterative stages:

Initial familiarization (Round 1): All 36 articles were read in full, and preliminary memos documented initial patterns, recurring concepts, and potential themes. Framework-based coding (Round 2): Articles were coded deductively according to the three climate resilience dimensions using the criteria above. Each article was assigned to primary and, where applicable, secondary categories. Emergent thematic coding (Round 3): Within each dimension, inductive coding identified sub-themes. For example, within mitigation, sub-themes emerged including 'passive design strategies,' 'renewable energy systems,' and 'material innovations.' Within adaptation, sub-themes included 'bushfire resilience,' 'flood adaptation,' and 'heatwave response.' Temporal pattern analysis (Round 4): Coded themes were analyzed temporally to identify shifts in research priorities. This involved creating timeline visualizations showing when specific themes peaked across the 2009–2025 period. The temporal clusters, frequencies, timeframes and interconnections were visualized using VOSviewer 1.6.20 software.

3. Results

The thematic analysis of 36 peer-reviewed articles revealed how Australian climate-resilient housing research has evolved from 2009 to 2025. The findings are organized according to the climate resilience theoretical framework of mitigation, adaptation, and transformation, revealing distinct temporal patterns and shifting research priorities across the decade studied.

3.1. Mitigation: Technical Solutions for Emissions Reduction

Mitigation strategies dominated Australian housing research throughout the study period, reflecting the sector's focus on reducing operational carbon emissions [20]. However, the evolution of research reveals significant limitations in purely technical approaches and growing recognition of implementation challenges [21]. This section examines three primary technical mitigation strategies and critically evaluates their effectiveness.

3.1.1. Building Performance Rating System

The Nationwide House Energy Rating Scheme (NatHERS) represents Australia's primary regulatory mechanism for residential emissions reduction, using thermal simulation software (e.g., FirstRate5 v5.5.5 [3.22]) to rate homes from 0 to 10 stars based on predicted annual thermal energy demand, with 6 stars set as the national minimum [22,23]. Exemplar developments such as Lochiel Park near Adelaide demonstrate the technical feasibility of higher performance, achieving 7.5-star ratings through double glazing, enhanced insulation, solar photovoltaic systems, and water harvesting [24].

Despite these advances, research consistently reveals substantial gaps between predicted and actual performance that undermine the system's mitigation objectives. Beckett et al. [23] demonstrated significant discrepancies between NatHERS simulations and measured performance in rammed earth houses in Kalgoorlie-Boulder, where real-world thermal comfort substantially outperformed simulated predictions. Occupants reported comfortable conditions throughout Summer (outdoor maxima 45 °C) and Winter (minima 1 °C) with no artificial cooling and minimal heating, while BERS Pro simulations predicted poor Winter performance and high heating demands. This performance gap is particularly pronounced in tropical and arid climates, where NatHERS's static assumptions fail to capture adaptive occupant behaviors, natural ventilation patterns, or local environmental variations [23].

Evidence suggests that NatHERS functions more effectively as a comparative benchmark than an absolute predictor of environmental outcomes [25]. Buildings rated as low as 0.3 stars can achieve over 5-star performance through targeted interventions, yet modelling limitations persist [23]. The system's focus on thermal performance ignores renewable energy generation, smart controls, and behavioral interventions that significantly influence actual energy use which is a critical oversight in an era of distributed energy systems [26].

Policy reforms have sought to address these shortcomings [27]. NSW and Victoria established plans to raise minimum energy efficiency standards from 6 to 7 stars under the National Construction Code 2022 [28], with Queensland, South Australia, and Western Australia following suit in 2024–2025 [25]. These regulatory shifts reflect broader recognition that improved building performance is essential for emissions reduction.

Regulatory approaches show promise but suffer from implementation inequities and measurement inadequacies [21]. Volume builders can achieve cost-effective upgrades due to bulk purchasing power (material costs can be reduced by up to 62%), while smaller developers and affordable housing providers face prohibitive expenses [25]. The focus on operational performance neglects embodied energy impacts, which can equal 10–15 years of operational energy consumption. Furthermore, policy targets based solely on simulated ratings may misrepresent actual environmental outcomes, potentially undermining long-term mitigation objectives.

3.1.2. Passive Design Strategies

Early research (2009–2018) focused on conventional passive design techniques, including optimized building orientation, wall system insulation, window glazing, and shading strategies [29]. Studies demonstrated that proper window orientation, sealing, glazing, insulation, and shading significantly reduce artificial heating and cooling demands, supporting energy conservation targets [30]. However, recent research has expanded passive design beyond traditional building envelope interventions to encompass integration with home energy management systems [31], solar photovoltaic integration, battery storage, and electric vehicle charging capabilities [32]. This represents a shift from component-focused solutions toward integrated approaches. For example, the University of Western Australia's 'Future Farm' demonstrates this hybrid approach, but such exemplars remain isolated demonstrations rather than mainstream practice [33].

In addition, research reveals that passive design strategies optimized for current climate conditions may become less effective under future climate scenarios [7,21]. Analysis using global climate models indicates that heating and cooling energy demand could increase by up to 350% by 2100 under high emissions scenarios, with higher-rated homes paradoxically more vulnerable to percentage increases due to their low baseline consumption [7]. Table 3 summarizes their projected impacts on heating and cooling energy demand under Australian emissions scenarios and climate conditions.

Current passive design optimization is for historical rather than projected climate conditions [7]. The apparent advantage of homes may become a liability without adaptive features, suggesting that mitigation strategies must incorporate climate adaptation from the design phase [34]. The evolving evidence base therefore suggests that future-oriented housing research needs to advance beyond static notions of passive efficiency, toward dynamic, climate-adaptive design frameworks that anticipate and respond to Australia's projected climate conditions.

Table 3. Projected percentage changes in annual heating and cooling energy requirements for 5-star houses.

Scenario	Year	Component	Darwin	Hobart	Melbourne	Sydney
550 ppm Stabilization	2050	Heating	-	−20%	−30%	−66%
		Cooling	+39%	+79%	+69%	+93%
		Total	+39%	−19%	−16%	+61%
	2100	Heating	-	−30%	−44%	−83%
		Cooling	+61%	+153%	+123%	+161%
		Total	+61%	−27%	−21%	+112%
A1B (Medium)	2050	Heating	-	−25%	−36%	−74%
		Cooling	+48%	+104%	+90%	+120%
		Total	+48%	−23%	−19%	+81%
	2100	Heating	-	−42%	−60%	−94%
		Cooling	+90%	+275%	+208%	+193%
		Total	+90%	−37%	−22%	+193%
A1FI (High)	2050	Heating	-	−28%	−42%	−81%
		Cooling	+57%	+133%	+111%	+146%
		Total	+57%	−26%	−20%	+101%
	2100	Heating	-	−58%	−78%	−99%
		Cooling	+135%	+572%	+380%	+462%
		Total	+135%	−48%	−14%	+350%

Source: Adapted from Table 6 from Wang et al. [7]. Negative values indicate reductions; positive values indicate increases.

3.1.3. Renewable Energy Integration

Research has increasingly examined hybrid zero-carbon home models that integrate efficient building envelopes with renewable energy generation and smart appliances. Modelling studies demonstrate significant mitigation potential, with such homes capable of reducing emissions by up to 11 tonnes CO_2e/year compared to 9.5 tonnes CO_2e/year for 5-star homes [35].

Australian research demonstrates the evolution of home energy management systems from simple battery storage toward more complex systems capable of demand response, grid services, and renewable energy optimization [33]. Battery storage systems now provide benefits for demand management programs, with households achieving significant energy consumption reductions through smart integration with solar PV systems [32]. These systems increasingly participate in virtual power plants, enabling coordinated energy management across multiple households to balance grid supply and demand [36].

While hybrid systems show the greatest technical potential for emissions reduction, they remain expensive and complex to implement. The modelling results are promising but based on idealized conditions that may not reflect real-world performance variability. Furthermore, the focus on individual household solutions may neglect broader grid integration challenges and equity considerations, which were not mainstream concerns in early research.

3.1.4. Mitigation Challenges

Research consistently identifies occupant behavior as a critical but underestimated factor in technical mitigation strategies [34]. Paradoxically, green buildings sometimes consume more energy due to operational complexity and inefficiencies overlooked during certification processes [37]. The findings challenge the assumption that technical solutions alone can achieve mitigation objectives. The weak correlation between green ratings

and occupant behavior suggests that certification systems may create false confidence in environmental outcomes while neglecting the human factors that ultimately determine building performance [38].

Despite technical advances, consumer adoption of energy-saving techniques remains limited [24,38]. Low engagement stems from a lack of awareness, understanding, and incentives, representing a significant barrier to achieving energy efficiency at scale [6]. Although premiums exist for energy-efficient features, these have not translated into widespread consumer demand for sustainability certifications [6,38]. Poor communication between professionals and end-users compounds these challenges, resulting in market failure for green homes [39].

There can be seen a growing recognition that technical solutions alone cannot achieve the emissions reductions required for climate targets [21]. The effectiveness of mitigation strategies requires changes from viewing households as passive recipients of technology to recognizing them as active agents of climate resilience.

3.2. Adaptation: Responding to Climate Risks

The research trajectory reveals a critical transition from optimistic prevention-focused approaches to pragmatic adaptation strategies. Early research (2009–2018) pursued housing decarbonization as the primary climate response, exploring design approaches to reduce carbon emissions and stabilize atmospheric concentrations. Energy-saving strategies through proper insulation, cooling roofs, and passive design approaches dominated the discourse, with researchers generally assuming these conventional decarbonization approaches would be effective.

However, perceptions shifted dramatically as climate impacts intensified [40]. Rather than continuing to focus primarily on preventing climate risks through emission reductions, researchers began modelling actual housing risks caused by climate change and developing practical responses to adapt to unavoidable climate impacts [41]. This transition reflected growing recognition that significant climate change is already 'in the pipeline' regardless of future emission trajectories, necessitating immediate adaptation responses alongside continued mitigation efforts. This dual focus acknowledges that housing sector resilience requires adaptation strategies tailored to local contexts in order to protect residents and infrastructure from unavoidable climate risks.

3.2.1. Bushfire Adaptation

Research increasingly addressed bushfire risks to residential buildings, examining both building design modifications and landscape-level planning strategies. Studies investigated bushfire-resistant construction materials, defensible space requirements, and building placement strategies to reduce ignition risk from ember attacks and radiant heat exposure [1].

Bushfire smoke emerged as a dominant factor affecting indoor air quality, altering ventilation system design requirements [1]. Studies demonstrated that smoke events can significantly increase indoor PM2.5 levels, often exceeding safety standards even in sealed buildings [40]. Research emphasized the critical need for improved building envelopes combined with advanced ventilation systems incorporating high-efficiency particulate air (HEPA) filtration capabilities. Table 4 summarizes indoor air quality impacts during bushfire smoke events across different building types.

Table 4. Indoor PM2.5 concentrations during bushfire smoke events.

Building Type/Ventilation Strategy	Study Location	Peak Indoor PM2.5 During Smoke (μg/m^3)	Outdoor PM2.5 During Event (μg/m^3)	Indoor/Outdoor Ratio
Conventional leaky building	Melbourne 2019–20	<500	~600	~0.83
Airtight home + F7 filter	Melbourne 2019–20	320–380	~600	0.53–0.63
Airtight home + HEPA filter	Melbourne 2019–20	<25	~600	<0.04

Source: Adapted from [40]. Australian 24-h PM2.5 standard: 25 μg/m^3.

The findings revealed that in airtight homes, pollutant levels could increase over time during prolonged smoke events, necessitating proper ventilation systems with particle filtration rather than simple air sealing approaches. Rajagopalan & Goodman [40] highlights the impact of climate-specific hazards such as bushfire smoke, introducing a new layer of complexity to IAQ concerns. This shift underscores the evolving nature of IAQ research, where past methodologies that simply focused on ventilation and material quality were increasingly seen as inadequate in addressing the broader health risks associated with outdoor air pollution and changing climates. This limitation has driven an investigation into smart air quality management systems capable of real-time monitoring and automated response to particulate matter concentrations, representing a shift from passive to active indoor environmental control strategies.

3.2.2. Flood Adaptation

Research increasingly examined coastal community vulnerabilities, with studies calling for consideration of residential buildings located in coastal areas that could be damaged or disrupted by rising sea levels [41,42]. This research stream represented a shift from design optimization toward vulnerability assessment and managed retreat planning.

Studies addressed flood impacts on housing infrastructure, examining both structural modifications to reduce flood damage and recovery strategies to minimize long-term displacement [42]. Research explored elevated construction techniques, flood-resistant materials, and rapid-drying building systems that could minimize disruption from increased flooding frequency and intensity [43].

Flood-related research revealed critical gaps in post-disaster building performance, particularly regarding mold growth in compromised structures [44]. Studies found that 40% of homes with recent mold remediation experienced regrowth within a year [44], demonstrating the need for integrated moisture management systems rather than reactive treatment approaches [45,46]. This high recurrence rate suggests that current remediation approaches fail to address moisture intrusion pathways, necessitating more comprehensive building envelope repair strategies combined with improved humidity control approaches.

3.2.3. Extreme Heat Adaptation

Thermal comfort research shifted significantly toward adaptation challenges. Research into thermal comfort in Australian housing moved beyond static and one-size-fits-all standards to become more adaptive approaches [47]. Studies by Safarova et al. [48] were pivotal in challenging traditional assumptions about thermal comfort, especially in extreme climates. They emphasized the necessity of adapting thermal comfort models to regional contexts [49]. This shift was part of a broader trend in which thermal comfort was increasingly seen not just as a matter of technical specifications but also as an experience-driven model that takes into account occupant behaviors [49], comfort preferences [50] and environmental factors [4]. Studies have called for integration of adaptive thermal comfort models suitable for naturally ventilated buildings, particularly in tropical and

humid climates where conventional HVAC-based approaches may be energy-intensive or unreliable during grid stress periods [48].

Studies examining modular construction revealed specific vulnerabilities, with high satisfaction levels for overall building performance but persistent problems with 'thermal discomfort in summer' and external noise infiltration [51]. Further investigation into these thermal performance issues revealed that the problems stemmed primarily from inadequate insulation specifications and insufficient shading rather than inherent limitations of modular construction methods themselves [52]. Specifically, many modular homes were designed to minimum regulatory standards. Apart from methodological limitations, this suggests that attention has to be paid to the cost-cutting design choices, regulation gaps and budget constraints [51,52].

3.2.4. Adaptation Challenges

Despite growing research attention, significant gaps remain in understanding actual building performance under extreme climate conditions. Most studies rely on modelling or post-event assessments rather than real-time monitoring during climate events, limiting validation of proposed adaptation strategies.

Furthermore, recent research recognized that climate hazards rarely occur in isolation, requiring integrated adaptation strategies capable of addressing compound and cascading risks. Studies began examining scenarios where bushfire smoke events coincide with extreme heat, creating conflicts between air quality protection and thermal comfort.

Research evolved toward system-level approaches, recognizing that individual building modifications may be insufficient without broader infrastructure and community resilience [53]. Studies have increasingly examined how housing adaptation strategies interact with energy systems, water infrastructure, and emergency services capacity during concurrent climate stresses [54]. For instance, according to research, the water-energy nexus presented significant challenges, as climate-independent water solutions like desalination and recycling require substantially higher operational energy costs which created economic and environmental trade-offs [54].

The research consistently identifies that effective adaptation strategies remain expensive and complex, raising concerns about equitable access to climate-resilient housing for example, cool roofs [55]. Limited attention has been paid to how adaptation costs and benefits are distributed across different socioeconomic groups. The research trajectory suggests growing sophistication in understanding climate adaptation challenges, but significant work remains to translate findings into scalable, equitable adaptation strategies.

3.3. Transformation

Transformation represents the shifts in values, governance structures, and social-technical configurations that reshape housing production. Australian research increasingly recognizes that achieving climate resilience requires changes that go beyond technical improvements or adaptive modifications to address complex challenges. This section examines emerging transformative trends and the significant implementation challenges that limit their realization in practice.

3.3.1. Emerging Transformative Trends

The COVID-19 pandemic accelerated recognition of urban nature's critical role, shifting green infrastructure from amenity toward essential urban investment [56,57]. Research demonstrates that green open space quality including natural spaces, recreational facilities, sports areas, and pedestrian connectivity significantly influences social interaction in neighborhoods, with provision of diverse functional spaces for different age groups proving crucial [57].

Cities globally are implementing nature-based solutions (e.g., green roofs, wetlands, sustainable drainage systems) to improve climate resilience, air quality, and flood management while generating employment and reducing healthcare costs [23]. For effective delivery, these solutions must function as healthy ecosystems integrated within wider urban infrastructure as systemic 'seeds' rather than spatial 'add-ons.' [55].

Additionally, the economic affordability for retrofitting or development climate-resilient housing as well as the financial burden of energy bills for lower income families have been increasingly investigated [58,59]. During Sydney's 2017–2020 downturn, 80% of developers cited quality improvement as their survival strategy, but this market-driven approach proved temporary [59]. Housing development is market driven. Low-income households face acute vulnerability. Renters, lower-income residents, and those in disadvantaged areas reported substantially poorer thermal comfort and control capacity due to prohibitive retrofit costs and strata governance barriers. One tenant's energy bill increased from AU$140 to AU$260 quarterly during heatwaves, creating significant financial burden [58].

Households' demographic features and their behavior feature also affect the climate-resilience of housing. Machine learning analysis of 39 Australian households revealed family structure shapes adaptation capacity. Homes with 2–5 distinct energy patterns averaged 3.32 occupants and 0.81 students; homes with 6–9 patterns averaged 2.46 occupants and 0.29 students [60]. Larger families demonstrated reduced behavioral flexibility due to interlocking school schedules, work commitments, and childcare routines, limiting their adaptive capacity during extreme weather or energy supply variability [60].

Australian dwelling preferences emphasize indoor-outdoor connectivity and natural ventilation, often conflicting with sealed, isothermal design approaches [57]. Only 4% heated and 11% cooled whole houses in Adelaide, with most conditioning selected areas as needed [7]. Opening windows remains more common than air-conditioning for thermal control, with occupants prioritizing cross-ventilation and fans before mechanical cooling [10,49]. Low-energy Victorian housing residents engaged diverse adaptive activities maintaining comfort without air-conditioning [29]. However, only two of four households utilized high-level windows as designed, with others believing they would draw hot air inward, illustrating how intuitive understanding can override technical intentions [24].

Moreover, research demonstrates evolution from viewing houses as isolated objects toward understanding them as nodes within interconnected systems [54]. Individual building performance cannot address climate challenges without coordinated changes across energy, water, transport, and social infrastructure [55].

Australian lifecycle analysis revealed higher-rated buildings (8.7 versus 6.0 stars) reduced total energy by 36–53% but increased embodied energy proportions from 20 to 40% to 50–75%, illustrating how improvements in one dimension create challenges in another without whole-system coordination [61].

3.3.2. Transformation Challenges

The evolution from building-centric toward integration of social justice frameworks, recognition of nature-based solutions as essential infrastructure, and attention to cultural behavioral dimensions all indicate conceptual advances [60]. However, these advances face barriers related to scale, coordination, economic feasibility [62], social acceptance, and institutional change [39].

Individual research projects may demonstrate innovative approaches, but transformation requires coordinated changes across multiple sectors, governance levels, and stakeholder groups that exceed the scope of housing research alone [63]. Transformative approaches often require significant upfront investments and policy changes that challenge

existing economic interests. The existing research provides a limited analysis of how transformative housing strategies could achieve political and economic viability within market-based housing systems that prioritize short-term returns over long-term resilience.

Research identifies the importance of behavioral and social factors but struggles with the practical challenge of achieving behavioral change at scale [63]. Studies document the complexity and unpredictability of household energy use patterns while providing limited insight into how to effectively influence these patterns toward climate-resilient practices. The development of sophisticated algorithms and scenario-based models represents technical advances, but their transformative potential depends on social acceptance and behavioral changes that remain poorly understood and difficult to achieve. Transformation may require bottom-up community-led approaches rather than top-down technical solutions [24]. Research should examine how communities are already developing innovative responses to climate challenges and how these local innovations could be scaled and supported through policy and investment [23]. Future transformation research requires stronger integration with policy analysis and governance studies to develop actionable pathways for institutional change.

3.4. Thematic Network Analysis

In Figure 4, node size represents theme frequency, with larger nodes indicating themes appearing in more articles (e.g., "energy efficiency" appears in 28 articles, "thermal comfort" in 22 articles). Node colors represent publication time periods as identified through VOSviewer 1.6.20's temporal clustering. The analysis reveals that these temporal clusters align with thematic emphases: warm colors (reds/oranges) represent early-period themes (2009–2018), which are mitigation-related approaches. Cooler tones (blues/greys) represent mid-period themes (2018–2022), which are associated with adaptation strategies. Purple represents recent themes (2022–2025), which reflect emergent transformation themes.

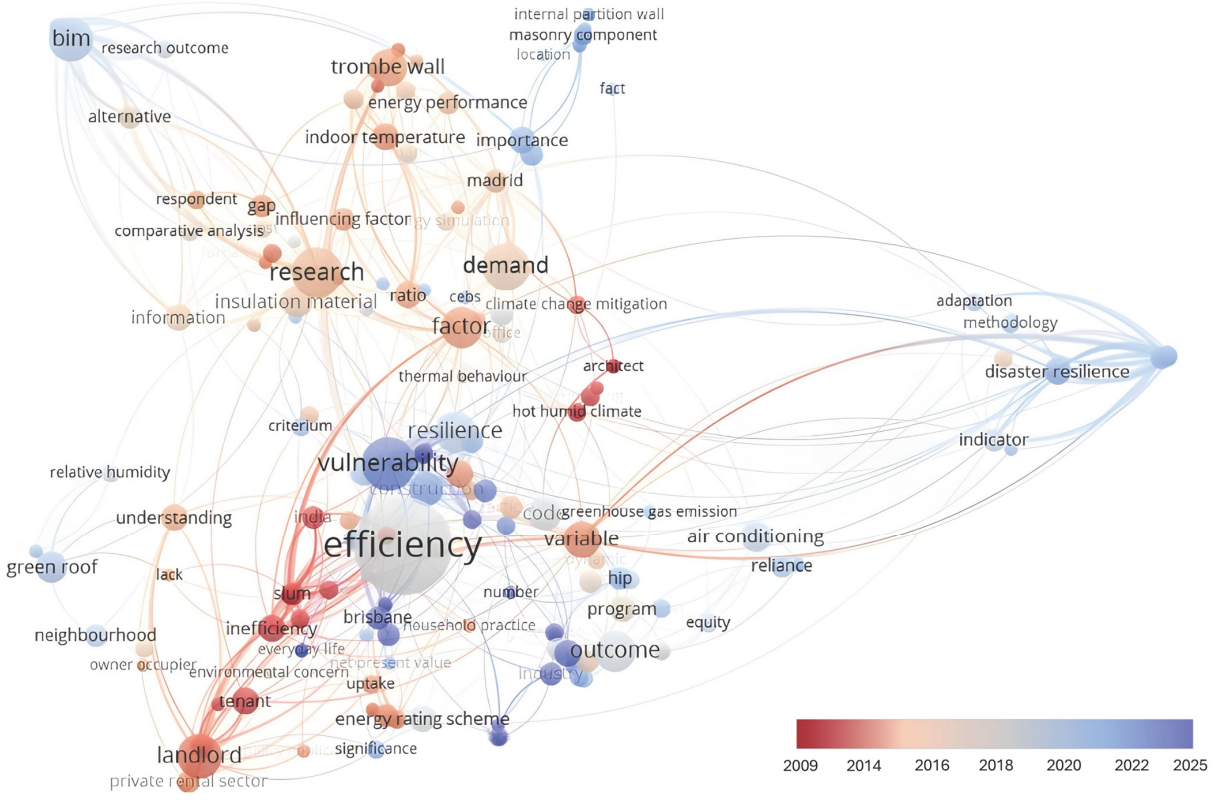


Figure 4. The association between all themes. Source: Authors. Visualized via VOSviewer 1.6.20.

Connecting lines represent co-occurrence relationships, with line thickness indicating association strength (i.e., how frequently two themes appear together within the same article). Spatial proximity indicates stronger thematic relationships; themes positioned closer together are more frequently discussed in conjunction.

The visualization reveals three key patterns: First, strong linkages between "energy efficiency" (mitigation) and "thermal comfort" (adaptation) indicate integrated approaches rather than siloed strategies. Second, transformation themes like "community resilience" and "social equity" occupy peripheral positions with weaker connections to technical themes, suggesting they remain under integrated in mainstream research. Third, "bushfire resilience" and "flood adaptation" form distinct clusters, indicating hazard-specific research silos with limited cross-fertilization, despite the need for compound hazard approaches. This network analysis reinforces findings that Australian housing research is transitioning toward integrated frameworks but still exhibits gaps in connecting technical solutions with transformative social and governance dimensions.

4. Discussion

This review examined the evolution of climate-resilient housing research in Australia from 2009 to 2025, revealing a paradigm shift from predominantly mitigation-focused technical approaches toward more comprehensive frameworks addressing adaptation and pushing for transformation (Figure 4).

The analysis demonstrates three distinct phases in Australian climate-resilient housing research since 2009. These phases were identified through systematic analysis of publication patterns, thematic clustering, and correspondence with major climate policy milestones and extreme weather events. The phase boundaries reflect observable shifts in research emphasis: Phase 1 (2009–2018) corresponds with Australia's Carbon Pricing Mechanism implementation and repeal, driving energy efficiency focus; Phase 2 (2018–2022) aligns with intensifying extreme weather events including the 2019–20 Black Summer bushfires and increased flooding; Phase 3 (2022–2025) coincides with the 2021 Glasgow Climate Pact and Australia's revised Nationally Determined Contributions, catalyzing transformative discourse.

Phase 1: Technical Mitigation (2009–2018)

Early research prioritized technical mitigation strategies, particularly energy efficiency improvements and passive design optimization. This focus reflected prevailing policy settings emphasizing emissions reduction through building performance standards. The dominance of mitigation themes during this period can be attributed to three institutional factors: (1) the introduction and subsequent abolition of carbon pricing created urgency around energy efficiency; (2) strengthening building codes (from 4-star to 6-star requirements) directed research toward compliance solutions; and (3) limited extreme weather experience focused attention on long-term climate prevention rather than immediate adaptation.

However, research during this phase revealed limitations in purely technical approaches. Studies documented significant discrepancies between simulated and actual performance, with occupant behavior accounting for up to 72% variation in energy consumption regardless of green building certification status [23]. This performance gap highlighted that design optimization and technical metrics alone were insufficient to deliver resilient housing outcomes.

Phase 2: Adaptation-Oriented Research (2018–2022)

The research landscape shifted decisively toward adaptation between 2018 and 2022, driven by escalating climate impacts. This transition was catalyzed by specific events: the 2019–20 Black Summer bushfires exposed housing vulnerabilities to extreme heat and smoke infiltration; intensifying flood events in Queensland and New South Wales

demonstrated inadequate adaptation measures; and consecutive heat waves revealed dangerous indoor conditions in ostensibly energy-efficient homes.

Institutionally, this phase coincided with the establishment of the National Bushfire Recovery Agency [64], and updates to Australian Standard AS3959 [65] for bushfire construction. Research priorities reframed from preventing climate change through reduced emissions to addressing lived vulnerabilities facing extreme events.

Adaptation scholarship during this phase demonstrated growing sophistication in understanding climate hazards. However, significant methodological limitations emerged: most studies relied on modeling rather than empirical monitoring during actual climate events, limiting confidence in proposed strategies. Integration challenges persisted, with approaches optimized for single hazards potentially compromising performance for others (e.g., bushfire-resistant construction increasing thermal mass that exacerbated heat stress). These trade-offs reveal limitations in regulatory frameworks and strategies that address hazards through separate codes and standards, suggesting that current regulatory framework is inadequate for multi-hazard climate adaptation.

Phase 3: Transformative Approaches (2022–2025)

The most recent scholarship has explored transformative socio-technical change, recognizing that neither mitigation nor adaptation alone can deliver climate-resilient housing at the required scale and equity. This phase reflects international scholarly discourse around transformation (e.g., IPCC AR6) and domestic recognition that Australia's housing system requires restructuring rather than incremental improvement.

Research increasingly examines implementation barriers related to coordination failures across governance levels, economic feasibility within Australia's housing affordability crisis, institutional path dependencies favoring conventional construction, and social equity concerns about adaptation accessibility. However, transformation research remains largely conceptual while scholars increasingly recognize the need for changes in governance structures, values, and socio-technical configurations, the pathway from transformative concepts to widespread practice remains underdeveloped.

5. Conclusions

This study reveals that Australian climate-resilient housing research has undergone a paradigm shift, evolving through three phases that progressively recognize the constraints of single-dimensional approaches. The research evolution from a narrow technical orientation toward broader recognition of adaptation and transformation. It documented in this review suggests that effective climate-resilient housing requires approaches that integrate technical performance with social, economic, and behavioral considerations.

Three key findings emerge across the three phases. First policy frameworks based solely on technical rating systems may misrepresent actual environmental outcomes, as performance gaps persist regardless of design optimization. Second, adaptation strategies that ignore equity considerations risk creating climate-resilient housing accessible only to affluent populations. Third, while transformative discourse has emerged, the pathway from concept to practice remains underdeveloped due to methodological challenges and institutional barriers.

Addressing these gaps requires research approaches that combine technical innovation with social, economic, and institutional analysis to develop climate-resilient housing strategies that are both effective and equitable. Future research priorities should include developing more accurate performance assessment tools that account for occupant behavior and local climate variations. Research should also establish evidence-based guidelines for integrated adaptation strategies and examine community-scale resilience approaches that address both technical and social dimensions of climate adaptation. Greater attention is

needed to governance reforms, financial mechanisms, and institutional innovations that can enable equitable scaling of resilient housing.

Author Contributions: Conceptualization, X.M., C.Y. and D.L.; methodology, X.M. and D.F.; software, C.Y. and D.F.; validation, X.M., D.F. and C.Y.; formal analysis, X.M. and C.Y.; investigation, X.M.; writing—original draft preparation, X.M., C.Y. and D.F.; writing—review and editing, D.L.; visualization, D.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.

Conflicts of Interest: The authors declare no conflicts of interest.

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