Scalable Retrofit Pathways for Government Housing Portfolios

Draft for Review

Background and Evidence Report

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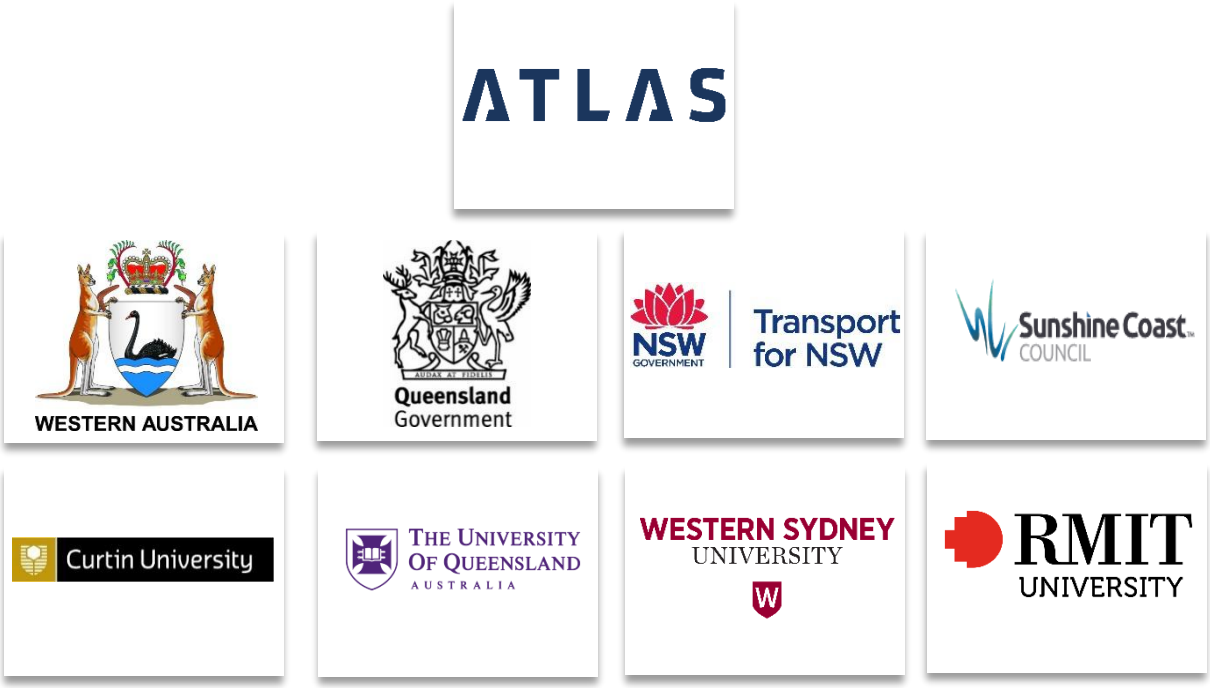
Research Project: SBEnrc 1.11.3 - Scalable Retrofit Pathways for Government Housing Portfolios

Date: November 2026

Acknowledgements:

This research has been developed by Australia's Sustainable Built Environment National Research Centre (SBEnrc). The SBEnrc develops projects informed by industry partner needs, secures national funding, project manages the collaborative research and oversees research into practice initiatives. Current core Members of the SBEnrc include ATLAS, Government of Western Australia, Queensland Government, Transport for NSW, Sunshine Coast Council, Curtin University, The University of Queensland, Western Sydney University and RMIT University. The industry-driven research outlined in this publication would not have been possible without the valuable support of our core industry, government and research partners.



Project Partners: This research was supported by



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Citation: Authors (year). Report Title, Project 1.11.3 – Scalable Retrofit Pathways for Government Housing Portfolios, Sustainable Built Environment National Research Centre (SBEnrc), Australia. (Link title to project webpage)

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Executive Summary

Project and report purpose

Australia had approximately **452,000 social housing dwellings** in June 2025. Across the residential sector, homes account for about **24% of Australia's electricity use and more than 10% of national carbon emissions**. Improving existing homes can reduce emissions and energy costs while improving thermal comfort and wellbeing for tenants who struggle to afford adequate heating or cooling.

SBEnrc Project 1.11.3 investigates how government housing providers can prioritise and deliver energy retrofits at scale across social and staff housing portfolios. This report gives partners and researchers a shared evidence base, informs the project's modelling and prioritisation methods, and proposes cases for further analysis. It draws on policy and research, housing stock analysis, and partner input from pre-project industry workshops, Project Steering Group meetings and dedicated discussions with partners.

Policy and delivery context

Australia needs to upgrade existing homes faster to meet its decarbonisation commitments. Australia has committed to cut emissions by **62–70% below 2005 levels by 2035** and **legislated net zero by 2050**. State and organisational commitments reinforce that direction. The National Construction Code sets energy efficiency requirements for new homes and certain alterations. It leaves most existing homes without a requirement to upgrade. The national energy-rating disclosure framework gives jurisdictions a common approach, however, Queensland, NSW and Western Australia have yet to make disclosure mandatory.

Current funding falls short of what is needed to retrofit social housing at portfolio scale. The $1.1 billion Social Housing Energy Performance Initiative (SHEPI) is expected to reach more than **100,000 properties by mid-2031**. Outside dedicated programs, partners report that upgrades compete with essential repairs for already stretched maintenance budgets. Like-for-like replacement can lock in poor performance for another equipment cycle. Providers also face the upfront cost of upgrades while tenants receive much of the benefit through lower bills and improved comfort. Those benefits need to count in investment decisions.

Research findings and implications

Building-level studies provide established methods for testing measures such as insulation, draught sealing and efficient heating and cooling. At portfolio scale, **RACE for 2030's Energy Upgrades for Australian Homes** project profiled **11.3 million homes** and modelled upgrade costs, energy savings and emissions reductions by dwelling type and location. Australian monitoring also shows why energy savings alone are an incomplete measure. Low energy use can reflect tenants going without adequate heating.

AHURI found that upgrades tenants value can differ from those typically funded or ranked highest on technical grounds. **SBEnrc Project 1.10.3** adds evidence from Yarrabah on how climate-responsive design, maintenance and energy infrastructure shape housing adequacy and resilience. Across the research reviewed, evidence is stronger on retrofit barriers than on successful delivery at scale. Project 1.11.3 will combine established modelling methods with portfolio managers' knowledge of

their stock and delivery constraints. It will explore approaches such as multi-criteria decision analysis to weigh comfort, affordability, emissions, whole-of-life costs and feasibility.

Portfolio findings, proposed case studies and next steps

Across NSW, Queensland and Western Australia, about **42% of social housing dwellings are detached**, compared with **69% of employer-provided dwellings** in the dataset. Social housing is concentrated in capital cities, while employer-provided housing is more concentrated outside them. Climate Zones 5 and 6 together account for about **two-thirds of attached dwellings and low-rise apartments** in the combined stock analysed. These patterns support testing both detached and multi-unit dwellings across relevant climates. Dwelling counts indicate how widely a case may apply, while partner input helps identify tenant needs and practical priorities that the counts cannot capture.

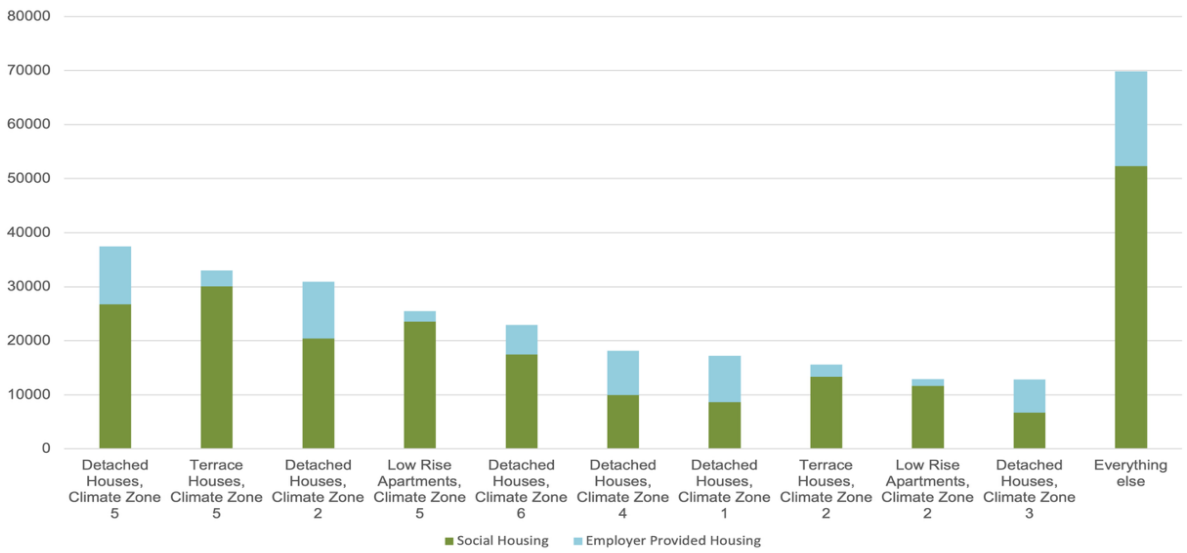

Figure 1 - Dwellings / NCC Climate Zones

Priority case study dwelling types and climate zones include the following four. Together, they cover a substantial portion of partners' portfolios. Specific building form to be confirmed for each.

Case study	Construction and dwelling type	Climate zones
Queensland	Brick veneer, Three-bedroom detached house	2, 5
Western Australia	Double brick, Detached house.	1, 5
New South Wales	Masonry, Two-bedroom apartment	5
Defence Housing Australia	Lightweight Cladding, Detached house	2 (TBC)

The Project Steering Group is invited to consider whether these cases reflect their portfolios and priority areas. The research team will use this feedback and confirm asset data availability before finalising the cases for retrofit modelling and testing the prioritisation approach.

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Section 1 - Project Context and Strategic Rationale

This Project builds on prior SBEnrc research on climate-resilient communities and social housing delivery to generate actionable evidence for decarbonising housing and improving outcomes for tenants. It identifies and prioritises feasible, high-impact retrofit strategies to support decarbonisation across large social and staff housing portfolios in Queensland, New South Wales and Western Australia. Using cross-state portfolio analysis, modelling of representative building types and a structured feasibility assessment, it generates clear evidence on which retrofit measures provide the strongest balance of carbon reduction, lifecycle cost savings, and practical deliverability. The outcomes aim to strengthen decision-making frameworks for portfolio managers, support cost-of-living improvements for tenants, and provide evidence aligned with partners' progress toward 2035 and 2050 decarbonisation housing commitments.

In Australia, Government agencies and Community Housing providers collectively manage more than 400,000 social and staff housing dwellings. Most of these dwellings will be occupied when 2035 and 2050 decarbonisation commitments are due. These portfolios represent a large share of public-sector emissions and ongoing energy-cost exposure for tenants. Despite strong policy commitments to decarbonisation, there is limited evidence on which retrofit strategies deliver the greatest carbon reduction and cost benefit per dollar invested, and how these can be deployed at scale within existing procurement and maintenance systems.

Project partners emphasised the need for practical, evidence-based guidance that links technical options with decision points, awareness of policy settings, financial constraints, and feasibility of different interventions. Partners also highlighted challenges around data availability, maintenance responsibilities, and long-term system reliability – issues that require systematic evaluation before large-scale roll-out. This project responds directly to those needs by creating comparable cross-state evidence and prioritisation methods that agencies can trust and apply.

This project helps governments and Community Housing providers improve wellbeing and cut carbon and energy costs across Australia's large social and staff housing portfolios. In analysing real housing typologies and testing practical retrofit options, it reveals the measures which have potential to offer the most impact and value. This supports smarter investment decisions and meaningful progress toward Australia's 2035 and 2050 decarbonisation targets - all of which benefits tenants, agencies and the wider community.

The report draws on published research, housing portfolio data and input from all project partners through pre-project industry research development workshops and the first two Project Steering Group meetings, supplemented by more detailed discussions with individual partners.

Australian Social Housing Context

Social housing in Australia is affordable rental housing for eligible people living on low incomes or with housing needs. It includes public housing, which is owned and managed by government, and community housing, which is provided by government or non-government (including not-for-profit) organisations. Australia's social housing sector is under sustained pressure from high demand, inadequate supply, and underinvestment, with low-income households increasingly dependent on it as the main source of secure and affordable housing. Over time, Australian social housing policy has shifted away from a traditional government-led model toward a more diversified, market- and not-

for-profit-based system, including community housing, private finance, stock transfers, and partnership delivery. This policy environment has also been shaped by “residualisation”, tighter targeting to the highest-need households, and reduced public investment, which together have made the sector more difficult to manage and expand.

Scale, Composition, and Distribution of Housing Portfolio

Australia's social housing sector represents a substantial publicly supported residential asset base, comprising properties managed by state and territory housing authorities, community housing providers and Indigenous housing organisations. Australian Government agencies and Community Housing providers collectively manage more than 400,000 social and staff housing dwellings. According to the Australian Institute of Health and Welfare (AIHW), Australia had approximately 452,000 social housing dwellings as of 30 June 2025, accommodating approximately 799,000 residents. Public housing accounted for approximately two-thirds of the national social housing program, with community housing representing the second-largest component. Most of these dwellings will be occupied when 2035 and 2050 decarbonisation commitments are dure, but there is limited evidence on which retrofit strategies are viable at scale and deliver the greatest carbon reduction and cost benefit. These portfolios represent a large share of public-sector emissions and ongoing energy-cost exposure for tenants, and drivers of health and wellbeing. There is a need for practical, evidence-based guidance that links technical options with decision points and policy settings.

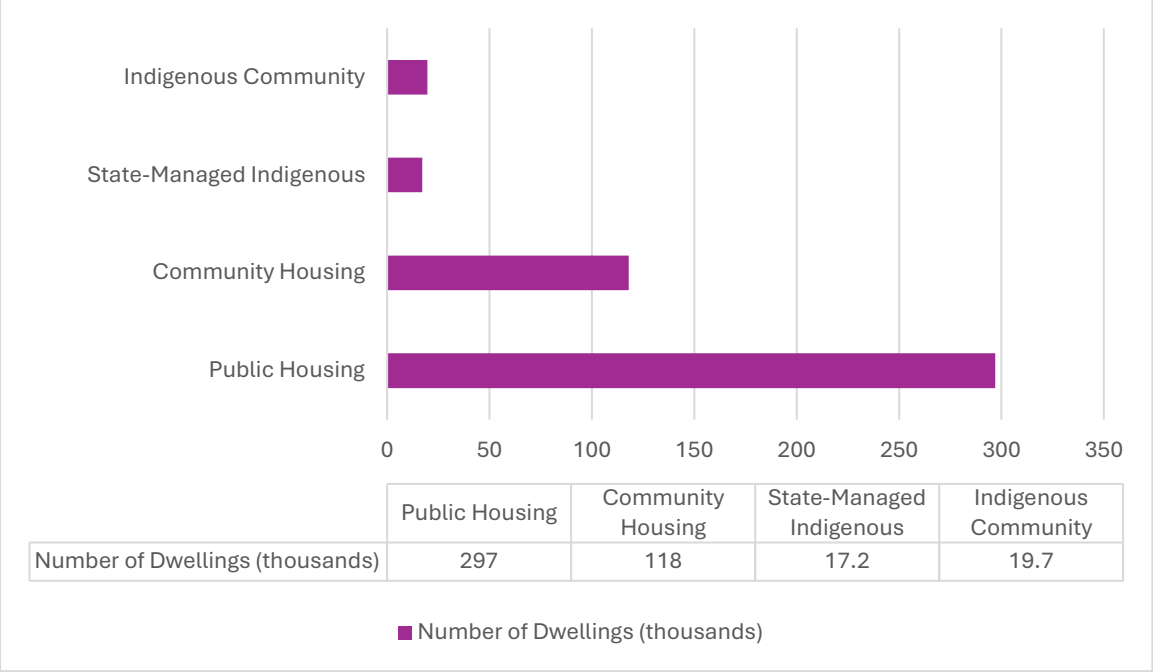


Figure 2 - Social Housing Dwellings by Program, June 2025

The composition of Australia's social housing sector has changed considerably over time, partly reflecting the transfers of housing management between public authorities and community housing providers, rather than simply the construction or demolition of dwellings. In the two decades between 2006 and 2025, public housing stock declined from approximately 341,000 to 297,000

dwellings, while community housing increased from approximately 30,100 to 118,000 dwellings. They distributed across four main categories (see Figure 2):

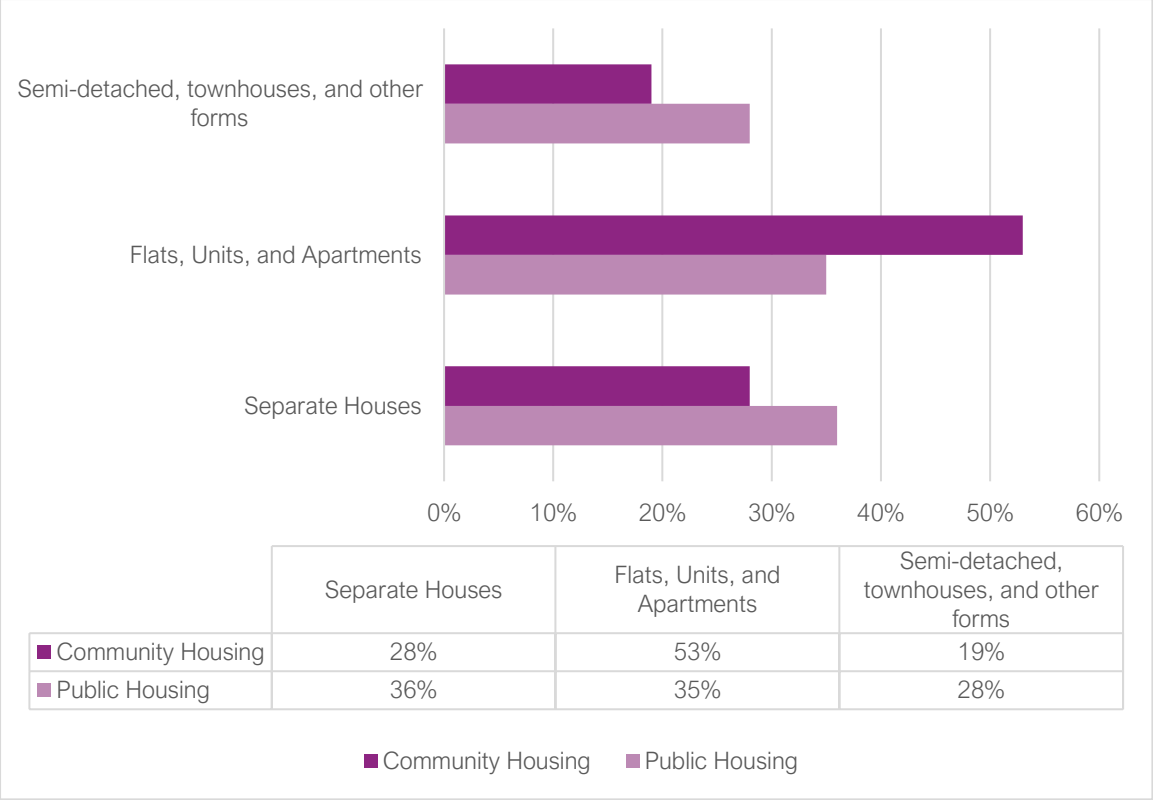
- Public housing: Rental housing owned and managed by state and territory housing authorities for eligible households, accounting for approximately 297,000 dwellings, or two-thirds of the sector.
- Community housing: Rental housing managed by community organisations, generally not-for-profit providers, for eligible households, accounting for approximately 118,000 dwellings.
- State-managed Indigenous housing: Housing owned and managed by state and territory governments specifically for Aboriginal and Torres Strait Islander households, comprised of approximately 17,200 dwellings.
- Indigenous community housing: Housing owned or managed by Indigenous community organisations for Aboriginal and Torres Strait Islander households, comprised of approximately 19,700 dwellings.

Geographic distribution is a significant factor, as the varying geographic differences place a demand for distinct retrofit requirements, particularly in relation to climatic exposure, access to skilled trades, material supply chains and maintenance logistics. For instance, approximately 76% of public housing dwellings and 65% of community housing dwellings were in major cities in mid-year 2025. In contrast, Indigenous-specific housing programs had substantially greater representation in regional and remote areas.

These factor highlight of significant implications for retrofit delivery, since portfolio ownership, asset management responsibilities, funding arrangements and operational capacity vary across providers. As a result, implementation of retrofit standards across the sector in a consistent manner requires approaches that can accommodate differences in organisational scale, asset management systems and investment priorities.

Housing Typologies, Construction Characteristics, and Building Performance

The Australian government and social housing portfolios are a diverse mix of detached houses, semi-detached and attached dwellings, townhouses, flats and apartments. The distribution demonstrates why a one-size-fits-all retrofit solution is unlikely to be technically or operationally appropriate across the entire sector.



	Separate Houses	Flats, Units, and Apartments	Semi-detached, townhouses, and other forms
Community Housing	28%	53%	19%
Public Housing	36%	35%	28%

Figure 3 - National Proportions of Housing Typology
Source: AIHW Dwelling Attributes, 2025

Detached houses tend to be more flexible for roof mounted solar, external envelope treatments and individual heating and cooling systems. By comparison, multi-unit developments may present more complex requirements involving shared services, common-property arrangements, restricted access to building façades and limited individual roof area.

The building's age and its architectural attributes induce further variation. Many of the houses that constitute Australia's current housing stock were constructed before modern residential energy efficiency requirements were introduced. The Australian Government recognises that many millions of older homes have relatively poor energy performance, contributing to avoidable energy use and reduced thermal comfort.

Performance problems are repeatedly associated with poor thermal comfort, temperature swings, vertical stratification, overheating, and low-quality construction. In Sydney and other Australian cities, social housing has been linked to low indoor comfort and poor environmental performance, especially under hotter conditions. Older housing stock is also described as increasingly exposed to aging-related deterioration, energy inefficiency, and climate and hazard vulnerability, with one study reporting that 70% of Australian houses show building-quality-related problems and many sit at NatHERS 3-star or lower.

Housing Condition, Asset Management, and Investment Pressures

The sector is hindered by scarce resources, insufficient investment, and outdated inventory, preventing numerous providers from tackling substandard housing conditions comprehensively. An

immediate challenge of asset management is presented. Many dwellings are described as rundown, not fit for purpose or needing renewal. Social housing providers are under competing pressures to sustain tenancies, maintain service continuity and improve building performance. Mobilising capital is difficult, which increases investment pressures. Financing gaps, low private institutional investment, risk perceptions and fragmented governance are the main constraints to portfolio expansion or improvement. Concurrently, social housing serves a crucial strategic function in retrofitting as it can be managed on a large scale by a singular owner; however, the actual delivery of retrofits is hindered by challenges such as insufficient heating, resident needs, and the complexities involved in implementation.

Tenant Characteristics, Housing Adequacy and Wellbeing

The quality and performance of social housing have particular implications for tenants, many of whom experience heightened vulnerability to poor indoor environmental conditions. National data indicate that 66% of social housing main tenants were aged 50 or older in 2025, while 39% of households included a person with disability [1]. Australian research has documented prolonged exposure to unhealthy indoor temperatures, with households frequently limiting heating and cooling to manage energy costs [2], [3]. Recent SBEnrc research in Yarrabah, Far North Queensland, similarly identified how inadequate climate-responsive design, maintenance and energy infrastructure can undermine housing adequacy and household resilience [4]. Research also demonstrates that tenants' priorities for housing improvements can differ from technically optimal retrofit measures [5]. Staff housing tenants have different needs and typical characteristics, necessitating different prioritisation. Collectively, these findings support considering thermal comfort, affordability, health and liveability alongside energy, carbon and financial outcomes when evaluating retrofit opportunities. They also highlight the importance of using appropriate occupancy and heating/cooling assumptions in energy modelling and recognising tenant needs in retrofit prioritisation.

Climate and Decarbonisation Commitments: National, State and Organisational

Australia's residential building sector is increasingly influenced by the national and state climate commitments and policies aiming to improve the performance of the existing buildings. Australia has legislated emissions reduction targets of 43% below 2005 levels by 2030 and net zero by 2050, alongside a commitment to reduce emissions by 62–70% by 2035 under the Paris Agreement [6]. Residential buildings account for approximately 24% of Australia's electricity consumption and more than 10% of national carbon emissions [7].

These national commitments are reinforced by state and organisational decarbonisation targets. Queensland has legislated a 75% emissions reduction by 2035 and net zero by 2050 [8], while NSW has legislated reductions of 70% by 2035 and net zero by 2050 [9]. Western Australia has committed to net zero by 2050, alongside an 80% reduction in state government operational emissions by 2030 [10]. At the organisational level, Defence Housing Australia (DHA) has voluntarily adopted the Australian Public Service's net zero government operations target for 2030, complementing Defence's broader Net Zero Strategy for 2050 [10]. These commitments provide further impetus for government housing agencies to improve the energy performance of their portfolios.

Housing Regulation, Assessment and Implementation Context

Regulation and standards

The National Construction Code (NCC) establishes minimum energy efficiency requirements for new buildings and certain alterations, but does not mandate upgrades across the existing housing stock. The Trajectory for Low Energy Buildings Implementation Plan 2026–27 commits to examining how NatHERS and the Disclosure Framework can enhance social housing performance including minimum standards for rental properties.

Energy assessment and disclosure

The Home Energy Ratings Disclosure Framework (2024) establishes a consistent approach to measuring and disclosing the energy performance of residential properties. This is supported through The Residential Energy Efficiency Disclosure Initiative (REEDI) supports its implementation, including considering how disclosure relates to social housing. Implementation varies by jurisdiction: The ACT has mandatory energy-rating disclosure requirements, but NSW, Queensland and Western Australia do not.

In July 2026, the national energy rating framework (NatHERS) was expanded to existing homes, providing better assessment tools, accredited assessors and tailored energy guidance. Together, these initiatives increase the consistency of assessing housing performance.

Investment and implementation

The Social Housing Energy Performance Initiative (SHEPI) is a federal-state investment scheme to improve energy efficiency in over 100,000 social housing units by mid-2031. Upgrades include insulation, electrification, efficient heating and cooling systems and solar energy.

Outside targeted programs such as SHEPI, housing upgrades often compete for funding within already constrained maintenance and asset renewal budgets, rather than benefiting from dedicated, long-term retrofit investment [5] [11]. Investment decisions frequently prioritise upfront costs without adequately accounting for whole-of-life maintenance and energy costs, or the wider benefits of improved housing quality for tenant health, wellbeing and climate resilience [4].

Policy Alignment and Implementation Challenges

Despite increasingly ambitious climate commitments and investment in housing energy efficiency, research identifies significant misalignments between policy objectives, regulatory requirements, funding arrangements and implementation [12]. Three challenges are particularly relevant:

1. **Regulatory misalignment:** Existing building standards and energy efficiency requirements do not establish a comprehensive pathway for upgrading Australia's existing housing stock to meet national decarbonisation commitments.
2. **Investment misalignment:** Government retrofit programs contribute to emissions reduction but are not demonstrably calibrated to the scale and timing of the 2035 and 2050 targets. Funding and investment decisions also frequently overlook whole-of-life costs and benefits, including energy affordability, health and wellbeing.

3. **Policy and implementation fragmentation:** National, state and local government policies, funding programs and delivery arrangements are not always coordinated, creating inconsistent requirements, competing priorities and implementation barriers.

Section 2 - Contemporary Research on Social Housing Retrofit

Existing research provides an extensive evidence base for evaluating housing retrofit interventions, assessing opportunities across building stocks, and supporting investment decisions. This section briefly reviews relevant Australian and international research, progressing from building-level assessment to portfolio-scale modelling, retrofit prioritisation, and the practical challenges of implementation at scale. The review also responds to priorities identified through partner engagement, particularly the need to translate established research into practical approaches for government housing portfolios.

Building-Level Retrofit Interventions and Performance

Building-level retrofit research draws on an extensive body of architectural science, including building energy simulation, empirical monitoring and evaluation of thermal, energy and environmental performance. Australian social housing studies provide important empirical evidence, with monitoring of dwellings in NSW and South Australia identifying prolonged periods of underheating and constraints on heating affordability [2] [13]. Importantly, low measured energy consumption may reflect constrained heating and cooling rather than adequate thermal performance, highlighting the need to consider unmet thermal needs alongside energy savings [14].

Research most often evaluates envelope upgrades such as insulation, windows/glazing, airtightness, roofs, and shading, alongside HVAC and service upgrades such as heat pumps, ventilation, lighting, appliances, and cooling systems [15-23]. Several studies [24-29] also examine integrated packages rather than single measures, because combined solutions can deliver greater energy and comfort performance, although cost-effectiveness varies. A recurring finding is that envelope measures are an effective starting point for reducing demand, but the “best” option depends on climate, building type, occupant behaviour, and cost constraints. Recent Australian research also highlights the importance of assessing retrofit interventions against future climate conditions and potential trade-offs between resilience objectives [30].

Housing Stock Assessment and Portfolio-Scale Modelling

Housing stock assessment extends building-level research to larger portfolios by characterising dwellings according to attributes such as building typology, construction age, materials, location and climate. Representative dwelling models and building archetypes can then be used to estimate retrofit opportunities and potential performance improvements across diverse housing stocks. In the Australian social-housing context, this matters because retrofit decisions are being made for a large, aging, and constrained stock where implementation barriers and asset-management pressure are already high. [31-36]

Housing retrofit research increasingly focuses on stock-level and district-level methods alongside individual-building studies, because large-scale rollout requires faster screening and representative archetypes. Australian research provides established examples of modelling retrofit opportunities at scale. The RACE for 2030 Energy Upgrades for Australian Homes project includes a CSIRO-led national Building Stock Model that has characterised approximately 11.3 million Australian homes. The model combines building typology and location data with estimates of upgrade costs, energy savings and emissions reductions, enabling assessment of retrofit opportunities at local, regional and national scales [37].

Several studies argue that scalability research can be supported by archetype-based modelling, surrogate models, machine learning, and hybrid simulation/optimization workflows, which can reduce computational demands but require appropriate validation to ensure reliability. The reliability of stock-level assessments depends on the availability and quality of building data, the representativeness of selected archetypes and the assumptions used in modelling. Australian research identifies significant gaps and inconsistencies in national housing condition and performance datasets, limiting their suitability for comprehensive stock assessment [38].

Retrofit Prioritisation and Decision-Support Methods

Retrofit prioritisation involves several related decisions: identifying dwellings most in need of improvement, selecting effective retrofit interventions, and allocating limited investment across housing portfolios. Research draws on approaches including building condition assessment, financial and lifecycle analysis, optimisation and stakeholder-informed decision-making. Australian precedents include CSIRO's Property Standard Index, developed to support Queensland's public housing asset management decisions [39], and research using discrete choice experiments to examine social housing tenant preferences for retrofit measures [5].

Multi-criteria decision analysis (MCDA) provides one approach to comparing retrofit options against multiple technical, economic, environmental and social criteria. Research has explored several methods for incorporating competing objectives and stakeholder preferences, including:

- AHP, TOPSIS, and ELECTRE for multi-criteria assessment, ranking, and exploring trade-offs between competing objectives.
- Archetype-based and stock-wide planning to identify which building types, neighbourhoods, or districts should be addressed first.
- Resident-informed prioritisation that incorporates preferences, dissatisfaction, or willingness-to-pay, rather than relying only on technical performance.

Retrofit assessment and prioritisation research draws on a range of performance measures and decision criteria, including:

Measure Type	Metrics used in literature
Energy Performance	Energy use intensity, source energy, heating/cooling demand, total energy consumption, annual savings, load reduction
Economic Performance	Life-cycle cost, net present value, payback period, cost-effectiveness, return on investment, economic performance ratio
Environmental Impact	Carbon emissions, embodied energy, life-cycle impacts, GHG reduction, environmental trade-offs
Comfort and Health	Thermal comfort, discomfort hours, indoor environmental quality, air quality, humidity, symptoms, occupant satisfaction
Implementation Feasibility	Technical feasibility, asset condition, tenant disruption, delivery constraints and maintenance requirements

Retrofit Feasibility, Implementation and Scalability

Technical barriers include the need to adapt retrofit measures to building typology, orientation, climate zone, floor level and local microclimate, as the retrofit effects are not uniform across the stock. Variations in building condition, construction systems and existing services can also constrain implementation. Occupant behaviour and trust present additional challenges. Differences between modelled and actual occupancy and building operation can contribute to gaps between predicted and measured performance, while tenant involvement in retrofit planning remains important but often underdeveloped [4, 5].

Beyond technical factors, the main barriers are limited financial resources, operational complexity and institutional capacity. A continuing challenge is that retrofit benefits are not always accrued by the owner, whilst costs and disruption fall on providers and on tenants. This is particularly problematic in social housing where providers often have limited resources and tenants are at risk from poorly managed interventions. Australian research further demonstrates how funding conditions, maintenance liabilities and asset management arrangements influence which upgrades can be delivered [5, 11].

Research on scaling implementation identifies opportunities for coordinated procurement, integration with maintenance programs, workforce and supply-chain development, and meaningful tenant engagement. RACE for 2030 is exploring place-based upgrade delivery approaches, while previous SBEnrc research highlights the importance of programmatic funding, whole-of-life investment and locally appropriate delivery models [37] [4]. Across the research reviewed, evidence is stronger in identifying barriers to retrofit than in demonstrating successful large-scale implementation models.

Implications for this Project

Existing research provides substantial evidence and established methods for assessing housing retrofit opportunities at both building and portfolio scales. Project 1.11.3 builds upon this foundation by integrating technical assessment with the operational priorities and practical constraints of government housing portfolios. Four implications are particularly relevant:

- **Integrated building and portfolio assessment:** Combine representative building-level retrofit modelling with portfolio characteristics to identify opportunities relevant to government housing portfolios.
- **Partner-informed decision support:** Work closely with government housing partners to establish practical assessment criteria and explore methods for prioritising retrofit investments.
- **Context-specific retrofit assessment:** Account for differences in dwelling characteristics, climate and tenant needs to ensure retrofit options and performance assumptions reflect actual housing conditions.
- **Implementation feasibility and scalability:** Incorporate financial and operational constraints into retrofit assessments to support feasible interventions and scalable delivery pathways.

Section 3 - Social Housing Portfolio Analysis and Assessment

Emerging Partner Insights and Operational Considerations

Partner engagement has informed the portfolio analysis and proposed case studies through pre-project workshops, Project Steering Group meetings and more detailed discussions with Defence Housing Australia (DHA), WA Department of Housing and Works, Main Roads WA and Homes NSW. Further partner engagement is underway.

Key insights include differences in portfolio characteristics and data availability, particularly for older buildings, and the different needs and standards associated with social and staff housing. Partners also highlighted that retrofit funding remains insufficient to meet broader housing quality and decarbonisation objectives. SHEPI provides an important dedicated funding stream, but other upgrades often compete with constrained maintenance budgets. In some jurisdictions, existing like-for-like replacement practices can miss opportunities to improve performance. Maintenance, acquisition, housing standards and investment planning offer important opportunities to integrate retrofit improvements. DHA has already incorporated this project into its ESG strategy, demonstrating the potential for direct organisational uptake. These emerging insights will inform subsequent research activities and be refined through further partner engagement.

Methodology, Sources and Data Availability

An initial, broad analysis of social and employer provided housing in New South Wales, Queensland and Western Australia was derived from Australian Bureau of Statistic's 2021 Census data. Housing flagged as being provided by 'state or territory housing authorities' and 'community housing providers' was combined as social housing, while housing flagged as provided by 'employer – government (including Defence Housing Australia)' and 'employer – other employer' was combined as employer provided housing. Housing within these two broad social housing and employer provided housing was further identified by 'dwelling structure' and by Local Government Area (LGA).

In the 2021 Census data, dwelling structure refers to the type of housing being provided: detached house, row/terrace house or apartment, as well as a longer list of less common housing types, including caravans, cabins, houseboats and tents. This analysis has separated detached housing, row/terrace housing, low rise apartments (1-3 storeys), medium rise apartments 4-8 storeys) and high rise apartments (9+ storeys) and disregarded other, much less common types.

This analysis has used LGA as a proxy for location within Australia. The National Construction Code (NCC) climate zone for each LGA has been identified from the Australian Building Codes Board climate zone maps for New South Wales, Queensland and Western Australia. Although not all Australian LGAs map to a single NCC Climate Zone (for example East Pilbara, Ashburton and Port Hedland in Western Australia), their alignment sufficiently accurate for initial mapping and analysis. Future mapping of social and employer provided housing will use post codes for locations, which map more accurately to NCC and NatHERS climate zones.

Social and Employer Provided Housing Characteristics across NSW, QLD, WA

Social and Employer Provided Housing Figures

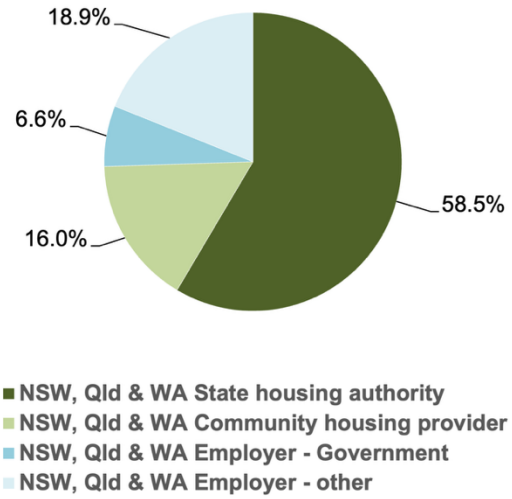


Figure 4 - NSW, QLD, and WA Figures for Social and Employer Provided Housing

- 296,832 total dwellings
- 173,698 (58.5%) in state and territory housing authorities
- 47,463 (16.0%) in community housing organisations
- 19,518 (6.6%) provided to government employees
- 56,156 (18.9%) provided to other employees

Broad Split Between Social Housing and Employer Provided Housing

Social housing and Employer Provided Housing serve different purposes, with implications for retrofit priorities. Social housing, comprising housing authority and community housing dwellings in this analysis, supports eligible households on low incomes or with additional housing needs. Tenants may face financial constraints, health conditions or age-related vulnerabilities that increase their exposure to poor indoor conditions. Social housing is relatively scarce, and tenants have limited capacity to contest and demand housing of a higher standard. Energy costs are of significant importance to this demographic, and the majority of tenants are carefully balancing thermal comfort with cost.

Employer-provided housing supports workforce accommodation and can play an important role in attracting and retaining staff, particularly in regional and remote locations. Housing standards, maintenance responsibilities and energy-payment arrangements vary between employers. Where electricity costs are covered by the employer, the financial benefits of efficiency upgrades may accrue primarily to the provider, while residents benefit from improved comfort. Because many of the homes that businesses provide their employees are located in outlying areas of Australia, where summers may be extremely hot and winters may be bitterly cold, thermal comfort is often a greater consideration to tenants than energy costs.

Housing Concentration

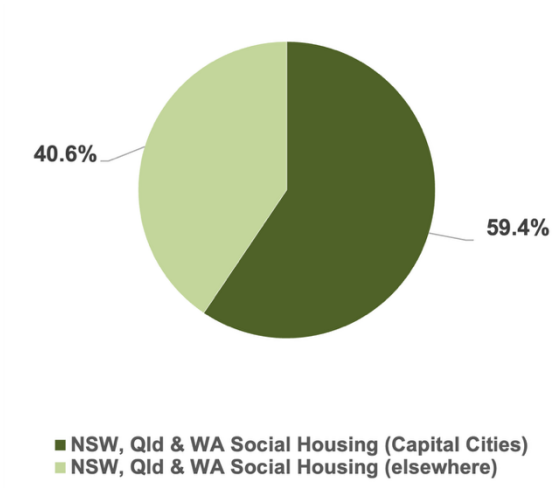


Figure 5 - Social Housing Concentration in Capital Cities

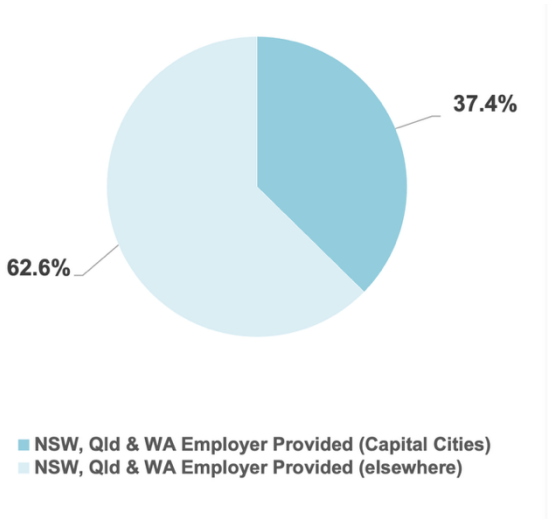


Figure 6 - Employer Provided Housing Concentration in Outside of Capital Cities

Most of the social housing is located in the nation's capital cities. Given that approximately 67% of Australians reside in capital cities, it is reasonable to anticipate that a comparable proportion of social housing will be situated in these cities.

Employer-provided accommodation is concentrated outside of capital cities. Employer-supplied accommodation is frequently an integral component of employment packages that facilitate individuals' work in rural regions (educators, healthcare personnel, law enforcement, military staff, mining workers, etc.).

Dwelling Types

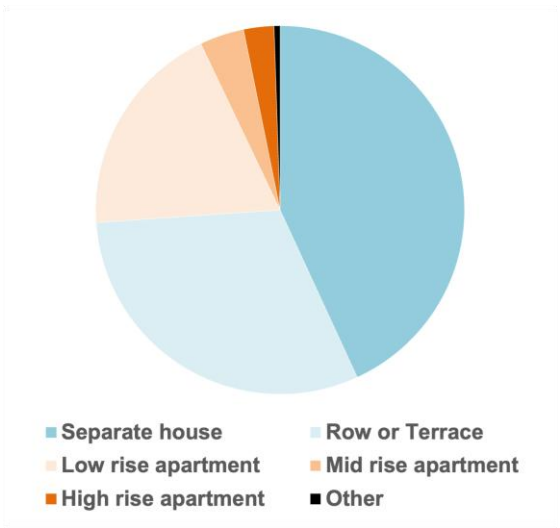


Figure 7 - Social Housing Dwelling Types

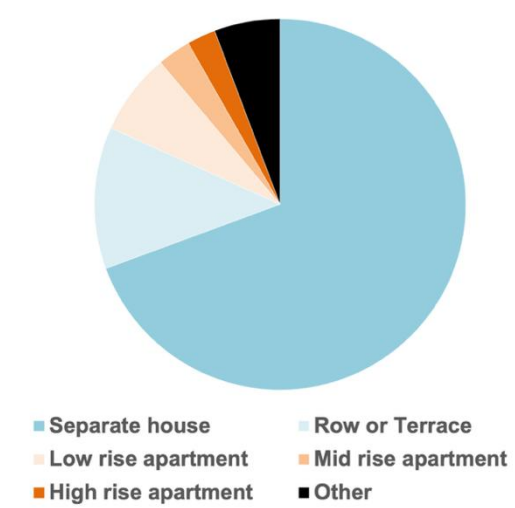


Figure 8 - Employer Provided Dwelling Types

Of the 220,947 social housing residences in NSW, Qld, and WA, fewer than expected are detached dwellings; detached houses make up around 70% of all Australian dwellings, but only 42.3% of social housing. In contrast, row or terrace housing and apartments make up a substantially greater percentage of social housing than they do of all dwellings in Australia. Almost 30% of NSW, Qld and WA social housing is row or terrace houses, while this housing type accounts for only 13% of all dwellings in Australia. 27.7% of NSW, Qld and WA social housing are apartments, which again is significantly greater than the 16% of all Australian dwellings which are apartments.

Employer Provided Housing includes 75,674 residences in NSW, Qld, and WA, and aligns more closely with typical Australian dwelling types. 69.4% of employer supplied housing is detached, against a national proportion of almost 70%. Row or terrace housing accounts for 12.4% of employer-provided housing against a national proportion of 13%. Apartments make up a further 12.5% of employer provided housing against a national proportion of 16%.

Detached and Attached Housing by Climate Zone



Detached Housing

146,037 detached dwellings total
CZ 5 (Coastal Sydney + Perth) is the largest at 25.7%
CZ2 (SEQ and NNSW) second largest at 21.2%
CZs 1, 4 and 6 all have between 10% and 15%

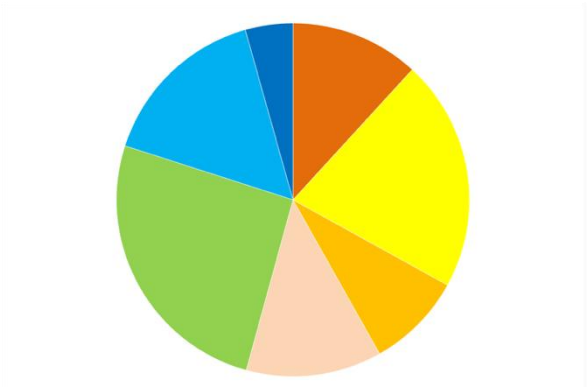


Figure 9 - Detached Housing by Climate Zone

Attached Housing

74,492 dwellings total.
Across NSW, Qld and WA, attached/terrace/row houses are concentrated in CZ 5 (Coastal Sydney) and CZ 6 (Western Sydney and Surrounds).
Together, this accounts for almost 2/3rd of all attached/terrace/row housing.

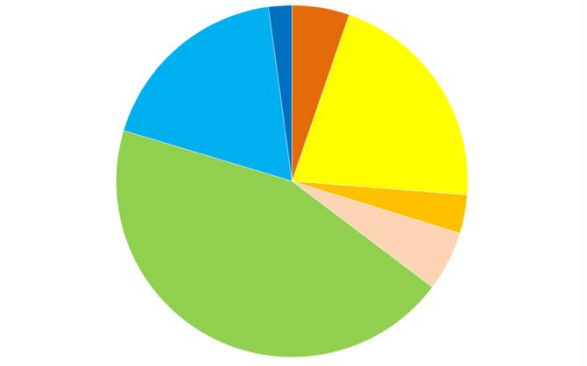


Figure 10 - Attached Housing by Climate Zone

Low, Mid, and Hi-rise Apartments by Climate Zone



Low Rise Apartments

52,461 dwellings total.
Across NSW, Qld and WA, low rise apartment dwellings are concentrated in CZ 5 (Coastal Sydney) and CZ 6 (Western Sydney and Surrounds). Together, this accounts for almost 2/3rd of all low-rise social and employer provided housing. Most of the remaining 1/3rd is in CZ2 (SEQ and NNSW).

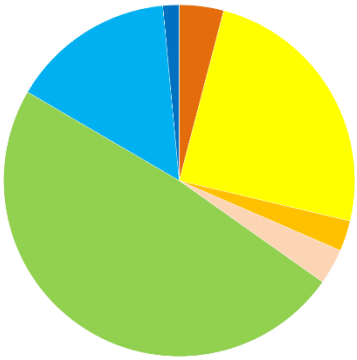


Figure 11 - Low-Rise Apartments by Climate Zone

Mid Rise Apartments

11,922 dwellings total.
Across NSW, Qld and WA, midrise social and employer provided housing houses are concentrated in CZ 5 (Coastal Sydney) and CZ 6 (Western Sydney and Surrounds). Together, this accounts for nearly 80% of all midrise social and employer provided housing. Most of the remaining 20% is in CZ2 (SEQ and NNSW). The relatively low numbers of midrise apartments make this a less interesting and useful dwelling type to study.

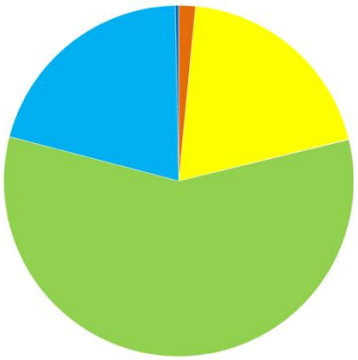


Figure 12 - Mid-rise Apartments by Climate Zone

Hi-Rise Apartments

6,208 dwellings total.
Across NSW, Qld and WA, high rise social and employer provided dwellings is concentrated in CZ 5 (Coastal Sydney), with nearly 70% of these dwellings in CZ5. The low numbers of high-rise apartments make this a less interesting dwelling type to study

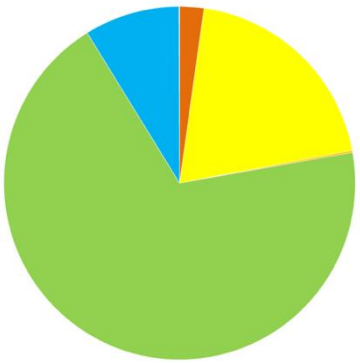


Figure 13 - High Rise Apartments by Climate Zone

Housing and Climate Zone

The charts (see Figure 14) identify dwelling types and climate zones where retrofit research could have the widest application across the housing stock analysed. The largest combinations are detached houses in Climate Zone 5, attached or terrace houses in Climate Zone 5, detached houses in Climate Zone 2, and low-rise apartments in Climate Zone 5.

The breakdown between social and employer-provided housing helps identify different delivery pathways. However, the charts do not establish whether employer-provided homes consume more energy than equivalent social housing dwellings. For housing outside participating government portfolios, opportunities will also depend on owners' willingness, available incentives and the project's capacity to influence upgrades.

Also missing is the relative energy intensity of housing in different climate zones – we might expect to see a higher rate of energy use in some dwelling types and climate zones than others. For example, detached housing in climate zone 1 (Tropical Northern Australia) might use considerably more energy than an equivalent detaching house in climate zone 2 (South East Queensland), where the climate is generally cooler.

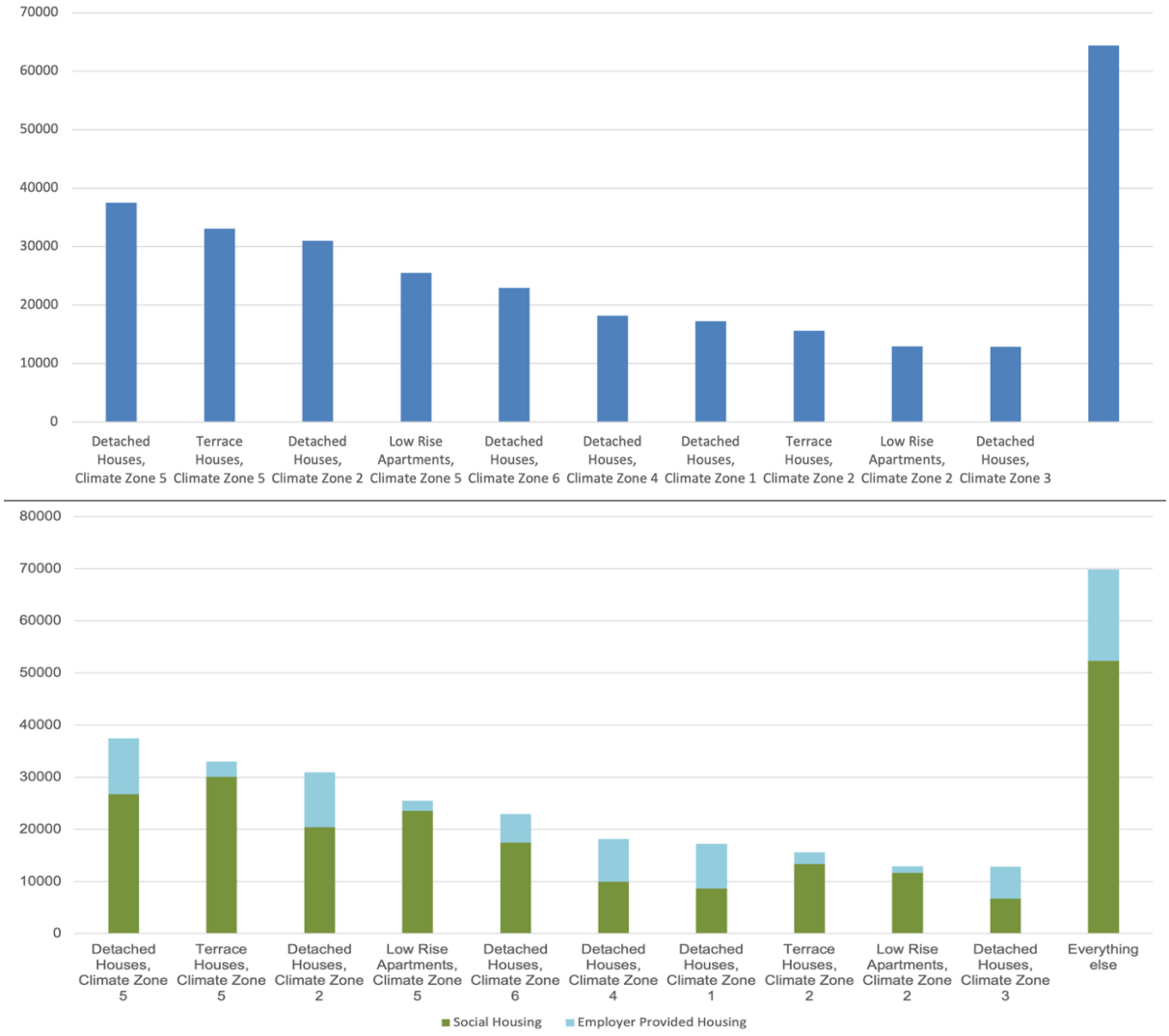


Figure 14 - Dwellings / NCC Climate Zones

Housing Stock Analysis

The below analysis of housing stock by state is drawn from the Australian Housing Stock Model – Regional Models produced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In the housing stock model detached, row and terrace housing is shown in orange, and apartments, including all low, medium and high rise, are shown in blue.

Western Australia

The below analysis of Western Australian housing comes from CSIRO's Australian Housing Stock model. The Western Australian housing stock analysis identifies a substantial cohort of older three- and four-bedroom houses, with detached dwellings prominent. The external-wall distribution is dominated by the "brick other" category, interpreted in the accompanying analysis as predominantly double brick or cavity-brick construction. Homes built in 1990 or earlier form the largest construction-age group.

The analysis also highlights the performance differences between older and newer housing. Figure 17 and Figure 18 illustrate NatHERS ratings for detached houses and row/terrace houses to be generally above 5 stars for homes built after 2003 and below 2.5 stars for older stock. Together, the findings support prioritising older three- or four-bedroom cavity-brick detached houses for further investigation, subject to verification of construction, condition and relevance to participating portfolios.

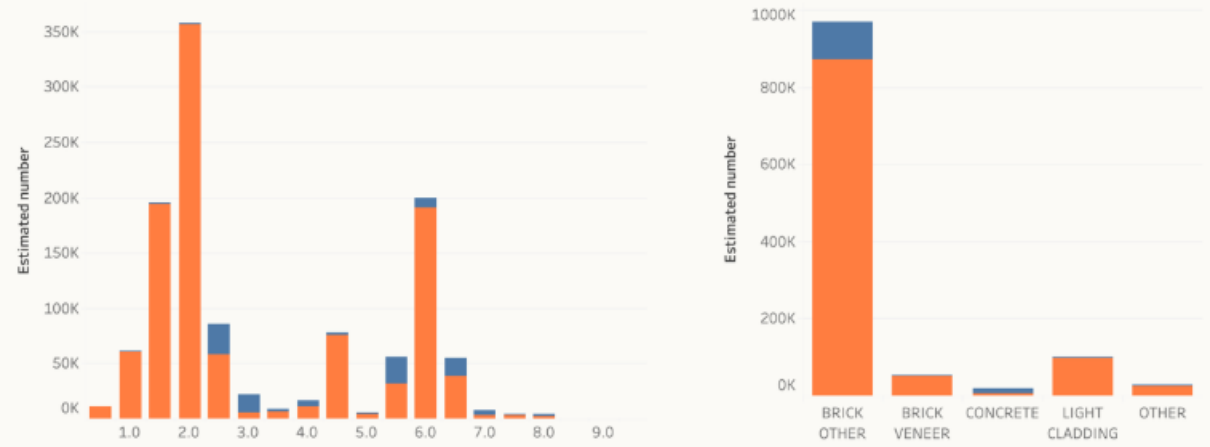


Figure 15 - Star Rating and External Wall Distribution across WA

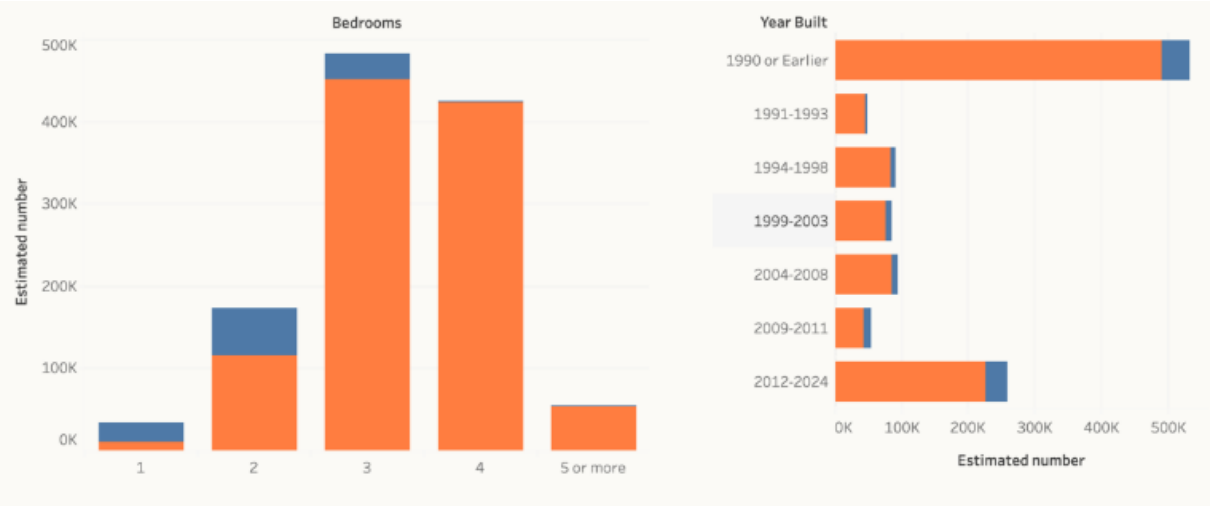


Figure 16 - Bedroom Number and Year Built Distribution across WA



Figure 17 - Weighted NatHERS Ratings for detached, row and terrace housing constructed post 2004 across WA

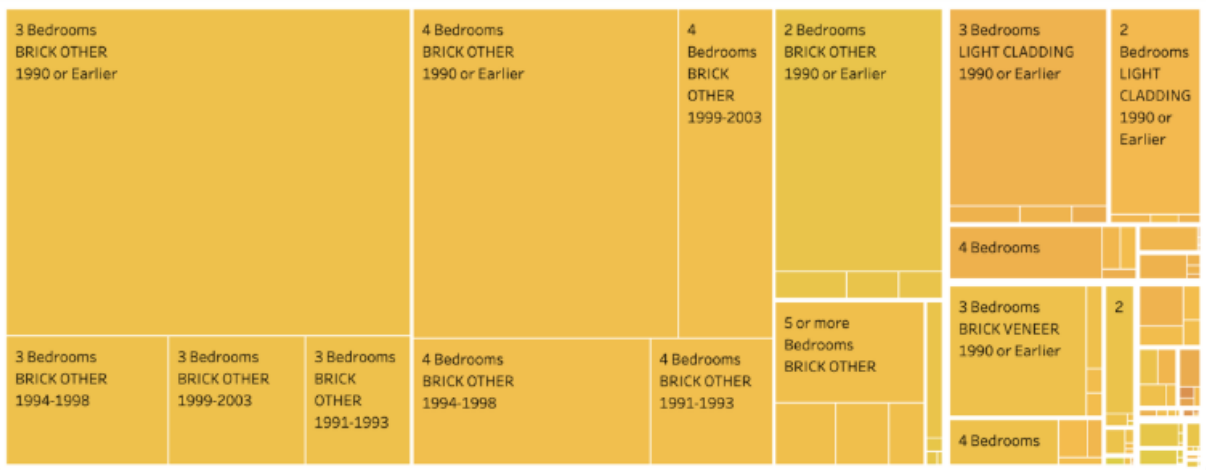


Figure 18 - Weighted NatHERS Ratings for detached, row and terrace housing constructed pre-2003 across WA

New South Wales – detached, terrace, and row housing

The NSW housing stock analysis of detached, terrace and row housing (in orange) identifies brick veneer as the largest external-wall category for detached, row and terrace housing, with older, three- or four-bedroom homes forming substantial cohorts. Dwellings built in 1990 or earlier represent the largest construction-age group. The accompanying analysis indicates generally lower estimated thermal performance among older homes, suggesting opportunities to improve comfort and energy efficiency through retrofit.

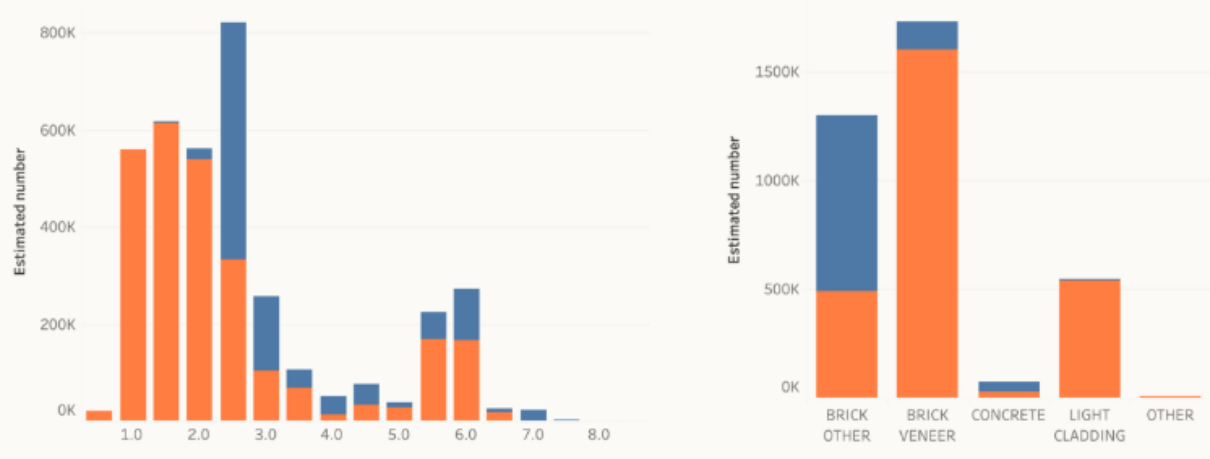


Figure 19 - Star Rating and External Wall Distribution across NSW

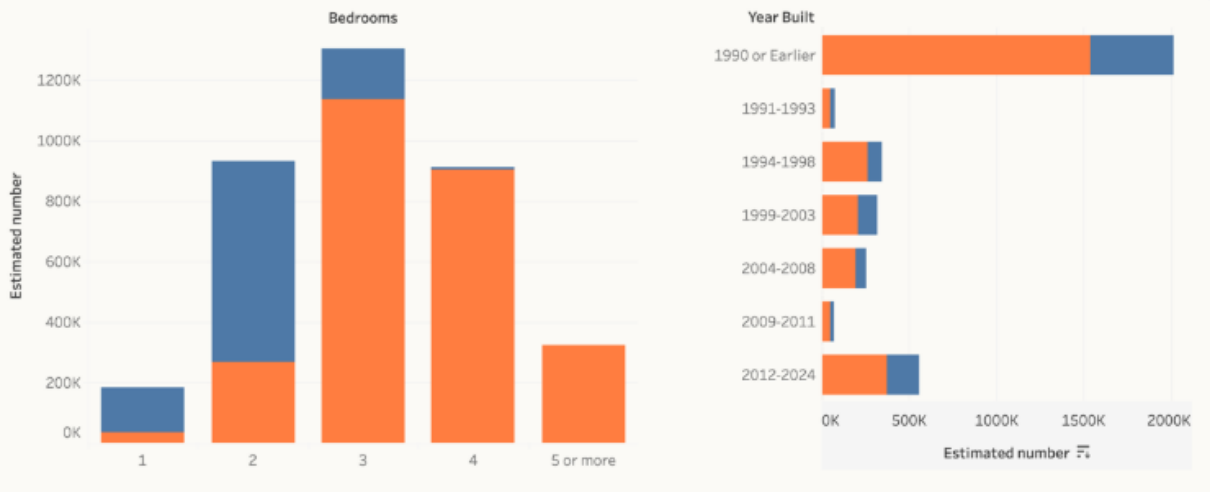


Figure 20 - Bedroom Number and Year Built Distribution across NSW



Figure 21 - Weighted NatHERS Star Ratings for detached, row and terrace homes constructed post-2004 across NSW

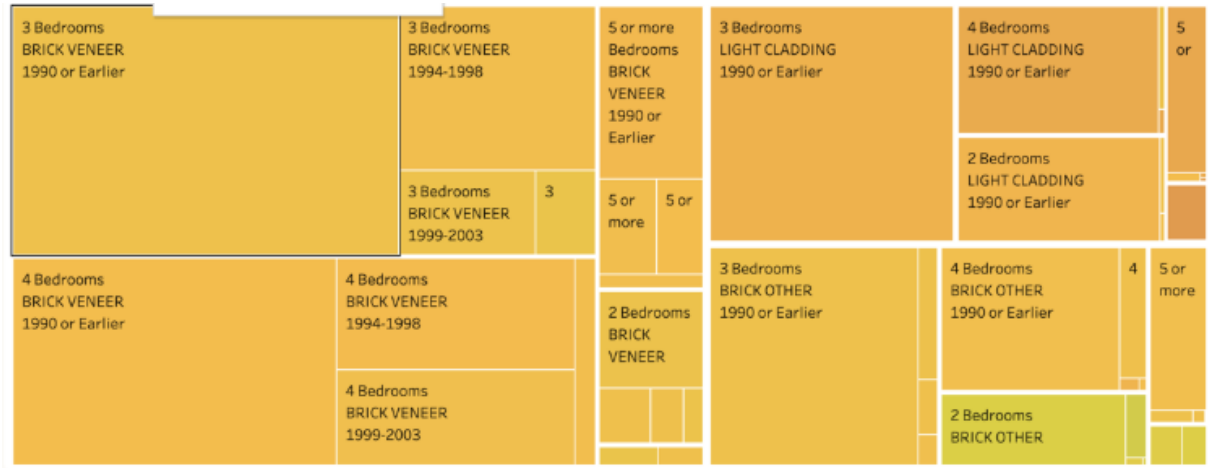


Figure 22 - Weighted NatHERS Star Ratings for detached, row and terrace homes constructed pre-2003 across NSW

New South Wales – Apartments

The NSW apartment stock analysis for apartments (in blue) identifies two-bedroom, 'brick-other' dwellings as the predominant type, which has been interpreted as cavity-brick construction, and indicates that much of the stock was built in 1990 or earlier. Figure 23 suggest lower thermal performance among older apartments, generally below 3 stars, compared with above 5 stars for later construction.

The bedroom and year built charts (Figure 24) for apartments (in blue), identifies that 2 bedroom, 'brick-other' (cavity brickwork) apartments constructed before 1990 are the most common type, while the NatHERS ratings charts show the differences in energy efficiency between post 2004 apartments (Figure 25) and pre 2003 apartments (Figure 26).

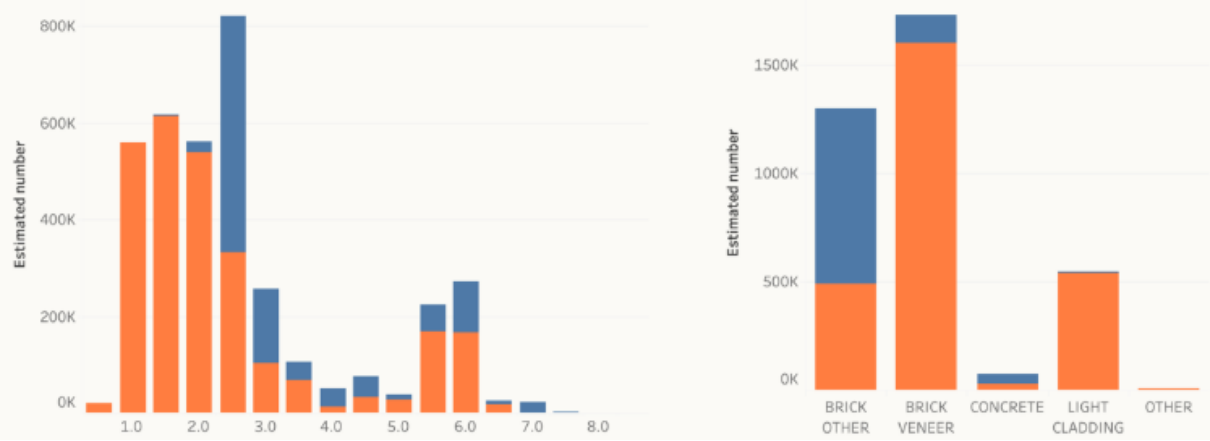


Figure 23 - Star Rating and External Wall Distribution across NSW Apartments

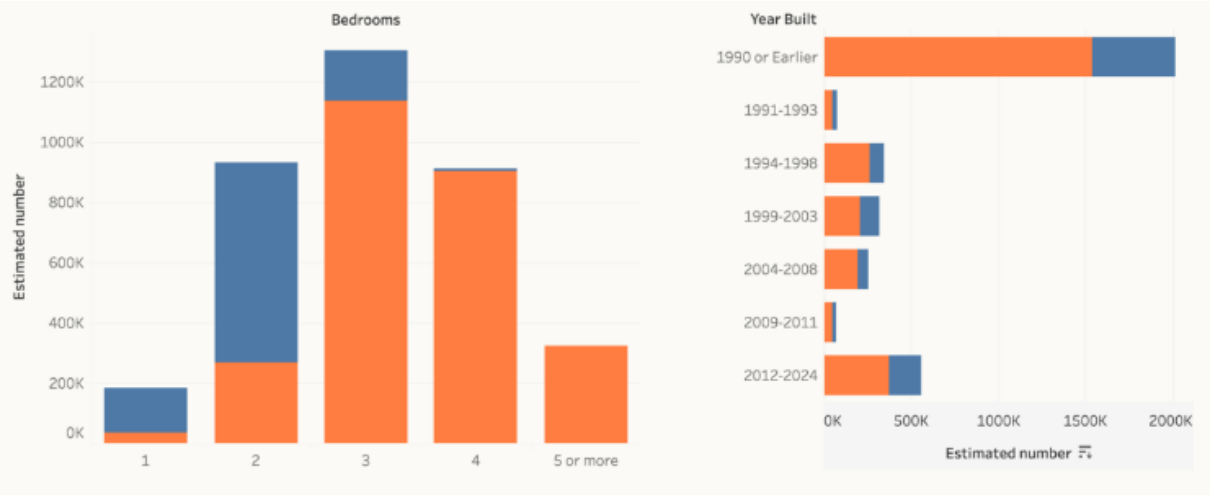


Figure 24 - Bedroom Number and Year Built across NSW Apartments



Figure 25 - Weighted NatHERS Ratings for apartments constructed post 2004 across NSW Apartments

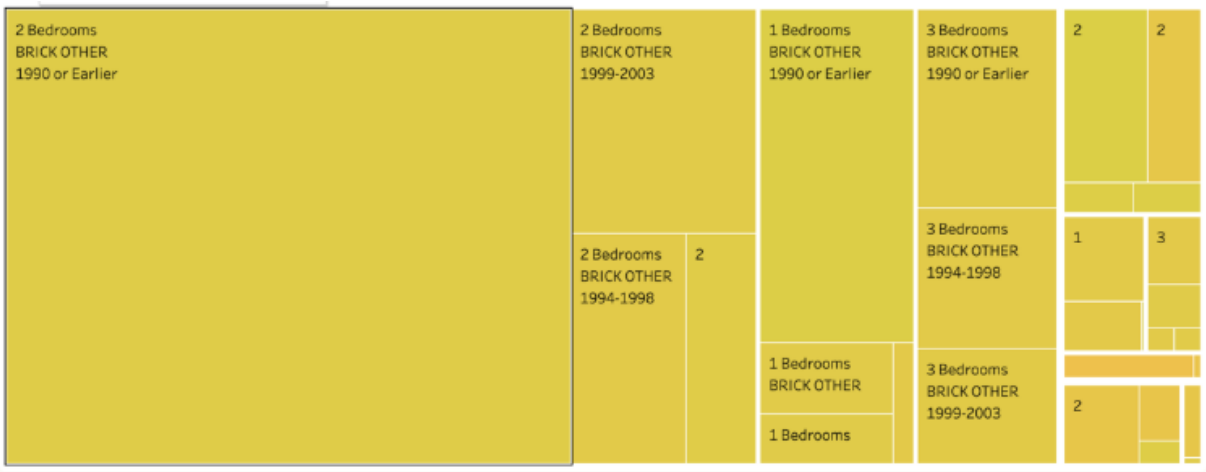


Figure 26 - Weighted NatHERS Ratings for apartments constructed pre-2003 across NSW Apartments

Queensland – Detached, Terrace, and Row Housing

The Queensland housing stock analysis identifies brick veneer as the largest external-wall category, in addition to a substantial lightweight-clad cohort. The greatest construction-age group consists of homes constructed in 1990 or earlier, with a significant number of three- and four-bedroom dwellings. The thermal performance of older homes is generally estimated to be lower, and highlights of the potential for retrofits to enhance energy efficiency and comfort. These findings support investigating older three- or four-bedroom brick-veneer houses, with lightweight-clad homes serving as a useful construction comparison.

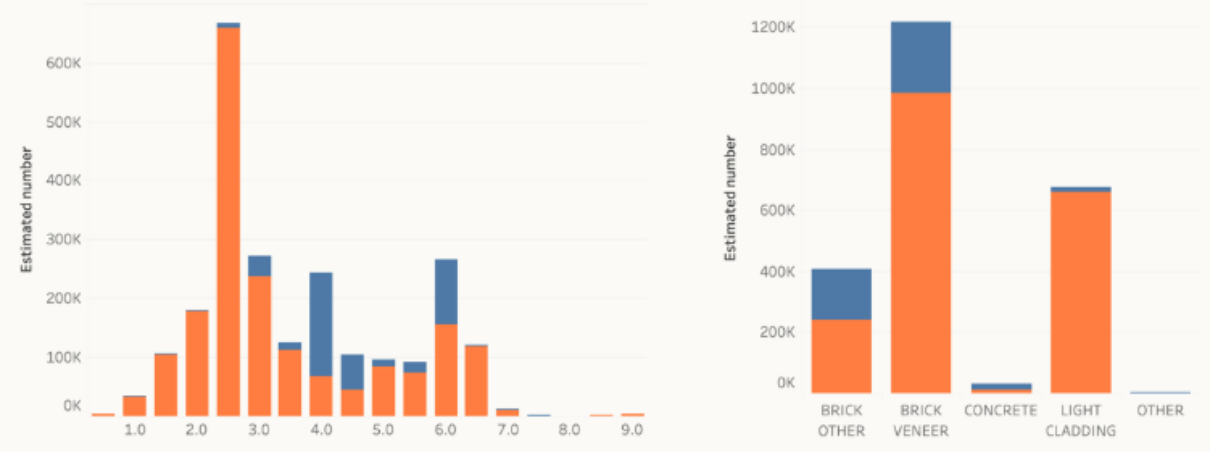


Figure 27- Star Rating and External Wall Distribution across Queensland

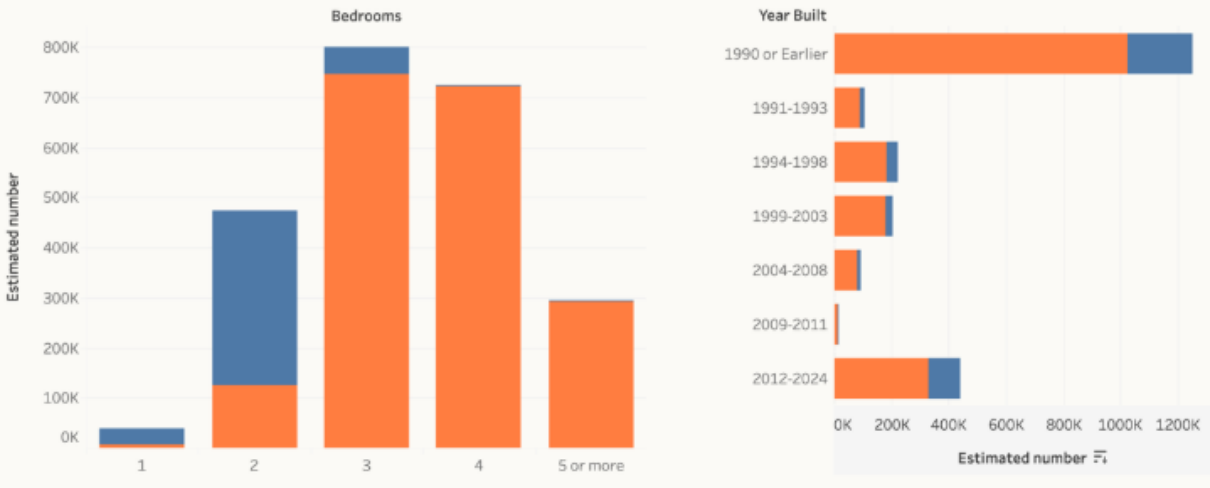


Figure 28 - Bedroom Number and Year Built Distribution across Queensland

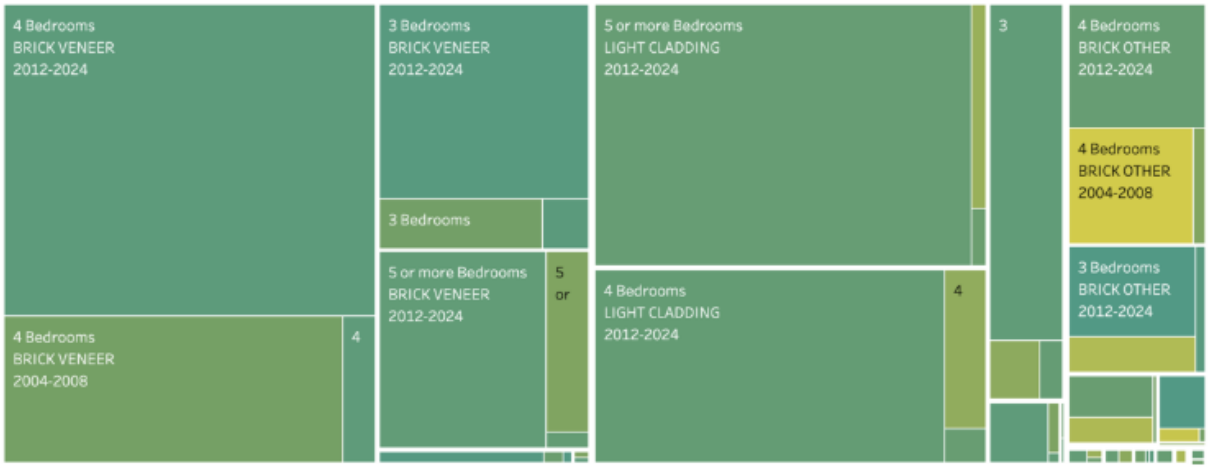


Figure 29 - Weighted NatHERS Rating post 2004 across Queensland

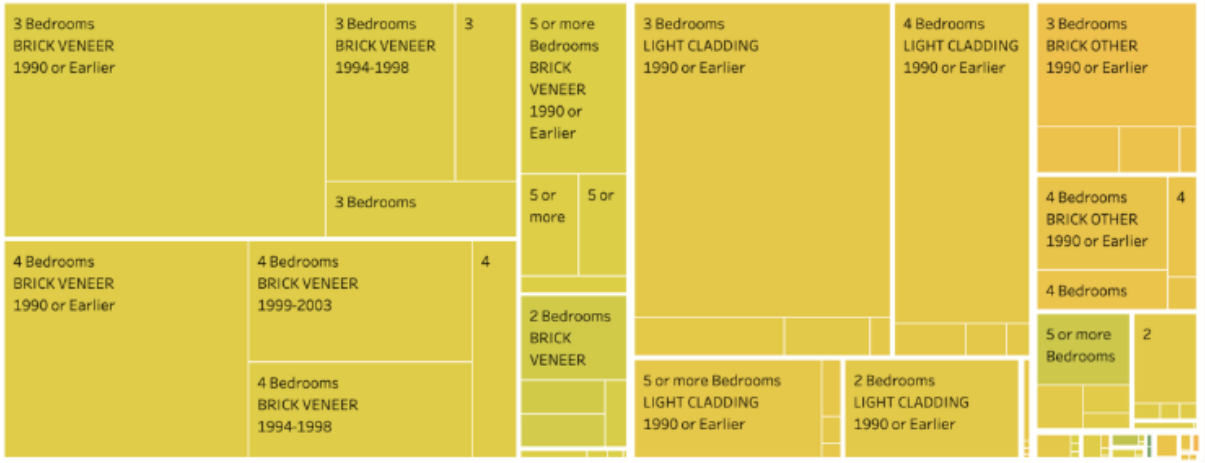


Figure 30 - Weighted NatHERS Rating pre-2003 across Queensland

Queensland – Apartments

The Queensland apartment analysis identifies older two-bedroom brick dwellings as candidates for retrofit assessment. Figure 31 and Figure 32 highlight both brick veneer and "brick other" construction. They also indicate generally lower estimated thermal performance among older apartments, suggesting opportunities to improve comfort and energy efficiency.

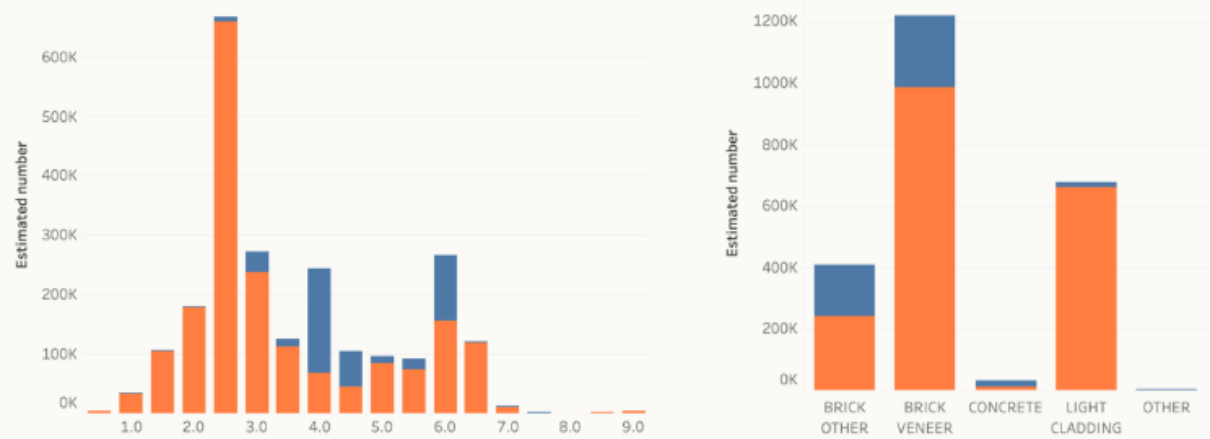


Figure 31 - Star Rating and External Wall Distribution across Queensland Apartments

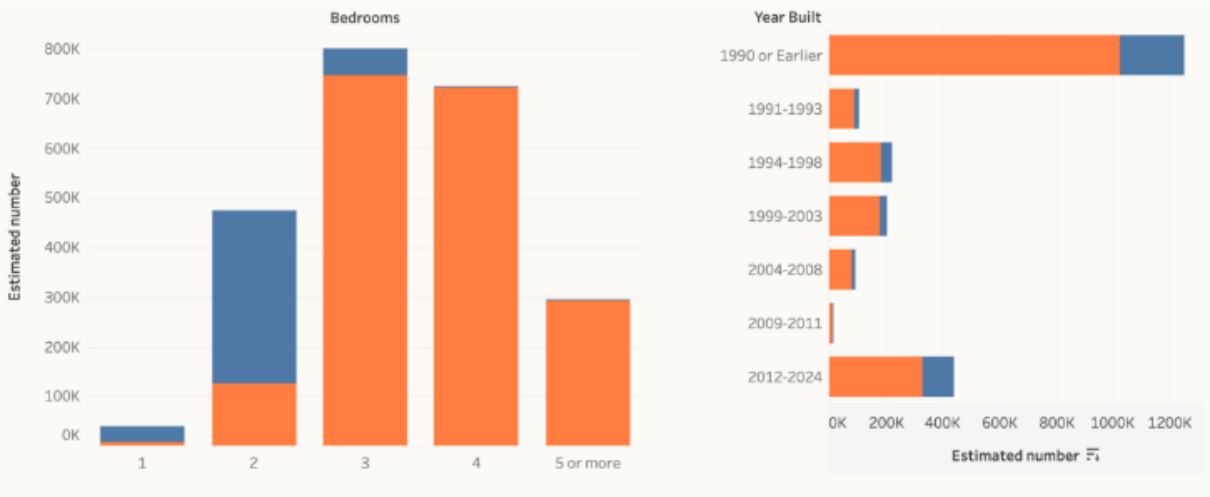


Figure 32 - Bedroom Number and Year Built Distribution across Queensland Apartments



Figure 33 - Weighted NatHERS Rating post 2004 across Queensland Apartments

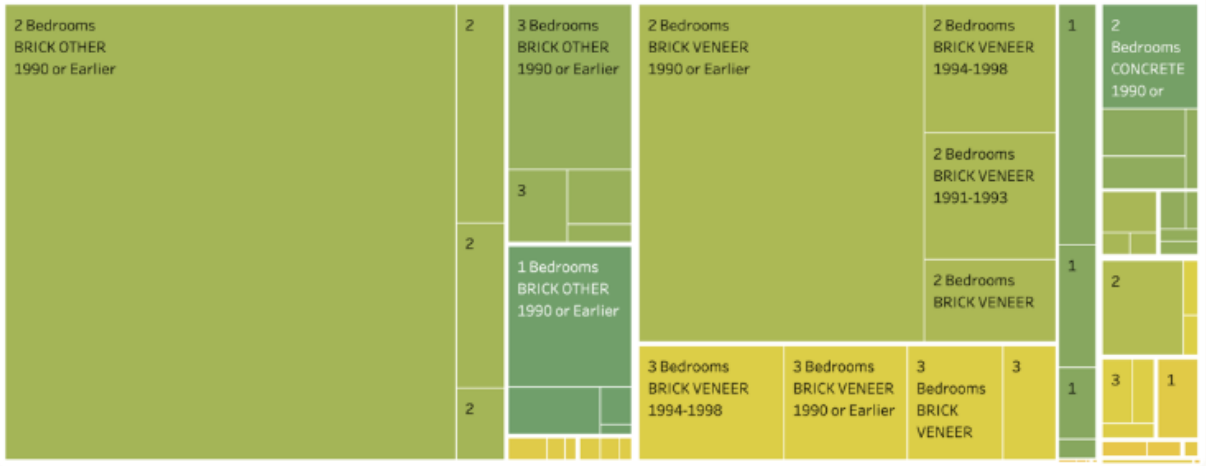


Figure 34 - Weighted NatHERS Rating pre-2003 across Queensland Apartments

Case Study Selection Summary

Four proposed case studies guide the assessment of retrofit pathways. The dwelling types and climate zones below draw on the housing stock analysis and partner feedback, with final selections subject to confirmation:

- **Western Australia:** A double-brick dwelling in Climate Zone 5, identified by the WA partner as representative of a substantial part of its portfolio. The case would examine retrofit opportunities for this prevalent masonry construction type.
- **New South Wales:** A two-bedroom masonry apartment in Climate Zone 5, proposed to capture older apartment stock and assess retrofit opportunities involving shared building elements. Cavity-brick construction, building height and unit position require confirmation.
- **Queensland:** A three-bedroom brick-veneer detached house in Climate Zone 2, proposed to represent a common dwelling type and examine retrofit opportunities in warm-humid conditions. Lightweight-clad housing could provide an alternative if prioritised by the Queensland partner.
- **Defence Housing Australia:** A representative staff-housing dwelling, with dwelling type and climate zone to be confirmed with DHA. Selection should reflect its portfolio characteristics and operational priorities while complementing the other three cases.

The selection draws on the Housing Stock Analysis including contrasting construction systems and climatic conditions, examining how dwelling form, construction and climate influence retrofit needs and performance. Together, these cases are intended to provide relevant coverage of partners' portfolios and contrasting retrofit conditions.

Table 1 - Case Study Selection Summary

Case study	Proposed dwelling type	Climate zone	Construction material	Selection rationale
Queensland	Three-bedroom detached house	2, 5	Brick veneer	Assess a common dwelling type in warm-humid conditions, focusing on improvements to thermal comfort and energy performance. Lightweight cladding remains an alternative, subject to partner priorities.
Western Australia	Double-brick dwelling; bedrooms and	1, 5	Double brick	Examine a construction type identified by the WA partner as representative of a substantial part of its

	dwelling form to be confirmed			portfolio, with potential for replicable retrofit solutions.
New South Wales	Two-bedroom apartment	5	Masonry; cavity brick to be confirmed	Investigate older apartment stock, considering unit position, shared building elements and coordination of upgrades. Building height and construction require verification.
Defence Housing Australia	Representative staff-housing dwelling; type to be confirmed	2 (TBC)	Lightweight Cladding (TBC)	Address staff-housing characteristics and operational priorities while complementing the dwelling types and climates covered by the other cases.

References

1. AIHW, *Housing assistance in Australia*. 2026, AIHW, Australian Government.
2. Daly, D., et al., *Indoor temperatures and energy use in NSW social housing.* Energy and Buildings, 2021. **249**: p. 111240.
3. Daniel, L., et al., *Warm, cool and energy-affordable housing policy solutions for low-income renters*, in *AHURI Final Report No. 338*. 2020, Australian Housing and Urban Research Institute Limited: Melbourne.
4. Maher, R., Greenop, K., Fantin, S., Go-Sam, C., Heynen, T., Bamdad Masouleh, K. and Feng, Y. , *Climate resilient regional communities: Decarbonisation and wellbeing in homes and energy systems. Project 1.10.3 Industry Report.* , S.B.E.N.R.C. (SBEnrc), Editor. 2026: Australia
5. Baker, E., et al., *Sustainable social housing retrofit? Circular economy and tenant trade-offs*, in *AHURI Final Report No. 397*. 2023, Australian Housing and Urban Research Institute: Melbourne.
6. Australian Government, D. *Reducing Emissions*. 2026; Available from: https://www.dcceew.gov.au/climate-change/emissions-reduction.
7. DCCEEW. *Residential Buildings*. 2026; Available from: https://www.dcceew.gov.au/energy/energy-efficiency/buildings/residential-buildings.
8. Legislation, Q. *Clean Economy Jobs Act 2024*. 2024 16 November 2026]; Available from: https://www.legislation.qld.gov.au/view/whole/html/inforce/2026-01-03/act-2024-016.
9. Action, N.C.a.E. *The Climate Change (Net Zero Future) Act 2023*. 2023 [cited 2026; Available from: https://www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/climate-change-net-zero-future-act-2023.
10. Government, W. *Government Emissions Interim Target*. 2024; Available from: https://www.wa.gov.au/service/environment/business-and-community-assistance/government-emissions-interim-target.
11. Liu, E., et al., *Public housing transfers: longer-term impacts on investment, tenant experience and sector outcomes*, in *AHURI Final Report No. 458*. 2026, Australian Housing and Urban Research Institute: Melbourne.
12. Larkin, N., Northrop, E., Xing, D. and Milligan, B., *Accelerating home energy efficiency upgrades in Australia: A policy gap analysis.* , U.C.f.S.D.R.a.R.f. 2030, Editor. 2025.
13. Sansom, G., et al., *Social housing temperature conditions and tenant priorities.* Australian Journal of Social Issues, 2023. **58**(3): p. 624–639.
14. Adam, C. and R. Steven, *Measuring housing affordability: Scoping the real cost of housing*, in *AHURI Final Report No. 427*. 2024, Australian Housing and Urban Research Institute: Melbourne.
15. Chabane, N., et al., *A Sustainable Multi-Criteria Optimization Approach for the Energy Retrofit of Collective Housing in Algeria Using the ELECTRE III Tool.* Sustainability (Switzerland), 2025. **17**(10).
16. Dominguez-Amarillo, S., et al., *Towards energy demand reduction in social housing buildings: Envelope system optimization strategies.* Energies, 2012. **5**(7): p. 2263–2287.
17. El-Darwish, I.I. and M. Gomaa, *Retrofitting strategy for building envelopes to achieve energy efficiency.* Alexandria Engineering Journal, 2017. **56**(4): p. 579–589.
18. Fan, Y. and X. Xia, *A multi-objective optimization model for energy-efficiency building envelope retrofitting plan with rooftop PV system installation and maintenance.* Applied Energy, 2017. **189**: p. 327–335.
19. Ji, Y., et al., *Retrofit Analysis of City-Scale Residential Buildings in the Hot Summer and Cold Winter Climate Zone.* Energies, 2023. **16**(17).
20. Rababa, W. and O.S. Asfour, *Façade Retrofit Strategies for Energy Efficiency Improvement Considering the Hot Climatic Conditions of Saudi Arabia.* Applied Sciences (Switzerland), 2024. **14**(21).
21. Shu, L. and D. Zhao, *Techno-Economic Analysis of Building Energy Retrofits: Integrating Occupant Behavior Impacts.* Computing in Civil Engineering 2024: Sustainability, Resilience, Safety, and Education - Selected papers from the ASCE International Conference on Computing in Civil Engineering 2024, 2024: p. 305–316.

22. Wu, K., Y. Li, and Z. Wu, *Energy Efficiency Retrofit for Existing Residential Buildings in China's HSCW Zone in Multiple Scenarios: Energy Economic Analysis.* Journal of Architectural Engineering, 2025. **31**(1).
23. Ziaeemehr, B., et al., *Multi-objective optimization and decision-making in building retrofits: A systematic review of frameworks, trends, and research gaps.* Building and Environment, 2026. **304**.
24. Asadi, E., et al., *Multi-objective optimization for building retrofit: A model using genetic algorithm and artificial neural network and an application.* Energy and Buildings, 2014. **81**: p. 444–456.
25. Marshall, E., et al., *Combining energy efficiency measure approaches and occupancy patterns in building modelling in the UK residential context.* Energy and Buildings, 2016. **111**: p. 98–108.
26. Qu, K., et al., *A novel holistic EPC related retrofit approach for residential apartment building renovation in Norway.* Sustainable Cities and Society, 2020. **54**.
27. Underhill, L.J., et al., *Modeling the resiliency of energy-efficient retrofits in low-income multifamily housing.* Indoor Air, 2018. **28**(3): p. 459–468.
28. Vallati, A., et al., *Energy retrofit optimization for social building in temperate climate zone.* Energy and Buildings, 2023. **282**.
29. Zhang, H., et al., *Robust building energy retrofit evaluation under uncertainty: An interpretable machine learning approach.* Energy Conversion and Management, 2025. **345**.
30. Lang, M., Parida, S., Rajagopalan, P., Horne, R. and Daniel, L, *Building climate resilience in Australian homes and households.*, A.F.R.N. 465, Editor. 2026.
31. Bertone, E., et al., *Guidelines, barriers and strategies for energy and water retrofits of public buildings.* Journal of Cleaner Production, 2018. **174**: p. 1064–1078.
32. Clarke, A., et al., *Reified scarcity & the problem space of 'need': unpacking Australian social housing policy.* Housing Studies, 2024. **39**(2): p. 565–583.
33. Flanagan, K., et al., *Understanding the experience of social housing pathways.* AHURI Final Report, 2020(324).
34. McCamley, C., et al., *Beyond tenant refusal: Organisational fragmentation, relational capacity, and social housing retrofit.* Energy Research and Social Science, 2026. **140**.
35. Muir, K., et al., *'A pathway to where?' Inquiry into understanding and reimagining social housing pathways.* AHURI Final Report, 2020(332): p. 1–67.
36. Pawson, H., V.R. Milligan, and C. Martin, *Building Australia's affordable housing industry: capacity challenges and capacity-enhancing strategies.* International Journal of Housing Policy, 2019. **19**(1): p. 46–68.
37. CRCP, *Racefor2030: Energy Upgrades for Australian Homes*. 2025.
38. Daniel, L., et al., *A national roadmap for improving the building quality of Australian housing stock*, in *AHURI Final Report No. 426*. 2024, Australian Housing and Urban Research Institute: Melbourne.
39. Tucker, S., Johnston, D. and McFallan, S. . *The Property Standard Index: How well has it performed? Proceedings of the CIB W070 2002 Global Symposium.* . 2002.