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Energy efficiency within mid-rise residential buildings: A critical review of regulations in Australia

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Energy efficiency within mid-rise residential buildings: A critical review of regulations in Australia

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Abstract

Within Australia, increasingly more people are choosing to live in cities. Due to a need for urban densification and more affordable housing, for the first time, development approvals for multi-residential developments have overtaken those for individual houses. The growing sector of mid-rise residential buildings in Australian cities has the potential to contribute significantly to improving the energy efficiency of the building stock. However, there is limited empirical research on this sector within the Australian context. The mandatory framework for the energy efficiency of mid-rise residential developments in Australia, with a focus on New South Wales with its distinct regulatory requirements, is critically reviewed and synthesised with the literature. The review provides an understanding of the regulatory context under which mid-rise residential developments are undertaken. The limitations of the current energy efficiency framework are highlighted. This study provides an understanding of the status quo in energy efficiency regulations for mid-rise residential buildings in Australia and demonstrates that there is both scope and an imperative for regulatory minima to be enhanced.

Peer-review under responsibility of the scientific committee of the International Conference on Improving Residential Energy Efficiency.

Keywords: Energy efficiency, Regulations, Apartments, Mid-rise residential buildings, BASIX, NatHERS

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1. Introduction

Concerns regarding scarcity of resources and the impacts of anthropogenic climate change are driving action around the world, at various levels, to move to a more sustainable future. Buildings represent over one third of final energy consumption, and related CO_2 emissions, globally [1]. In 2013-14, the residential sector accounted for approximately 11% of final energy consumption in Australia [2]. Around two thirds of the energy consumed in Australian homes relates to space heating/cooling and water heating [3]. Internationally, it has been stated that the building sector has the greatest potential to mitigate climate change using low-cost measures [4], [5]. Therefore, both voluntary and mandatory pathways to energy efficiency within residential buildings are of increasing importance.

After a decade and a half of consistent volumes of residential construction, from 2009 the number of dwellings being constructed in Australia has been increasing [6]. Driven by population growth within cities, demand for more affordable dwellings, and greater employment opportunities, apartment construction has been central to this increased residential construction activity [6]. Indeed, statistics at the time of writing suggest that for the first time, more apartments are being constructed in Australia than individual houses [7]. But worryingly, there is evidence that per capita energy consumption in apartments is higher than that of single-family houses [8].

Over 75% of the apartment developments constructed since 2011 have been within the larger capital cities of Sydney, Melbourne and Brisbane [6] and have been either centrally located or close to existing transport infrastructure. Many of these developments in central locations or close to transport infrastructure are mid-rise developments, which for the purposes of this paper are defined as between four and eight storeys.

Whilst concerns over energy security, rising energy prices and environmental impacts have started to drive policy change within the Australian context [9], it has been asserted that the regulatory standards for energy efficiency in homes in Australia fall well below the level of those in various countries with similar climatic conditions to the climate zones of Australia [10]. Therefore, the aim of this paper is to critically review the mandatory pathways to energy efficiency for mid-rise residential buildings in Australia, with a focus on the NSW context, thus highlighting the limitations of those regulations. The reason for the focus on NSW is that it has distinct regulatory requirements for the energy efficiency of homes and has been the state with the greatest level of building work (by current price) for the past four years [11]. The focus of this review paper is on mandatory instruments relating to energy efficiency in-use of mid-rise residential buildings. Therefore, although embodied energy and construction stage energy consumption are of increasing importance, these are beyond the scope of this paper. Similarly, whilst it is acknowledged that addressing the energy efficiency of the existing building stock is of great importance, this review focuses on new build mid-rise residential buildings due to the significant increase in new developments within this sector. The final limitation in scope is the focus on only mandatory pathways to energy efficiency; previous research has shown that legislation is the most significant driver in this respect [12]. In undertaking this review, academic journals, academic conference proceedings and books have been used as sources along with relevant grey literature from the Australian context.

Section 2 of this paper establishes the mandatory standards and regulations for residential energy efficiency in Australia, before an example of the design energy efficiency of a mid-rise residential building is presented in Section 3. Next the findings of the review are discussed in Section 4 before the paper concludes in Section 5.

2. Mandatory standards and regulations for energy efficiency

A variety of motivations drive the regulation of energy efficiency in buildings: countries with harsher winter climates have been quick to implement mandatory building energy efficiency standards; the energy crisis of the 1970s drove many European nations to consider the need to reduce their dependence on fossil fuels, and therefore improve the energy efficiency of their buildings, [13]; and more recently, mandatory energy efficiency regulations have become increasingly stringent as a result of concern over climate change and its potential impacts [14],[15]. Sweden has had national minimum building energy efficiency requirements since the early 1950s [16] and the Building Regulations in the UK have included standards for limiting heat loss since 1965 [17]. Whereas, in Australia, national energy efficiency regulations for homes were not introduced until 2003 [9]. Australia is the sixth largest country in the world by area. It is formed of six states and two territories, each with their own legislation.

The vast geographical nature of the country, with both tropical and alpine areas, and the devolved governing status, together present issues for the setting of national standards for energy efficiency.

The National Construction Code (NCC) is the regulatory framework which establishes all on-site requirements for construction projects at a national level in Australia; it is formed of three separate volumes. Different building types are classified within the NCC in order to be able to address their varied needs. Mid-rise residential buildings fall within Class 2 of the NCC: '*a building containing 2 or more sole-occupancy units each being a separate dwelling*' [18:37]. Requirements for Class 2 buildings are covered within the NCC Volume One; energy efficiency performance requirements are set out in Section J of this volume. The NCC defines eight climate zones across Australia [18:18]. It serves to provide a mandatory minimum, although it is possible for state and territory level legislation to supplant national legislation. And this is the case with the energy efficiency of buildings, where, for example, in New South Wales (NSW) the Building Sustainability Index (BASIX) transcends the federal regulation.

2.1 NCC Section J

Performance requirements covered within Section J include: energy efficiency, building fabric, glazing, airtightness, and air-conditioning and ventilation systems. One route to energy efficiency compliance is for a home to be assessed under the Nationwide House Energy Rating Scheme (NatHERS).

2.2 NatHERS

NatHERS is a ten star design-based rating system [19] that provides information about the heating and cooling needs and thus the energy efficiency of a house. The star rating is derived from an assessment of the home's design and construction materials, using an accredited software, and is specific to the climate in which it is being built. In addition to their use in assessing compliance with the NCC, star ratings can be used by homeowners and builders as a design decision-making tool and to advise prospective homebuyers on the thermal performance of a home.

Since 2010, Section J has mandated a 6* rating average performance within new Class 2 developments, allowing a minimum performance of 5* rating for individual apartments [18]. Although, as can be seen in Table 1 (showing the legislatory requirements for mid-rise residential buildings and the climate zones for the states and territories), some jurisdictions have chosen not to align their regulations with the 2010 update: Queensland requires apartment developments to achieve an average NatHERS rating of 5* with an individual apartment achieving a minimum rating of 4*; and NT requires a 3.5* average rating and 3* individual minimum rating. Similarly to the majority of European energy efficiency standards, NatHERS excludes energy used for cooking and plug-in appliances. However, unlike these European regulations, NatHERS excludes energy used for hot water and lighting. Previous research has found NatHERS to be unsuitable for the calculation of the energy demands of homes designed to operate passively with limited heating and cooling [20]. Criticism has also been levelled at the occupancy profiles adopted within the model, it being suggested that they are not representative of a typical Australian household [21].

Table 1: Design quality and energy efficiency regulations for mid-rise residential buildings in different Australian jurisdictions

Jurisdiction	Climate zones	Regulations	
		Design Quality	Energy Efficiency
Commonwealth of Australia	-	-	NCC Section J / NatHERS 6* average, 5* min.
New South Wales (NSW)	2, 4, 5, 6, 7, 8	SEPP 65 Apartment Design Guide	BASIX
Queensland	1, 2, 3	-	NCC Section J / NatHERS 5* average, 4* min.
South Australia (SA)	4, 5, 6	-	NCC Section J / NatHERS 6* average, 5* min.
Tasmania	7, 8	-	NCC Section J / NatHERS 6* average, 5* min.
Victoria	4, 6, 7, 8	Better Apartments	NCC Section J / NatHERS 6* average, 5* min.
Western Australia (WA)	1, 3, 4, 5, 6	-	NCC Section J / NatHERS 6* average, 5* min.
Australian Capital Territory (ACT)	7	-	NCC Section J / NatHERS 6* average, 5* min.
Northern Territory (NT)	1, 3	-	NCC Section J / NatHERS 3.5* average, 3* min.

2.3 BASIX

BASIX was initially introduced in 2004 in Sydney as a mandatory standard for certain classifications of new dwellings. The aim of the policy is to realise quantifiable improvements in both potable water consumption and greenhouse gas emissions through the encouragement of sustainable building design. In 2005 the standard was extended as a state-wide policy across NSW to include all forms of dwelling developments [22]. BASIX currently takes precedence over Section J in terms of energy efficiency in NSW. Before BASIX was introduced, a benchmark was established for both per capita average water consumption (90,340 litres per annum) and per capita average greenhouse gas emissions relating to energy for heating and cooling (3,292 kilograms per annum) [22]. BASIX establishes targets for a percentage improvement over these benchmarks, which will be increased in 2017. The target percentage improvement is dependent upon the location of the development, and the type of development (Table 2). Housing developers are obliged to commit to water and energy efficient building designs to meet these target improvements before development approval is granted, the way in which they achieve these targets is not prescribed [23]. Derived from the target improvements, separate maximum heating and cooling loads for dwellings are established in megajoules per square metre per year ($MJ/m^2/yr$) for each postcode area within NSW. Within this single state there are significant differences in terms of the requirements under BASIX. Indeed, the maximum heating load for an apartment in Byron, northern coastal NSW (NatHERS climate zone 2, BASIX climate zone 1) (37.9 $MJ/m^2/yr$), differs from the maximum heating load of a dwelling in Cabramurra (NatHERS climate zone 8, BASIX climate zone 3), Alpine NSW (842.6 $MJ/m^2/yr$), by a factor of 22 [24]. Similarly, there is a difference of a factor of 6 between the highest and lowest cooling load limits applied in different areas of NSW (e.g. 19 $MJ/m^2/yr$ in Orange – NatHERS climate zone 7, BASIX climate zone 3 - and 132.1 $MJ/m^2/yr$ in Moree – NatHERS climate zone 4, BASIX climate zone 3).

Table 2: BASIX energy targets (percentage improvement over benchmark) [22]

Project type	Pre-2017 targets			2017 targets				
	Zone 1	Zone 2	Zone 3	Zone 1A	Zone 1B	Zone 2	Zone 3	Zone 4
Detached and attached houses	40	35	25	50	50	45	40	35
Low-rise units (2-3 storeys)	35	30	20	45	40	35	30	25
Mid-rise units (4-5 storeys)	30	25	15	35	30	25	20	15
High-rise units (6 storeys +)	20	15	5	25	20	15	10	10

Mid-rise residential buildings developed in NSW (defined within this paper as four to eight storeys) are required to be assessed using a multi-dwelling BASIX tool [22]. The multi-dwelling tool assesses both the overall heating and cooling loads for the building against a project-wide cap and individual apartments against a less stringent individual apartment limit. This, for example, allows apartments with less than optimal orientation, to consume more energy for heating and/or cooling than the average apartment, but for this to be balanced out by better performing apartments within the building.

2.4 Mandatory disclosure of energy performance

Disclosure of the modelled energy efficiency performance of a home within the Australian Capital Territory (ACT) has been mandatory at the point of sale or lease since 1999 [25]. For this purpose, the rating of a home's energy performance is assessed using NatHERS software. In 2007, a statistical study was conducted which ascertained that there was a significant relationship between house price and energy efficiency rating in the ACT [26]. In 2010, Queensland introduced a requirement for vendors to complete a *Sustainability Declaration,* in the form of a self-completion factsheet, providing potential purchasers with information on the energy, water, safety and access attributes of their home [27]. However, the scheme was short-lived, being repealed in 2012.

In 2009, the COAG proposed that mandatory disclosure of energy efficiency should be introduced for all residential buildings, nationally, at the point of sale or rent [25]. Consultation was undertaken on the proposals within a Regulation Impact Statement (RIS) [28]. The potential benefits of mandatory disclosure within the Australian housing market are stated to be that it would address the current information asymmetry in which the person purchasing or leasing a home does not have access to the same information as the vendor or landlord at the point of making a decision. It is also asserted that a lack of information in terms of energy efficiency drives high quality products out of the market [25]. The importance of a nationally consistent approach was highlighted within the consultation process but agreement on such an approach failed to be reached [9]. Thus, despite the RIS identifying a simplified thermal assessment approach to mandatory disclosure as being cost beneficial [28], there is currently no national requirement to disclose the energy efficiency performance of a home in Australia.

2.5 Design standards which impact upon energy efficiency of apartment buildings

There are currently no national design standards for apartment buildings within Australia. State Environmental Planning Policy No. 65 (SEPP65) is a NSW State Policy for the design of apartments. It is applied to multi-residential developments of three or more storeys containing four or more dwellings. The aim of the policy is to *'improve the design quality of residential apartment development in New South Wales'* [29:4] in order to take best advantage of the social, economic, cultural and environmental benefits of good quality design. SEPP65 defines nine design quality principles which must be considered, including: built form and scale, density, sustainability, landscape, and amenity.

The Apartment Design Guide (ADG) is a supplementary document to SEPP65 which provides guidance to both designers and planners in terms of achieving and evaluating the required design quality principles. Certain objectives, criteria and guidance within the ADG are mandated within SEPP65. A number of these criteria are intrinsically related to the energy efficiency of an individual apartment and a development as a whole. For example, solar and daylight access criteria require that a maximum of 15% of apartments within a development receive no direct sunlight within habitable rooms between 9am and 3pm in mid-winter [30]. Solar access not only has the potential to reduce the amount of artificial lighting required, but also to provide solar gains to offset heating required. The ADG also requires at least 60% of apartments within a development to be naturally cross ventilated for buildings up to nine storeys, reducing the need for mechanical ventilation and cooling. Other mandated design criteria include: ceiling heights, apartment size and layout, and private open space and balconies.

The Victoria State Government published design standards for '*Better Apartments*' in December 2016 [31]. The standards were developed to ensure that all new apartments built in Victoria provide healthy and liveable conditions for occupants, whilst also ensuring affordability. The standard, to be introduced through the Victoria Planning Provisions in March 2017, is intended to be supported by design guidelines as well as education and training for planning and design professionals. The categories covered within the standard include: energy efficiency, natural ventilation, windows, and room depths, all of which have the potential to influence the energy consumption of apartments. In order to improve minimum standards for thermal performance in summer, maximum cooling loads have been introduced. Research undertaken to inform the development of these standards found that, within individual apartment buildings, vast differences in terms of both comfort and peak cooling loads currently exist [32].

3. Example of the design energy efficiency of a mid-rise residential building

For the purpose of illustrating how BASIX and NatHERS compare when applied to a mid-rise residential apartment building, a brief example is presented here for discussion in the context of the literature. An archetype mid-rise residential building has been designed on a notional site in Sydney. The building is seven storeys above ground level (Ground to Level 6) with a single basement car park level (**Error! Reference source not found.**). The building contains 60 apartments of varying size from 1-bedroom to 3-bedroom. It has been designed to be typical of the sector, not exemplary, and hence to comply with but not significantly exceed any regulatory requirements.

Figure 1: 3D visualisation of archetype mid-rise residential building.

A BASIX assessment of the archetype building has been carried out and the NatHERS rating calculated using BERS Pro v4.3. Table 3 presents information relating to the three poorest performing apartments and the three best performing apartments from the archetype building in terms of energy efficiency, together with the averages across the whole building. For the archetype building, the maximum heating load permitted under BASIX is 66MJ/m^2/yr and the maximum cooling load is 59MJ/m^2/yr. None of the apartments failed to meet the cooling load requirement, but eight apartments required additional measures to meet the heating load requirements. It is notable that the worst performing apartment in terms of heating load differs from the best performing by a factor of 2.5. Furthermore, the worst performing apartment in terms of cooling load differs from the best performing by a factor of 3.

Table 3: Design and energy performance data from selected apartments within the archetype mid-rise residential building

Unit no.	Descriptive information				Energy performance			
	Level	Area (m^2)	Orientation	Aspect	NatHERS rating	Heating load (MJ/m^2/yr)	Cooling load (MJ/m^2/yr)	Additional measures required
2	G	79.5	S & W	Dual, corner	3.5	66.0	36.5	Stairwell & subfloor ins.
38	3	78.6	S & W	Dual, corner	3.4	65.5	39.3	-
48	4	78.6	S & W	Dual, corner	3.4	65.9	43.2	Stairwell insulation
13	1	81.4	E & W	Dual, cross	6.6	30.8	13.1	-
23	2	81.4	E & W	Dual, cross	6.6	30.4	14.0	-
49	5	99.7	N & E	Dual, corner	6.6	25.4	18.6	-
Ave.	-	*76.0*	-	-	*5.0*	*46.6*	*23.1*	-

4. Discussion

In 2005, when debate was occurring regarding proposals to increase the minimum NatHERS requirements from a 4* to a 5* rating, an international comparison study was undertaken [10]. The study identified that, even after the proposed stringency increase, Australian houses would consume significantly more energy than those built to meet the regulations in comparable climatic locations. Across the eight comparison locations, a total of 51 house plans were assessed using NatHERS software; the median rating in those comparable locations at that time (2005) was 7.5*. The authors concluded that increasing the stringency of the energy efficiency requirements in Australia was not only practicable, but warranted to avoid acting as '*a brake on the Australian economy in a world of increasing fossil fuel scarcity and rising prices*' [10:5]. The increase to a 5* rating occurred in 2006, but since then the routemap for increasing stringency has been deviated from. It has been suggested that Australian energy efficiency policy has entered '*sleep mode*' since the most recent (and only partially adopted) stringency increase to NatHERS 6* rating in 2010 [9]. This is despite research concluding that it is possible to improve the energy efficiency of homes by one star rating through design adaptations tailored to a site and its orientation with *reduced* construction costs [33]. Furthermore, in 2013, Morrissey et al. [34] concluded that requiring new homes to reach an 8* rating would have the greatest whole economy benefit over 25 years when compared to a 6* or 7* rating requirement. It is therefore surprising that proposals for the 2019 update of the NCC suggest that a consolidation approach will be taken at that stage to ensure the 2010 levels are being met [35] rather than setting more aspirational standards for developers to achieve. No similar studies have been conducted more recently to update the 2005 comparison, but the fact that 12 years on, Australia has yet to reach the energy efficiency levels other countries were setting at that stage (and in the context of continued stringency increases in those comparison locations) suggests that the Australian construction industry is being left behind when the global context is considered. It has thus been concluded that although net zero carbon housing is both technically and economically feasible in Australia, '*the missing link is the political will to improve the environmental, social and economic performance of Australian homes*' [9:971].

BASIX places minimum requirements on both heating and cooling loads (to ensure energy efficiency and thermal comfort throughout the year), whereas, NatHERS makes a requirement for the maximum overall heating and cooling load of a home. The NSW Department of Planning has argued that NatHERS delivers thermal comfort enhancements for occupants, but that these fail to be linked to reduced greenhouse gas emissions [22], and thus that BASIX provides a more appropriate assessment in terms of energy efficiency. However, the example presented in

Table 3 illustrates that the BASIX requirements result in an overall energy consumption that is significantly higher than would be allowed under NatHERS. The worst performing individual apartments in the archetype building were rated at 3.4* under NatHERS. These apartments suffered from poor performance in both winter and summer conditions, and thus had both the highest heating and cooling loads. If the NSW Government had adopted Section J, these individual apartments would need to achieve a NatHERS rating of 5* and the building overall would require an average rating of 6* as opposed to the 5* average achieved under BASIX. The example therefore casts into doubt whether BASIX does indeed result in greater reductions in greenhouse gas emissions, and also highlights the broad variations in energy consumption and thermal comfort between apartments in the same building that result from BASIX. The diverse energy load results for the apartments within the archetype building are also, in part, as a result of the solar access and natural ventilation design criteria established by the ADG. Whilst these criteria offer flexibility to architects when designing apartment buildings, they fail to challenge them to produce buildings in which *all* apartments are designed to provide comfortable environments using passive design. As a result of similar concerns regarding the variability in summertime performance of apartments in Victoria under Section J, '*Better Apartments*' [31] introduces cooling load caps for apartments. This additional constraint starts to address concerns regarding overheating under NatHERS whilst encouraging passive design for the prevention of overheating [32].

The NSW Government is currently consulting on introducing voluntary disclosure of energy efficiency performance for homes at the point of sale or lease from 2018, transitioning to mandatory disclosure from 2020 if proved to be efficient and effective [36]. Previous research on the mandatory disclosure scheme in ACT (introduced in 1999) illustrates that it has, in time, delivered a tangible impact upon the housing market there [28]. Indeed, by 2006, house prices were shown to increase by 1.91 percent for each 0.5* rating improvement, with homes included in the study ranging from zero to six stars with an average rating of 1.7*. It is therefore of concern that the proposed timescale between voluntary and mandatory disclosure in NSW is only two years, and that the NSW Government plans to assess the efficacy of the programme within that time. It has been found previously that the take-up of voluntary rating systems has been slow and limited [37]. It is therefore likely that voluntary adoption will be minimal and thus unlikely that tangible results will be evident by 2020.

5. Conclusion

This critical review has explored the regulatory framework for energy efficiency in mid-rise residential buildings in Australia. It is acknowledged that the vast geographical nature of the country, and hence the significant variance in climate between the eight climate zones, present a complex context within which to establish energy efficiency regulations. However, by accommodating these climate zones with targets which address these variations, the regulations set out in Section J of the NCC should allow for equitable treatment in all areas. The fact that not all states and territories are willing to adopt the national regulations, when they have been previously demonstrated to be aspirationally low at the global level, is of concern. Of even greater concern is that the forward trajectory for regulation fails to establish a pathway to net zero energy or net zero carbon, despite its technical feasibility. The paper has highlighted the limitations of NSW policy including BASIX in failing to effect significant energy savings within mid-rise residential apartments, and the ADG in allowing a proportion of each development to avoid being designed to passive design principles.

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