Issues in Compliance with Low-Carbon Requirements in the Australian Residential Building Industry

Yi Lu, Gayani Karunasena and Chunlu Liu

January 30, 2023

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Yi Lu[1*], Gayani Karunasena[2] and Chunlu Liu[3]

[123]School of Architecture and Built Environment, Deakin University,
Geelong VIC 3220, AUSTRALIA

[1]yi.lu@deakin.edu.au; [2]gayani.karunasena@deakin.edu.au; [3]chunlu.liu@deakin.edu.au
* Corresponding author

Abstract:
Low-carbon requirements have long been acknowledged as critical instruments to facilitate residential building industry's transition toward decarbonization in Australia. However, recent studies in the residential building sector have shown that compliance with low-carbon requirements is under-researched, which has led to a significant divergence between low-carbon requirements' intentions and actual performance. Therefore, based on the methodology of literature review, the paper aims to provide a comprehensive exploration of issues in compliance with low-carbon requirements within the Australian residential building industry. Through reviewing research works and policy documents, the paper firstly demonstrates the Australian developments in promoting low-carbon residential buildings, by summarizing key low-carbon requirements and their corresponding purposes. This highlights the significance of these requirements in spurring emission reduction from residential buildings. Subsequently, relying on regulatory studies concerning the National Construction Code (NCC) energy efficiency provisions, the paper reveals the wide presence of non/under-compliance challenges across every construction stage. It further indicates that such issues are largely attributed to major stakeholder groups including regulators (policymakers, building control officers), regulated building practitioners and occupants. Finally, the paper identifies research gaps and proposes future works in the areas of enhancing enforcement regimes, design of the energy simulation tool, raising occupants' awareness and investigating building practitioners' compliance behaviour. The paper implies the urgency to investigate the suboptimal compliance phenomena in the Australian residential building industry, as these issues have already impeded the achievement of the industry's low-carbon future. It also brings contributions via enlightening future research areas to address the issues.

Keywords:
building practitioner, compliance, energy efficiency, low-carbon, residential building industry

1 Introduction

Australia is one of the highest emitters per capita in the world (Ahmed et al., 2021). In 'Australia's Long-term Emissions Reduction Plan' released ahead of the United Nations Climate Change Conference (COP26) in 2021, the government's commitment to net-zero emissions by 2050 is reaffirmed (Commonwealth of Australia, 2021). For achieving this target, as stated in this whole-of-economy Plan, Australia's building sector will need to nearly achieve decarbonization by 2050 (p. 69). Along with the evolution of Australian climate change mitigation policy, residential building has always been highlighted as a critical and indispensable part of the strategy to reduce Australia's carbon emissions. Currently, residential buildings consume around 12% of total carbon emissions in Australia, 2% more than non-residential buildings' contribution (Commonwealth of Australia, 2022). Apart from the challenges of this existing carbon emissions profile, the significantly increased number of new dwellings alongside the growth of Australian population has imposed an even larger burden.

According to Urban Property Australia (2016), Australia is estimated to have 2,700,000 new homes by 2030.

Governments in Australia have issued a wide range of policies to drive the low-carbon transition in the residential building industry. However, notwithstanding the considerable efforts made via regulatory measures, the current residential building industry will be unlikely to deliver a low-carbon housing as targeted (Hurlimann et al., 2018; Doyon & Moore, 2020). A prevailing explanation is the difficulties in compliance with low-carbon building requirements (van der Heijden, 2016; Enker & Morrison, 2019). In Australia's National Energy Productivity Plan 2015-2030 which seeks to reduce carbon emissions (Council of Australian Governments (COAG) Energy Council, 2015), one of the measures (measure 32) is to improve compliance with building energy efficiency regulation. Furthermore, in a report that particularly investigates the Australian building regulation framework, Harrington and Toller (2017) stress that key elements of an optimal low-carbon policy setting for the built environment should constitute, among others, encouraging compliance and over-compliance with the regulation. Accordingly, for Australia to fulfil the 2050 net-zero carbon built environment commitment, the issues with compliance with low-carbon requirements must be addressed urgently (Bannister et al., 2018).

Nevertheless, recent study suggests that the compliance with low-carbon requirements within the residential building industry is still under-researched (Chen, 2021). Therefore, the current research seeks to comprehensively explore the issues in compliance with low-carbon requirements within the Australian residential building industry through the methodology of literature review.

2 Literature Review

Globally, some organizations and countries have issued a set of requirements which seek to accelerate residential housing's movement to decarbonization. For instance, in 2021, the European Commission has proposed a revision for its earlier version of Energy Performance of Buildings Directive (2018/844/EU). The proposal provides a trajectory for Europe to achieve a zero-emission and completely decarbonized building stock by 2050 (European Commission, 2022). In New Zealand, the central government also initiated 'Building for Climate Change programme', which sets operational and embodied carbon reduction targets for buildings (New Zealand Government, 2022). Other developed countries such as the USA, UK, Canada also established their corresponding regulatory framework aiming at low-carbon dwellings. Such initiatives underline the importance of regulatory measures within the residential sector in spurring carbon emission reduction internationally.

Parallel in Australia, building policies have also long been recognized as a critically important instrument to systematically facilitate the reduction of emissions from Australian residential buildings, especially if the industry is to transition to a lower-carbon future (Moore et al., 2019; Commonwealth of Australia, 2021; Li et al., 2022). On that account, many regulatory measures targeted at low-carbon residential buildings have been developed and implemented in Australia. A summary of the key policies and their corresponding low-carbon targets residential buildings is provided in Table 1.

Table 1. Australia's policies targeting low-carbon residential buildings
Source: Doyon and Moore (2020), ABCB (2022) and NatHERS (2022)

Policy	**Year**	**Mandatory or voluntary**	**Low-carbon related target**
National Construction Code (NCC)	1990 1st edition; 2022 is the latest edition	Only the minimum performance requirements are mandatory	Energy performance is set and linked to the NatHERS
Nationwide House Energy Rating Scheme (NatHERS)	Introduced in 1993; Revised in 2022	Mandatory	A stringency increased to 7-star in 2022, determined based on home's design, materials and climate zone
Trajectory for Low Energy Buildings	Issued in 2018; agreed in 2019	Voluntary	An outline of trajectory spanning from 2018-2027 towards the achievement of low energy (and carbon) ready buildings
Your Home Manual	2001 1st edition; currently 6th edition	Voluntary	Improved sustainability in a broad sense. No specific targets set
National Australian Built Environment Rating System - Home	Launched in 1998	Mandatory for all new buildings over 2000 m^2 and buildings that are up for lease and sale	Improved energy and water use. Specific targets are set based on building type, use and located climate zone
National Carbon Offset Standard for Buildings	2017	Voluntary	No specific targets set

Since the Australian Labor Party campaigned on legislating a net zero emissions target by 2050, with a 43% reduction by 2030 (Evans, 2022), the federal election of the Labor government in May 2022 offered a glimmer of hope that Australia may join actions to combat global warming more ambitiously (Pears, 2022). Nevertheless, though under the pressure of achieving the net-zero commitment by 2050, the overall manifestation the low-carbon policy developments in Australia greatly reflects a glacial speed of change rather than a radical transformation, which is also implied by Berry and Marker (2015) and Doyon and Moore (2020). Remarkably, it takes the national government more than a decade to increase the stringency level of minimum energy performance from 6 star in 2010 to 7 star in 2022, which lags well behind other developed countries' developments (Fuerst & Warren-Myers, 2018). Compared with the federal-level slow development, the state-level government seems to have a stronger will to expedite the low-carbon activity, with exploring multiple guidelines and program that go beyond the NCC requirements, similar to Harrington and Toller (2017)'s findings. However, most of these policies are not mandatory. At the municipality level, whilst still voluntary approach, the attempt to find a way around the federated system can also be observed. Under these circumstances, if the compliance status is continuously suboptimal, the effectiveness of the low-carbon regulation will be further negatively impacted (Meacham, 2016), and the 2050 net-zero target will probably not be achieved (Bannister et al., 2018).

3 Research Methodology

Compliance studies in the context of low-carbon buildings typically involves research areas concerning low-carbon building regulations (van der Heijden & De Jong, 2009), legal studies involving compliance theories (Becker, 1968) and behavioural science (Enker & Morrison, 2019). As per Snyder (2019), literature review is an excellent way to provide a comprehensive exploration of a certain issue of which the research work is disparate and interdisciplinary. The current research thus adopts a three-step systematic review methodology, including planning, conducting and reporting stages, which have been popularly leveraged in recent review studies (Cai & Choi, 2021; Srinivas et al., 2022).

In the first step of planning, the key activity is to identify keywords that result in a list of academic works regarding compliance with the low-carbon residential building requirements. As mentioned in section 1, studies in this domain are under-researched, the researcher manually investigated the titles, abstracts and keywords of relevant articles. Ultimately, ‘compliance’, ‘building regulatory compliance’, ‘low carbon’, ‘building regulation’ ‘energy efficiency’ are determined as the keywords for retrieving papers. In the second step, a search query was performed in Scopus and 136 articles were retrieved. Subsequently, inclusion and exclusion criteria were established to perform filtering process manually. By reading the titles and abstracts, papers on indoor air quality, urban planning and those not related to residential domain were excluded. Complementing the Scopus query, the researcher also tracked and inspected articles that were referenced in the filtered papers. Notably, 4 reports under the National Energy Efficient Buildings Project (NEEBP) were included, as the NEEBP specifically investigates compliance with the NCC energy efficiency provisions in Australia. In the final stage, 22 articles were selected for review. Based on keywords, objectives and findings, the reviewed articles are segregated into compliance issues relating to regulators (13), regulatees (10) and occupants (9)[1], with many works investigating more than one type of stakeholders. The articles which provide a general compliance status information that do not fall under any of the earlier categories, were classified as others (5). The literature retrieval and segregation process are summarized in Figure 1.

In order to analyse the influencing factors that impact compliance, the collected literature was analysed through method of code-based content analysis using NVivo 20. Content analysis is a research method which is used as subjective interpretation of the article content by systematic classification process of coding (Hsieh & Shannon, 2005). The multi-level coding 'factors from regulators', 'factors from regulatees' and 'factors from occupants' was used in analysis for identifying common themes separately under each of the key project phase, which is consistent with stakeholder group classification in the work of Pan and Ning (2015). Data processing in NVivo 20 was conducted following six steps (i) importing files; (ii) running word frequency query to get a list of keywords; (iii) generating nodes based on relevant keywords; (iv) conducting text search query for keywords; (v) visualizing; (vi) reporting. In this study, the articles were imported into the software and explored to identify keywords. Accordingly, under three main nodes (design stage, construction stage, operation stage), sub-nodes were identified, and coding structure was established. Subsequently, 'text search query' was performed by restricting the search to minimum three keywords. The coding structure was then visualised in Figure 2 and ready for analysis.

[1] In the current study, regulators refer to policy makers and building control officers, which include e.g., law makers, building surveyors, energy assessors. Regulatees refer to regulated building practitioners such as architect, builder, engineer etc. Occupants refer to occupiers and end-users of the residential dwelling.

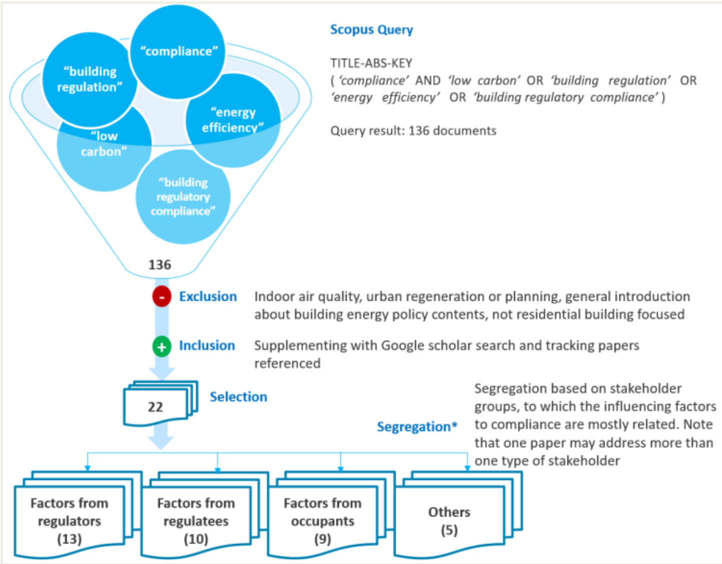

Figure 1. Flowchart of the literature retrieval and segregation process (*segregated papers may address more than one stakeholder)

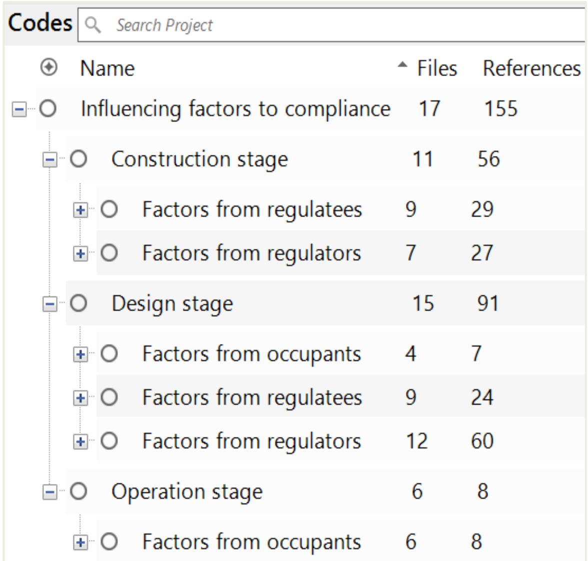

Figure 2. Overview of the coding structure

Key findings derived from data analysis are illustrated below.

4 Findings and Discussion

Most of the selected literature relates to the Australian building industry (54.5%), followed by UK (13.6%), the USA (9.1%), and other countries. In the following section 4.1, the issues prevailing in compliance are revealed, which focuses on the specific Australian residential building industry. Section 4.2 then specifies the contributing factors to compliance which draws predominantly from Australian studies, with supplementation from works in other countries.

4.1 Overview of Issues in Compliance

Low-carbon requirements in the residential building industry concern more than energy efficiency, however it is discovered that all the reviewed articles in Australian context pay their attention to the NCC energy efficiency provisions. This more narrowed focus is consistent with arguments from recent low-carbon building policy studies. For example, Li et al. (2022) state that energy efficiency provisions in the NCC are the most critical instrument to drive the low-carbon future in Australia's residential building industry. In the context of NCC energy efficiency provisions, compliance means complying with both the governing requirements of the NCC and the performance requirements. This infers that the compliance is relevant to not only the design phase (i.e., pre-building permit stage) but also the construction stage (i.e., post-permitting stage) (Miller et al., 2020). Several studies have highlighted that compliance issues exist systematically along the building project stages. Such research in Australia is typically represented by NEEBP commenced in 2012, which is led by the Government of South Australia's Department of State Development and is co-funded by all Australian states and territories through the Council of Australian Governments (COAG) Energy Council.

Under NEEBP, the study by Pitt & Sherry (2014) undertakes a national investigation of non-compliance with NCC energy efficiency provisions and argues that non-compliance exists in each jurisdiction, and covers all stages of a residential construction project. Though this report does not quantify the extent of compliance or non-compliance (Pitt & Sherry, 2014, p. vii), it indicates the wide-presence of non-compliance issues across the Australian residential building industry. Then, subsequent NEEBP studies examine possible solutions concerning the inspection process and building data management system to address the compliance issues. Other than the NEEBP research, Moore et al. (2019) and Jensen et al. (2020) have also provided empirical evidence on how the Australian residential building industry stands in terms of its NCC energy efficiency compliance level at the design and construction stages. Drawing substantially from the above findings, key points of issues in compliance in the Australian residential building industry are summarized in Figure 3. As indicated by Bannister et al. (2018) and Miller et al. (2020), these compliance issues are still present.

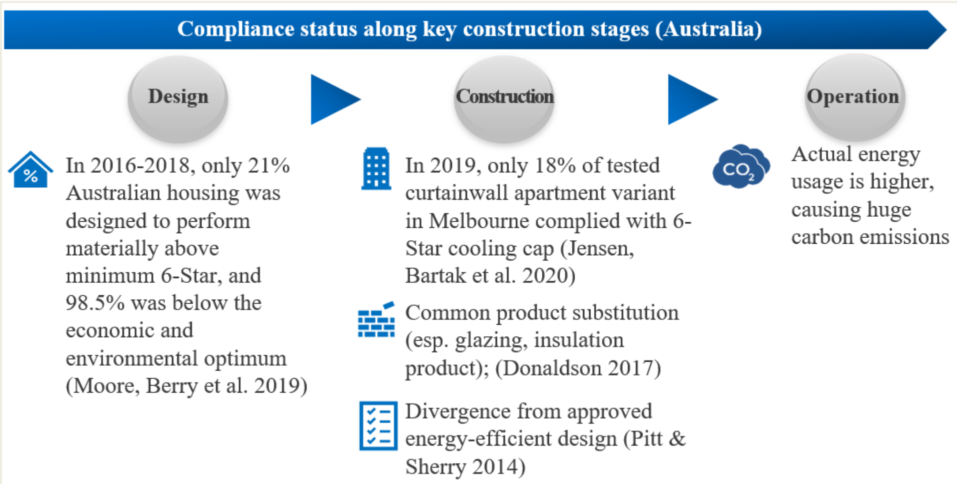

Figure 3. Issues in compliance with the NCC energy efficiency requirements

This high-level summary figure indicates that compliance with the NCC energy performance requirements is generally poor, and issues cover key aspects of the building project stages. In the design stage, most housing designed in Australia was designed only to meet minimum standard, without aiming for economic and environmental optimum. Such situation was described as '*mediocrity*' by Moore and Holdsworth (2019, p. 602), which reveals building industry stakeholders' hesitance to move beyond code minima. Moving to the construction stage, the recently tested compliance result by Jensen et al. (2020) reflects the severance of non-compliance, with only 18% of tested samples achieving minimum cooling cap. Additionally, substitution with low-efficiency building products and systems was commonly observed. Furthermore, projects were largely not delivered as per approved design documents. All the weaknesses presented above have negatively impacted the energy performance during the operation stage. They imply higher energy consumption and higher costs for building owners. Importantly, they imply higher emissions to society, and jeopardize the country's motion toward net-zero.

Therefore, it is necessary to investigate what contributes to these issues in compliance. A list of factors was recognized and described in subsequent section 4.2.

4.2 Influencing Factors to Compliance

Through reviewing a set of empirical studies in Australia and other countries, several contributing factors to compliance have been identified, which are sorted according to its relevance to key project stage. Detailed list of factors and corresponding referenced articles are presented in Table 2.

Table 2. Influencing factors to compliance with building energy requirements

Stage			Influencing factors to compliance	Stakeholder			Reference (* are studies conducted beyond the context of Australia)
Design	Construct	Operation		Regulator	Regulatee	Occupant	
✓			As-designed not as-built energy assessment	✓			[1],[2]
✓			Changes in code provisions	✓			[1],[3*],[4*]
✓			Divergent energy performance requirements set in the regulation cause confusion on levels of compliance needed and negatively affects the compliance with rules[2]	✓			[5]
✓			Emphasis level on energy efficiency issues by building control officers	✓			[1],[3*]
✓			Flawed energy assessment tool	✓			[1], [6*],[7*],[8*],[9],[10],[11]
✓			Inconsistent code interpretation in different states	✓			[1],[4*],[5],[9]
✓			Lack of accountability settings	✓			[1],[2],[4*],[5]
✓			Lack of mandatory disclosure of energy performance	✓			[1],[2]
✓			Lack of options to prove compliance	✓			[1]
✓			Sign-off culture among (private) surveyors and energy assessors	✓			[1]
✓			Skills insufficiency and lack of training for building control officers	✓			[1],[2],[3*],[10],[15]
✓			Unclarity in the regulation	✓			[1],[4*],[5]
✓			Under resourcing of inspectors within Local Government	✓			[1],[9]
✓			Gaming around different compliance pathways		✓		[11]
✓			Ignorant and apathetic attitude toward energy efficiency provisions		✓		[1],[12]
✓			Low compliance-related knowledge		✓		[1],[2],[3*],[4*],[14],[15]
✓			Moral duty to obedience		✓		[13*]
✓			Shopping-around culture among regulated building practitioners		✓		[1]
✓			Social norms to comply		✓		[12],[13*]
✓			Unbuildable design		✓		[1]
✓			Consumer lacking interest on energy-efficient design			✓	[1],[2],[12],[15]
	✓		As-designed not as-built energy assessment	✓			[1],[2]
	✓		Changes of code provisions	✓			[3*],[4*]
	✓		Lack of accountability settings	✓			[1],[2],[4*],[5]
	✓		Lack of mandatory inspection	✓			[1],[2],[9],[15]
	✓		Lack of performance testing of building products	✓			[1],[9],[15]
	✓		Builders' removal of energy-efficient features or designs		✓		[1],[10]
	✓		Ignorant and apathetic attitude toward energy efficiency provisions		✓		[1],[12]
	✓		Low compliance-related knowledge		✓		[1],[2],[3*],[4*],[13*],[14],[15]
	✓		Moral duty to obedience		✓		[13*]
	✓		Social norms to comply		✓		[12]
	✓		Substitution of high-efficiency version products		✓		[1],[15]
		✓	Occupant behaviour			✓	[1],[6*],[7*],[10],[16*],[17*]

List of referenced articles

1 Pitt & Sherry (2014)
2 Harrington and Toller (2017)
3* Pan and Garmston (2012)
4* Nwadike and Wilkinson (2021)
5 Miller et al. (2020)
6* Carpino et al. (2020)
7* Ouf et al. (2019)
8* Choi (2017)
9 Bannister et al. (2018)
10 Enker and Morrison (2020)
11 O'Leary et al. (2018)
12 Enker and Morrison (2019)
13* May (2004) USA
14 NEEBP (2016)
15 Donaldson (2017)
16* Martinaitis et al. (2015)
17* Gill et al. (2010)

[2] In the NCC 2022, Class 1 dwellings will be required to achieve 7-stars NatHERS and the corresponding heating and cooling load limits. Class 2 dwellings will be required to achieve an average of 7 stars and minimum of 6 stars.

As per the coding structure in Figure 2, during design stage, 12 referenced articles ([1]-[11],[15]) discussed influencing factors that are generated from the regulators side. 9 works ([1]-[4],[11]-[15]) concerns factors from regulatees side, and 4 articles ([1],[2],[12],[15]) relate to factors from occupants. In the construction phase, 7 literature ([1]-[5],[9],[15]) relates to factors from regulators and 9 articles ([1]-[4],[10],[12]-[15]) to factors from regulatees. In the operation stage, 6 articles ([1],[6],[7],[10],[16],[17]) indicate factors from the occupants side.

Observing the overall building project cycle, following main findings can be elicited. First, the energy rating tool is identified as one of the most significant influencing factors. 7 of chosen literature indicates the flawed design of the energy assessment tools in that they do not reflect actual energy usage, or they generate varied simulation results even on a same building project, which could be potentially gamed by practitioners through switching to different tools to achieve a compliant result when the project is actually under-compliant (O'Leary et al., 2018). Second, knowledge level toward compliance with energy requirements is low for all stakeholder groups. Building control officers have insufficient skills to assess energy compliance, while building practitioners have not mastered energy-efficient techniques or knowledge regarding available compliance options that are offered in the NCC. Third, implementation and enforcement are also a paramount challenge. Among others, inconsistent implementation and interpretation of the NCC energy requirements among different states and territory, lack of mandatory inspection regime on energy efficiency feature especially during post-design stage, and inadequate tracking of building products and systems' information are all considered significant. Fourth, human behaviours relating to building occupants and residential building practitioners play a central role in contributing to the current compliance status. As the building end-users, occupants generally have low awareness of energy efficiency. Resultantly, the way they use the buildings has greatly undermined the energy-efficient design's value. From the building practitioners' side, many factors are manifested which include ignorant attitude toward low carbon and energy efficiency, social pressure from clients, and personal moral concerns.

5 Conclusion and Further Research

This research has conducted a review on the literature in order to explore main issues in compliance with low-carbon requirements within the residential building industry, with a focus in Australia, supplemented by relevant evidence in other countries. It is uncovered that countries worldwide have developed and implemented a series of policies, which are meant to be a powerful and preferred instrument for delivering improved building performance outcomes. However, analysis shows that the effectiveness of these requirements has been negated by problems with compliance issues along the construction stages. As key research findings, influencing factors to compliance can be attributed to all stakeholder groups based on a compound of technical, social and behavioural aspects. Considering the issues discovered in the selected literature, a set of gaps warranting further research is discovered.

The first future research area relates to the enforcement regimes from the regulators side, which is deemed as a serious challenge in the Australian low-carbon residential building industry (Bannister et al., 2018). Special focus can be put on the quality assurance mechanism which facilitates the implementation, tracking and verification of compliance with the NCC energy efficiency requirements.

Furthermore, there is an urgent need to develop an energy rating tool that can better reflect better true occupants' practices upon various residential building types (Ouf et al., 2019)

In addition, future studies should draw notions from behavioural economics to enhance building occupants' awareness of the benefits of energy efficiency (Enker & Morrison, 2020).

The fourth area is to investigate practitioners' compliance behaviour. It is implied by Pan and Ning (2015) and Enker and Morrison (2019) that there is insufficient research on understanding on why practitioners perform such compliance behaviour as they respond to these low-carbon requirements, and under what situations will their behaviour be triggered to change (Pan & Ning, 2015; Enker & Morrison, 2019). This overlook in the research works has caused significant divergence between low-carbon requirements' intentions and actual compliance behaviour (Pan & Ning, 2015). It is important to understand why practitioners perform such compliance behaviour as they respond to these low-carbon requirements, and under what situations will their behaviour be triggered to change.

6 Acknowledgement

The authors thank Mr Stephen Kip (Board member of the Australian Building Codes Board) in providing insights on the current research topic with his depth of knowledge and experience in the area of Australian building regulations.

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