Level of preparedness of the residential building industry in Australia to climate change adaptation: a case of residential building companies in Brisbane, Queensland

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Abstract
The consequences of climate change are profound for the residential building industry and, unless appropriate adaptation strategies are implemented, will increase exponentially. The consequences of climate change, such as increased repair costs, can be reduced if buildings are designed and built to be adaptive to climate change risks. This research investigates the preparedness of the Australian residential building sector to adapt to such risks, with a view to informing the next review of the National Construction Code (2022), which at present does not include provisions for climate change adaptation. Twelve semi-structured interviews were conducted with construction managers from residential building companies in Brisbane, Queensland to understand their level of preparedness to adapt with climate change risks. Three aspects of preparedness were investigated: participant’s awareness of climate change risks, their company’s capacity to include climate change information in planning, and actions taken to address climate change risks. Participants were also asked about climate change adaptation policies and what they thought the path towards increased preparedness in the residential construction industry to climate change risks might involve. Qualitative analysis of interview data was undertaken using NVivo software, and illustrative examples and direct quotes from this data are included in the results. The results indicate a low level of preparedness of the residential building industry to adapt with climate risks. Levels of awareness of managing the consequences of climate change risks, analytical capacity, and the actions taken to address climate change were all found to be low. Legislating climate adaptation practices and increasing the adaptation awareness of the residential constructors are some of the recommendations to enhance the preparedness of the residential construction industry in Australia to adapt with climate change risks.

Keywords Climate change · Adaptation · Risks · Residential building · Awareness

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1 Introduction

Industrialization, human population growth, and urbanization that result in increased greenhouse gas emissions are the main drivers of climate change, as they have increased energy consumption and the release of greenhouse gases (Hurlimann et al. 2018; IPCC 2021). Not only do accommodating and housing the planet’s growing human population have significant climate effects, with residential and non-residential buildings accounting for 40% of the world’s energy consumption and one-third of global greenhouse gas emissions (Ren et al. 2011; Oberheittmann 2012), but also significant changes are demanded of the residential building sector in response to actual and expected impacts of climate change (IPCC 2021). Climate change is expected to increase the frequency and severity of floods, droughts, heatwaves, sea-level rise, increased air temperature, and extreme weather events (Few 2003; Tompkins 2005). Examples of extreme weather events are heavy precipitation, prolonged droughts, and windstorms (Beniston et al. 2007).

As described by Moser and Ekstrom (2010), climate change adaptation strategies and actions are multiple and complex. They can range from short-term coping to long-term, deeper transformations. A central concept in climate change adaptation is risk. A combination of the likelihood and the consequence of an occurrence is generally defined as risk (Jones 2003). One example of key climate change risks identified for the international building industries are effects on the timely completion of the construction projects, health and safety considerations on site due to increasing temperature (Hertin et al. 2003; Sussman and Freed 2008). Taylor et al. (2012) highlight the risks of decreasing property values, requirements to upgrading building design standards and costs of insurances as mostly perceived climate change risks by the Urban Design Institute of Australia. For instance, the extreme weather events that hit Queensland in 2011 had resulted in increasing property insurance premiums by 1000% in certain disaster-prone areas in the state (Ma et al. 2012).

The preparedness for the adaptation of climate change risks in this research is understood based on three dimensions: awareness of climate change risks, analytical capacity to transform information on climate change into planning and management as well as actions to address climate change risks. This is based on the framework developed by Moser and Luers (2008). According to this framework, these dimensions must be equally enhanced to increase preparedness for adapting to climate change risks as shown by Fig. 1. This graphical representation of the Moser and Luers framework has been described by Ekstrom et al. (2017).

For this research, risk awareness is measured based on the definition by Jen (2012) which is, an understanding within the population of the risks (relevant to health, economy, and environments around the residential construction projects) that exist, their impacts, and how to manage the impacts. Results from the interviews on the three dimensions were used to suggest the degree of preparedness by the residential construction sector for climate change adaptation. Further, recommendations have been made on which dimensions have to be further strengthened to enhance the climate change adaptation preparedness.

The Australian government is committed to becoming zero emissions by 2050 with the set interim target of reducing 30% of the emissions compared to 2005 levels by 2030 (Martek and Hosseini, 2019). As the state with the highest greenhouse gas emissions in Australia, accounting for 152.1 million tonnes of CO$_2$e in 2015 (Caldwell, 2017), Queensland has a clear role to play in Australia’s emissions reductions. According to regional climate projections in 2017, Queensland’s mean temperature (°C) in Queensland is set to increase by 0.9 °C in 2030, breaking all historical records (1960–2010) (Queensland Government
It is also prone to climate extremes and climate events such as floods, bushfires, heatwaves, and droughts (Marek and Mohd 2016). To plan for and respond to the future climate challenges facing Queensland, the Queensland government has committed to meeting the set targets through strategies such as the increased use of renewable energy, carbon farming, and improving the adaptability of buildings to climate change (Department of Environment and Heritage Protection 2017). Improving the construction, operations, and maintenance of buildings — which are responsible for over 19% of the global greenhouse gas emissions (Chalmers 2014; Hurlimann et al. 2018) and 25% of the emissions in Australia (Martek and Hosseini 2019) — will also be a key part of this commitment. The construction industry can be linked to three main areas of activities: engineering construction (e.g. mines), non-residential buildings (e.g. schools), or residential building (2016). This research focuses on the latter of these, the residential building sector, mainly due to the impacts to and from the residential building sector on climate change and due to the relatively low prominence of climate change adaptation in the Australian residential building sector.

According to Shearer et al. (2016), many urban areas in Australia can now be considered ‘hot-spots’ for future climate change impacts. In South East Queensland (SEQ), most urban areas are located in low-lying areas, and forecasted increases in the intensity of extreme weather events will see these areas become particularly vulnerable to flooding (Hennessy et al. 2007). As shown by Lloyd (2019), according to the long-term climate modeling, the number of hot days and nights in Brisbane would be doubled by 2050. High heat stress would not only impact outdoor work (such as residential constructions), sports (Lloyd 2019), and other livelihoods, especially tourism, but also building materials if they have not been built to adapt to the future climate risks.

Compared to countries like the UK and Ireland, for example, the design and implementation of energy-efficient and climate adaptable structures in Australia have been limited (Kinnane et al. 2016). Only some states of Australia, such as New South Wales, are moving towards incorporating adaptation strategies into the residential building industry. For

![Fig. 1 Interlinked three dimensions of preparedness to adapt with climate change risks. Source: Ekstrom et al. 2017, p. 168](image-url)
instance, some controls include banning dark roofing and specifying space for trees in the back yards in Sydney’s south-western area (Davies 2020). However, predicted climate changes that would result in impacts such as rising sea levels and more frequent extreme weather events have been found to be impacting the design of the buildings (Kinnane et al. 2016). Also, researchers have predicted that residential property values would reduce significantly, with an estimated decline of $571 billion or 9% of the total Australian residential property value by 2030 (Ryan 2019).

Due to these reasons, the adaptation of residential housing is likely to become a future legislative requirement as the adaptability designs are beneficial for both business and environment (Gu et al. 2004; Gosling et al. 2013). The Queensland government has identified adaptation in human settlements as an essential factor to minimize the cost of living of Queenslanders’ for changing future climates (Department of Environment and Heritage Protection 2016). Also, limited research has been conducted on awareness of climate risks, the analytical capacity to climate adaptation and actions to address climate change by the residential constructors and thereby to find how prepared the Australian residential housing industry to future climate risks. As a consequence, there is limited information available to assess the preparedness of the Australian residential industry for future climate change risks. Therefore, this research focuses on identifying the level of preparedness of the residential building sector in Australia especially targeting Brisbane as the focal study area.

1.1 Objectives of the research study

This research draws on qualitative research methods and semi-structured interviews with key employees of residential building companies to explore the extent to which these organizations are preparing for the unique risks and challenges of climate change and to identify the level of awareness of the Australian residential construction industry with the set targets and policies by the state and the federal governments. The findings of this research will then be used to make recommendations for improving the level of preparedness of the Australian residential construction industry, so it can work more effectively towards climate change adaptation.

1.2 Significance of the study

Findings of this research will be valuable and provide much-needed inputs for the next review of the National Construction Code (NCC) in 2022, which currently does not contain provisions for climate change adaptation other than minimum standards for construction (Courtois and Barnes 2019). Research findings would also provide insights to the residential construction companies and help them evaluate their preparedness for future climate risks by assessing their current strategies to climate risks.

1.3 Study area

Located in the south east corner of Queensland, Australia, the city of Brisbane consists of 189 suburbs and takes up 5.9% of south east Queensland’s land area (Syeed and Bunker 2015). Brisbane has a subtropical climate characterized by hot, wet summers, and mild, dry winters (Kottek et al. 2006). It lies 28 m above the sea level and the average temperature is about
20.3 °C which varies by 10.3 °C during the year (Fig. 2). The precipitation range between the driest and the wettest month is around 133 mm (Climate-data.org 2020).

Figure 3 presents the average monthly temperatures both day and night together with average yearly precipitation both rain and snow with days of wet weather per month in Brisbane. The projections of climate (temperature and precipitation) in 2030 and 2070 for the south east Queensland region under the scenarios of high and low emissions are presented in Fig. 4 through bar charts. The extent of each bar represents the range of changes in temperature and precipitation.
Fig. 4  Climate projections for South East Queensland region. Queensland Government, n.d Source:

2 Methodology

This research was conducted with human research ethics approval from the University of Queensland (Approval number: 2019003103).
2.1 Participant recruitment

Thirty Brisbane-based residential building construction companies were contacted via phone, email or both, in order to recruit the construction managers of those companies. From the 30 companies who were approached from the Brisbane local government area, a total of 12 construction managers agreed to be interviewed. Unfortunately, the interview completion rate was negatively affected by the Covid-19 pandemic situation, making contacting the interviewees in person difficult. Interviews were conducted virtually over the phone or using Facetime. Out of the 12 companies, five construction managers said their companies are large scale while seven have said their companies are small scale. According to the respondents, the demarcation between the large and small scales is based on several elements. For instance, the number of years they have been in the industry, the magnitude of the projects they are engaged in and the type of ownership (e.g.: whether it is individual ownership or of the board of directors). The participant information was kept anonymous, and the information was recorded by assigning codes for each participant (Codes for the participants from the Large Scale Companies: LSC1, LSC2, LSC3, LSC4, LSC5 and participants from Small Scale Companies were: SSC1, SSC2, SSC3, SSC4, SSC5, SSC6, SSC7). A participant information sheet (containing project and ethical information) and a consent form were sent prior to the interview.

2.2 Data collection

This research followed a qualitative research design that drew on semi-structured interviews to collect data. Participants were invited to share their ideas openly, and discuss their personal experiences and preferences, along with their views and opinions on recommendations and limitations to adapt to climate change risks in the residential housing industry in Brisbane, Queensland. The duration of the interviews was in between 20 and 40 min. All the interviews were audio-recorded. The framework by Moser and Luers (2008) was used to collect data and the questions were adapted from several selected researches: Ekstrom et al. 2011; Hurlimann et al. 2018; Hurlimann et al. 2019; Moser and Luers 2008.

2.3 Data analysis

Data analysis was done using the NVivo (version 12) software package, a commonly used software tool for qualitative management studies (Jones and Diment 2010). All interview recordings were transcribed and then imported into NVivo to analyze and explore the data using coding and query functions. While transcribing the interviews, all the data have been de-identified by deleting the personal identifiers.

Individual participants/transcripts were given separate case nodes in NVivo which helped in keeping all the data related to a particular participant in one place. For each interview, data relevant for the analysis was coded to the three key components from the Moser and Luers (2008) framework and were identified and coded again as sub-categories. Frequency counts were obtained for the themes identified within each component and presented in summary tables to present the number of mentions and number of interviews. To further analyze and highlight the examples of significantly important examples, individual responses within each code were presented.
2.4 Participant characteristics (Table 1)

3 Results

The following sections outline the results from the analysis of interviews carried out with construction managers from small- and large-scale residential construction companies in Brisbane. The results are arranged in four main sections: the three components in the framework by Moser and Luers (2008) and awareness of climate change policies by the Queensland government and suggestions to the government to create a climate-adapted housing industry.

3.1 Participants’ awareness of climate change risks

Firstly, participants were asked about their awareness of climate change. All the participants were aware of climate change, and none expressed any doubt regarding the occurrence of climate change. They were then asked about the climate change risks facing current and past completed construction projects, with the intention of seeing whether they were able to identify climate change risks during their past and present projects, discuss their potential impacts and also how to manage the impacts (Jen 2012). Of the 12 participants, only 2 could discuss climate change risks without being prompted by the interviewer regarding the types of climate risks facing construction. Ten participants initially indicated that they had not encountered climate risks in their projects.

However, when these same 10 respondents were asked follow-up questions naming examples of climate risks, such as extreme weather events (i.e. heat/prolonged drought period), they typically answered that they had indeed encountered these events during their past and/or ongoing projects. This indicates that participants did not immediately interpret

| Table 1 | Presents a summary of the key demographic information of the participants |
|---------|---------------------------------------------------------------------|
| Participant characteristic | Response |
| Gender | |
| Male | 75% |
| Female | 25% |
| Average industry experience | |
| Male | 15.5 years |
| Female | 12.2 years |
| Average industry experience in Brisbane from the total years in the residential construction field | |
| Male | 12.5 years |
| Female | 10.7 years |
| Education | |
| Bachelor’s degree | 66.67% |
| Master’s degree | 25% |
| Doctoral degree | 8.33% |
managing the impact of extreme weather as the same thing as dealing with ‘climate change risks’. This term may not have enough meaning for participants.

When prompted, the most commonly mentioned climate change risk was high heat and its impacts on the construction materials (the impacts of heat on construction materials will be discussed in the following sections). High heat was mentioned in 8 of the interviews, while bushfires were only mentioned in 1 interview. Only a single participant identified all the climate change risks mentioned throughout the interviews.

Extreme weather conditions such as heavy rainfall, flooding, storm surge, and bush fires were identified as the key climate change risks during the construction period (Hurlimann et al. 2019). Figure 5 shows responses in the order of most common to least commonly encountered risk. Participants identified the consequences like heat stress impacts on housing materials (this is the mostly encountered risk which is mentioned 11 times across 8 interviews), how droughts could affect their working schedules, molding due to heavy rains and fire.

The participants were also asked about their experiences with the impacts of the climate change risks on the timely completion of the residential construction projects (Sussman and Freed 2008). This question was intended to gain insight into their awareness of managing the impacts of the risks for their projects. Participants’ responses to this question varied. Four participants said that their companies had in the past failed to meet project deadlines due to extreme weather conditions, but that had not created conflicts with the customers. However, the perspectives of respondents on accepting their failures due to climate change risks and providing excuses to the customers were varied among these respondents. Two participants (SSC 2 and 3) reported that although their companies closely collaborated with their customers to deliver the final product during the anticipated period, the consequences due to climate risks were beyond their control. Two reported that climate events had interfered in the timely completion of a couple of projects but did not provide information about those projects or where those constructions took place.

![Image: Number of interviews the topic was mentioned and Number of mentions](image)

**Fig. 5** Climate change risks identified from past and present construction projects
3.2 Participants’ accounts of the analytical capacity of their organizations to apply climate change information into construction activities

Tribbia and Moser (2008, p. 319) define organizational analytical capacity as the “tools that managers often used in their management duties to display and transform available technical information into useful management actions.” They highlight the advantage of having in-house expertise available to develop these tools (for example, forecast models and analytic models) for reducing the cost of hiring external expertise.

When asked about the levels of internal and external knowledge of climate change and its incorporation into organization planning, participants’ responses varied in line with the scale of the company and the experience of the respondents within their current organization. In contrast to the tools highlighted by other researchers (Moser and Luers 2008; Tribbia and Moser 2008; Hurlimann et al. 2018), participants were only able to answer with the strategies that they themselves practiced to include climate change information into future planning. When asked if they had access to in-house expertise for the purpose of incorporating climate change information into the management processes, only four respondents responded positively that they have specially qualified sustainable managers available in their companies, especially targeting economic sustainability and providing energy-efficient products.

Figure 6 shows a summary of participants’ responses regarding how climate change information is used for future planning. It shows several stages of a construction project where this information was used: during upfront discussions, when scheduling the future project plans, when identifying mitigation measures, and when applying mitigation measures.

The most commonly mentioned response was “no action” as mentioned eight times across five interviews and those companies do not include or consider climate change information into their future planning of construction works.

Fig. 6 Reported ways of climate change information is used for construction work (past, present and future)
The second most commonly mentioned answer was the upfront discussions with the company/project team members. These discussions were targeted at changing the programs at the construction sites, and mainly focused on work efficiency and worker safety. One example of such a discussion is quoted below. In it, a participant (LSC4) talks about a company making sure that project/construction works are conducted without experiencing interruptions from climate change risks. The participant says that the company has come up with strategies to adapt with existing extreme weather events in order to maintain work efficiency and worker safety. One way of doing this is to change the working hours during hot summer periods. It is also apparent from this response that the company prepares for climate change risks during the construction period, but preparing for more abstract, future risks is less clear.

“Whenever it is a drought time and summer it is hot, so have to make sure that all our sites have adequate power and adequate water and toilets, etc. From another perspective during the hot/drought/fires period we have to change the working hours and start far early than we normally do (5.30 am) and also our materials are also impacted by heat stress” (LSC4).

Another participant (LSC5) discussed how climate change events require them to implement innovative strategies and to modify traditional construction practices. The example this participant uses is roofing. Whereas the traditional approach is to build the building first, climate change has led them to start the construction of the roof first to provide shelter for workers during hot and wet conditions. This maximizes work efficiency during extreme weather.

Those participants who stated that their companies do not use climate information appeared to have less belief that climate change required urgent consideration. In the quote below, for example, a participant (SSC6) rationalizes that the impacts of climate change were not dramatic enough to warrant consideration. Instead, this participant advocates a more relaxed ‘wait and see’ approach:

“Because it’s not really so dramatic, like it hasn’t change that much if you’re really just going with the flow and seeing how it is..., seeing our winter how cold it does get. But again, in Australia, it doesn’t really fluctuate that much.... Here (Brisbane) you feel the seasons, but it’s not so dramatic” (SSC6).

Four respondents confirmed that they have in-house sustainability managers for their companies. Hagbert and Malmqvist (2019) emphasized how construction companies with sustainability managers perform differently crises. Without sustainability managers, companies lack in-house expertise and record-keeping capacity. However, because this research did not interview sustainability managers, it is impossible to cross-reference this result and thus this can be identified as one limitation of this research.

3.3 Participants’ reported actions taken to address climate change risks

The respondents were asked what actions their companies have taken to address climate change risks. The participants were allowed to answer freely without prompting to categorize the actions as either mitigation or adaptation actions. The responses to this question are summarized in Fig. 7 and can be classified into four categories: undertaking research on durable materials, energy-efficient constructions, proper infrastructure facilities at construction sites, and no action (which means no actions have been taken
to address climate change impacts). Although only five respondents reported no actions to utilize climate change information into construction activities (Fig. 7), two of them mentioned that they have been working on using energy-efficient constructions always but never have thought it as an action to address climate change risks.

As shown in Fig. 7, the most commonly mentioned action that participants reported taking was using durable and resistant materials able to survive with extreme weather conditions. Respondents mentioned their approved plans to use materials with more longevity than those they used currently. Moreover, these materials are targeted to resist mould problems. In the quote below, a participant (LSC1) describes using a pronto panel which has benefits for water resistance and noise blocking as well as meeting the new regulatory requirements of the NCC (Brickworks n.d.):

“A panel called pronto panel, basically like a tilt slab construction… about 67 cm wide and can anywhere between 2–3 cm height. Now it’s concrete with polystyrene frames styrofoam balls injected into it. And also has a layer special sheeting which is also acoustic, it doesn’t get mouldy.” (LSC1).

Pronto panels also have high fire resistance but are only suitable in non-load bearing walls (PP-Technical manual 2018). Yet for this respondent, the central benefit was increased water resistance.

In the quote below, a participant from another company (LSC3) provides an explicit example of adaptative material suitable for all hazardous conditions including bushfires:

“Based on various researches and development and bringing on materials that have more longevity and also other abilities where current materials don’t seem to have…we are using, which is about to be manufactured by CSR (CSR brought the company so this won’t anymore be called as INEX), called Inex board acoustic, fire resistant so can go up to 800 °C, it has the quality of instead of absorbing and
holding water and then causing molds it expels the water... this product is fantastic” (LSC3).

This participant’s account aligns with recommendations made by insurance companies regarding climate-resilient housing industry in Australia to reduce the substantial amounts of dollars spent on insurance claims (Spatial source 2018). Only one company (LSC3) has been using INEX boards in their constructions, a well-known mould-, fire- and termite-resistant material that has been available in Australia since 2014 (The Hardware Journal 2016). This indicates a contrast between the innovations in the hardware industry and practical handling by the construction industry.

The participants were also asked who would be responsible for the damages to the residential buildings caused by the climate change risks. The answers varied since some participants discussed that material manufacturing companies should communicate with both homeowners and home builders about the materials they are supplying for the construction. One participant (LSC1) mentioned that decisions made by their previous managers influenced their choices when it comes to using traditional materials, and also stressed the need for enhancing the awareness of customers also on the characteristics of the products they bought. This participant related how homeowners are often unaware of the characteristics of the material (for example, the longevity and the adaptability of the material used during extreme weather events) used for their homes, and how this impacts demand for more efficient and resilient products. An example given was the use of Hebel, a less durable building material that is prone to becoming mouldy after absorbing water, an aspect of the product that manufacturers were reluctant to communicate to homeowners. This indicates that consumers’ and manufacturers’ levels of interest in or awareness of climate risks may also influence the adoption of climate adaptive building material and finding ways to increase accountability regarding the choice of building product may be needed.

The four companies with in-house sustainability managers demonstrated the need for accountability for the damages caused by climate change. For instance, the answer by the participant LSC2 mentioned that they believe the responsibility rests in material producers (hardware retailers) and their communication with the homeowners and the residential constructors. One respondent (LSC3) has stated that it is up to the housing insurance companies to be accountable for the property damages due to the climate change impacts in the future. Both participants, LSC2 and LSC3 had in-house sustainability managers with their companies.

The energy efficiency actions practiced by the interview participants mostly related to installing energy-efficient technologies in the new constructions as well as incorporating those technologies into their ongoing construction. Actions taken were commonly undertaken in response to the client’s priorities:

“We do have our own team of expertise on constructions and designing, customer’s satisfaction and the requirement is our priority. If they would like to establish solar systems, we are capable of providing them the requirement” (LSC2).

Only one participant identified ‘discussing mitigation methods’ as a way of using climate change information, but when relating the actions taken to address climate change, three participants gave examples of adopting energy-efficient construction activities to reduce emissions. These energy-efficient measures such as solar-powered systems and the use of disposable materials all help in mitigating GHG emissions. Adaptation was the most-mentioned action while mitigation was the second most-mentioned answer according to this research. Hence, it is inconsistent with other studies (Morton et al. 2011; Smith
(Hurlimann et al. 2019) where there was a trend in more mitigation than adaptation in residential construction.

Some participants either had no analytical capacities to include climate change in planning or had not taken any actions to address climate change despite being aware of the risks. For instance, participant SSC1 identified prolonged droughts, hot weather, and heavy rains as risks for their construction, which could delay the projects and damage the materials used for the construction. Based on the responses, the life span of the houses built by the respective companies ranged from 10 to 60 years. Hence, moving on with the mindset of developing no action to withstand climate change risks is arguable because the Queensland government (n.d.) has already predicted that even with low emissions conditions, there will be a substantial temperature increase during the hottest days, frequency of hot days, a 1 °C increase in the summer average temperature by 2030 and increase in the intensity of heavy rainfall. Therefore, not only the awareness within the housing industries but also the analytical capacity on how to utilize that knowledge into practice need to be considered to enhance the preparedness for climate change risks for the housing industry.

3.4 Participants’ suggested pathways towards a climate-adapted housing industry

Participants were asked about their awareness of the current climate change adaptation policies by the Queensland government which are related to the residential building industry. All were aware of the NCC of Australia, but not of any policies specifically related to sector adaptation planning strategies by the Queensland government.

The respondents were asked about improvements to make towards a more climate-prepared housing industry in Queensland, Australia. Only three participants made suggestions. Those suggestions were mainly focused on: (1) initiating a legislative approach to utilize sustainable technology with an element of environmental impacts due to construction works, (2) promoting utilizing environmentally friendly materials, (3) enhancing awareness of climate change adaptation. An example of this third suggestion is shown below:

“.... maybe more can be done to enhance our awareness. Maybe from the government enforcing it more.... Constructions, planning and designing, .... because they government always turns a blind eye on climate change. They think it’s a big joke.... they think it’s not main made”. (SSC4).

This suggestion also related to the first suggestion of having legislative support to utilize sustainable construction materials. Here, the respondent is suggesting active government enforcement to ensure that climate change impacts into the housing development activities that are considered. The need to enhance the awareness of the climate change adaptation for the housing industry has been acknowledged by other scholars, for instance, Shearer et al. (2016). This is also consistent with what Hytten (2013) has discovered, as the amount of available information and the nature of the issue affects the responses by people to climate change. Hytten (2013) further has shown that this is mainly because climate change cannot be directly understood or experienced by people or organizations (Hytten 2013).

According to Runhaar et al. (2016), the number of climate change adaptation measures incorporated within a particular sector is a diagnostic tool for its climate change preparedness level. According to these research results, it is evident that the level of awareness of climate change risks to housing construction, the analytical capacity to climate change, and actions taken to address climate change is affecting how far the company could practice
climate change adaptation actions. Therefore, the policies should associate with all these three components in establishing a climate prepared housing industry in Australia.

4 Discussion

The climate change risks identified by the participants are consistent with the findings by Smith (2016) who has also shown that capital intensive nature (water requirements during the construction period, need of long-life fixed assets) of the residential building sector in Australia and globally has always been vulnerable to extreme weather events. Further, all the climate change risks identified by the respondents are consistent with the risks identified by most of the other research on the housing industry both in and out of Australia (Jewell 2014; Evershed 2019; Hurlimann et al. 2019; Ryan 2020).

With regards to the analytical capacity of the participant’s companies, three key points from the results are highlighting the lower level of analytical capacities within these industries. Firstly, the majority of the participants are not using climate change information for their future planning. Secondly, none of the participants has used climate change forecasting models like tools. Thirdly, only four out of twelve participants have had in-house expertise to assist with including climate change information into planning.

The participant’s answers to the question for accountability of the final residential construction products are aligned with other research conducted on climate risks and the housing industry in Australia (Vergnani 2019; Ryan 2019; Fernyhough 2019). Ryan (2019) highlights that not all property owners have home insurances and not all the insurance policies are covering all types of damages, i.e.: the current general home insurances are not covering damage from coastal erosion and inundation. Fernyhough (2019) has revealed that since the insurance companies are working towards the sole purpose of businesses, they are not in a position to bear the risks of the damages that the communities will face due to the extreme weather events. Due to this reason, Fernyhough (2019) further emphasizes the need for developing “a resilience culture” in the Australian residential construction industry also. As identified by Vergnani (2019), the predicted loss of the Australian property market by 2030 is $571 billion. In and of itself, all these illustrate that the responsibility of the future climate risks rests upon no one, yet the costly consequences will have to endure by the nation.

In the case of utilizing innovative hardware materials for housing constructions, there seems to be a contrast in designing and the application of climate-smart and energy-efficient housing models. Because none of the participants has mentioned their upcoming or past approaches with the housing designers and architectures in developing climate-smart houses to withstand future climate risks. Yet, there are area-specific research that take place in developing zero energy houses. Such as Kwan and Guan (2015) have modeled a five-star energy-rated house using a building computer simulation technique and validated it by comparing the energy performance with a conventional/typical house in Brisbane. This shows the need for linkages between research into energy-efficiency and the climate-smart housing industry in Australia.

According to Courtois and Barnes (2019), climate change adaptation is not included in Australia’s NCC except for minimum standards for construction. The absence of clear policies and guidelines is also connected with the absence of accountability for future climate change impacts. As illustrated by a team of researchers of Consult Australia (2017), it is because of not having proper climate change adaptation policies that the liability/accountability of the
future climate change risks and impacts would involuntarily fall on designers/planners of the housing project, and also incur higher project costs during unprecedented climate risks due to under-compensating as a result of the absence of clear parameters (or predictions). Hence, establishing a policy framework together with clear parameters is essential to enhance the preparedness of the housing industry for future climate risks. Moreover, the research results are providing suggestions, see the following quotation.

“We do have our own team of expertise on constructions and designing, customer’s satisfaction and the requirement is our priority. If they would like to establish solar systems, we are capable of providing them the requirement” (LSC2).

Accordingly, the industry is prepared to accept the adaptation strategy of incorporating solar energy. Queensland, including Brisbane has very strong potential for utilizing solar power for its energy needs, particularly in terms of utilizing solar panels in the development of climate-smart residential construction practices. This can be seen as an adaptation that can be taken into the unique Brisbane setting.

The suggestion by the participant LSC2 on having legislative enforcement to use climate-adapted construction products is consistent with Dalton et al. (2013). Accordingly, sustainable housing constructions are always relying on innovative construction materials and engineering advancements, but all these are significantly determined by regulations. The NCC of Australia was established by the Australian Building Codes Board (ABCB 2017) and it includes both the Building Construction Code of Australia (BCA) and the Plumbing Code of Australia (PCA). Since BCA itself doesn’t have provisions to take legal actions against those who do not satisfy these minimal standards, it is up to the state/territory governments to enforce building regulations in Australia.

According to the Queensland government publications, there are certain legislative actions to guarantee the safe design and construction of buildings. For instance, the establishment of the audit task force in 2017, launching of a safer building website in May 2021, development of Material Library of cladding materials in collaboration with the University of Queensland (Queensland government 2019). With effect from 18th of October 2019, the Queensland Government has banned the use of “aluminum composite panels (ACP) with a polyethylene (PE) core of greater than 30% by mass to all new buildings, and expanded polystyrene (EPS) product for use in external walls, including as an attachment on all Class 2–9 building of type A or B construction” (Queensland government 2019, p. 1). However, according to the respondent’s suggestion towards the climate prepared housing industry in Queensland, none of the above-mentioned regulations or any initiatives requires the constructors to utilize materials that are more adapted to future climate risks. As such, there is a legislative gap in the requirement of utilizing climate-adapted building materials and the enforcement by the government. Expediting the implementation of the said adaptation and regulatory actions would not only help increase climate preparedness but also comply with the United Nations Sustainable Development Goals (SDGs) especially SDG 13 on climate action.

5 Conclusion and recommendations

This research has presented the results of qualitative research exploring the preparedness to adapt to climate change risks in the Australian residential construction industry. Twelve interviews with construction managers from Brisbane residential construction companies were conducted, and questions focused on awareness of the climate change risks, analytical
capacity to include climate change information into planning, and the actions taken to address climate change risks.

Based on the responses for the three dimensions of preparedness to adapt to climate change risks, three key conclusions can be made. Firstly, the research found that participants are aware of climate change and can identify climate change risks and their impacts. However, their awareness was limited to managing the actual impacts and effects of the risks after they have been experienced, for example, when projects were not completed on time. Secondly, the research found that the companies that the participants worked for were not adequately equipped with in-house expertise to apply climate change information into construction activities. Information about potential risks posed by future climate trends and changes was not considered. Thirdly, the use of construction materials to withstand adverse weather conditions was the most commonly mentioned action to address climate change. Of the current climate change adaptation policies implemented by the Queensland government, respondents were only aware of the NCC of Australia. This indicates a significant limit to participants’ knowledge, as this Code does not include provisions about climate change adaptation, except in relation to minimum standards for construction. For these reasons, it can be concluded that preparedness to adapt to climate change in the residential building sector is lacking, and strategies and actions are needed to enhance preparedness.

Based on the qualitative analyses of the results together, it is recommended that four key actions be undertaken to enhance the preparedness of the residential construction industry to future climate risks. These actions are:

1. **Legislate climate adaptation practices and the use of sustainable building material**

   Research interviews showed that many participants did not fully recognize the pressing need for the residential construction sector to adapt to climate change risks, and to incorporate climate change adaptation into planning, decision-making, and actions. This suggests that legislation may be a good instrument to drive much-needed changes in the residential construction industry. A lack of legislation has already been recognized as a barrier to the adoption of sustainable material strategies to the construction industry in the literature (e.g. Ametepey et al. 2015), and by the Queensland government itself. The Queensland Department of Climate Change and Energy Efficiency (2011), for example, identified several factors in existing regulatory frameworks that hinder adaptation into climate change in Australia’s infrastructure. These included a lack of recognition of the need to adapt to climate change, compliance that was costly or difficult to achieve and weak law enforcement mechanisms.

2. **Implement strategies to build corporate knowledge, within residential construction companies, regarding future climate change risks and climate-adaptive construction**

   Results from this research have shown knowledge gaps in participants’ awareness of climate change risks and strategies to prepare for and manage climate change impacts. Moreover, accounts from participants indicate that construction companies have relatively low levels of analytical capacity when it comes to understanding future climate change risks and taking actions to address them. According to Carter et al. (2015), raising awareness of the existing and potential future weather and climate is vital for increasing the capacity to deliver adaptation responses by the construction sector. Moreover, further research is essential in the housing construction industry, especially in the
hardware material for the housing construction industry. Those research must focus on developing and designing more innovative outputs that are more climate-adaptable and resilient.

3. Implement more effective communication strategies to connect residential building constructors and the government in preparing adaptation policy frameworks with clear parameters to implement actions for future climate risks

The research interviews found that participants’ awareness of Queensland government climate change adaptation policies was extremely poor. The majority of participants’ policy knowledge was limited to the NCC. This indicates that adaptation policy frameworks need to be developed with engagement with and input from residential constructors and other relevant stakeholders (such as designers/architects and financial companies). Policies developed using bottom-up approaches, inclusive of the requirements and suggestions of all the stakeholders are more likely to be adopted and can help develop actions to address climate risks. Moreover, having policies with clear parameters assists in evaluating the actions implemented.

4. Promote a culture of accountability in the residential housing sector regarding preparing and adapting to climate risks

As climate-related extreme weather events grow in frequency, it is likely that insurance companies will become more reluctant to underwrite damages to the residential constructions due to these extreme weather events. A climate-resilient culture in the residential building sector and a sense of responsibility for building houses that are designed and constructed to withstand future climate risks are vital (Fernyhough 2019). However, increasing this sense of responsibility and climate preparedness is not a one-step process, and a driving factor in building this preparedness will be a clear designation of accountability in the building sector for future climate damages. Policy discussions must grapple with questions about responsibility — either in regard to it belonging to one entity or being shared among all the stakeholders. This accountability should be promoted through legislation after defining the responsible parties through collaborative strategic planning with all the stakeholders (for example, constructors and insurers).

Inclusion of provisions to increase awareness on climate change adaptation actions to address climate change into the NCC is fundamental given that residential construction companies primarily follow the code rather than other government policies on climate change. These recommendations will help revise the NCC of Australia and enable and inform the residential construction industry to be compliant with strategies to adapt to future climate change risks. Consequently, they would result in a more climate-change–prepared residential construction in Australia.

**Declarations**

**Ethics approval and consent to participate** All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.

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