Sustainable timber use in residential construction: perception versus reality

D. Thomas, G. Ding & K. Crews
University of Technology Sydney, Australia

Abstract

Close to 90% of new project homes in NSW, Australia are constructed with reinforced concrete flooring and brick veneer envelope whereas many traditional Australian homes were built of timber floor structures with timber walls and cladding. The adoption of concrete and brick homes originated from a perceived advantage of longevity, low maintenance and thermal comfort. Innovation in wood treatments, wood protection and insulation have provided solutions to these issues so that timber is once again a viable option with added benefits such as environmental sustainability and erection speed. This paper reviews literature and analyses the results of a home occupants' survey on the perception of timber use in new homes in NSW, Australia. It also investigates the comparative performance of a timber veneer/structural timber home to a concrete floor/brick veneer home to evaluate whether perception of timber performance matches reality. This paper highlights Australian homeowners' reluctance to use timber as a sustainable building product for homes even when they are willing to pay for a more environmentally sustainable home. It also discusses the time and environmental advantages of a timber home over a concrete and brick home based on the results of a test case study.
Keywords: sustainable timber, residential construction, homeowner perception, timber performance, embodied energy.

1 Introduction

Sustainability has become a frequented topic in Australia media through the introduction and repeal of carbon tax legislation in the last 5 years in addition to regular public debate on Australia's commitment to climate change action [1, 2]. The construction industry is responsible for close to 25% of the nations' carbon

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emissions and has received much attention in the effort to reduce the operating energy of buildings through building design and technologies [3, 4]. Legislation has also been introduced to regulate building performance for both detached and multi-residential housing in order to minimise heating, cooling, lighting and water usage [5, 6]. There have also been a number of government subsidised schemes to assist homeowners reduce their power usage through increased insulation, solar powered water heating and photovoltaic electricity generation [7, 8]. However there is little attention given to reducing carbon emissions through decreasing building's embodied energy despite growing literature dedicated to the topic. A number of case studies have identified timber as the most efficient material in terms of carbon emissions when compared to reinforced concrete, masonry and steel construction in residential housing [9–12]. Whilst timber may be a more environmentally sustainable building material the perception of homeowners and consumers may not match this reality. Current market domination of concrete and brick veneer in new homes suggests that new home purchasers may have misperceptions about timber performance. This paper investigates literature about homeowner perception of timber in housing and analyses data from a recent timber material perception survey of NSW homeowners and occupants. The survey found that the majority of home purchasers have negative perceptions of timber that are not founded on current literature. This paper also presents results of a case study that compares a new home constructed of concrete floors and brick veneer to a structural timber home with painted timber cladding. The case study compares embodied energy and life cycle costing of the different building envelopes as well time and thermal performance between the two building types and reveals that timber comes out advantageous in all categories except for cost. Finally, this paper makes recommendations on correcting homeowner perception of timber and reducing the cost of timber housing construction.

2 Perception of timber in residential housing

Current literature on the perception about timber use in residential is based on both the perspective of the construction professional and the home occupant and includes both detached and multi-residential buildings. Construction professionals such as engineers, architects and construction project managers have expressed concerns about timber related to structure, fire and acoustic performance, legislative barriers, unpredictable costs, durability and termites [13–16]. The perceived advantages of timber by construction professionals were aesthetics, environmentally sustainable, easy to adjust, time and cost factors in addition to worker safety [14–16]. Homeowner and occupant perception was similar to construction professionals regarding timber benefits such as aesthetics, sustainability, and natural characteristics whereas their negative perception focused on the strength, durability, fire and acoustic performance [17–19].

2.1 Australians' perspective of timber in detached housing

Despite there being a comprehensive study on timber use in the Australian construction industry 5 years ago there is limited research into Australian's home occupants and owners perception of timber use in homes [20]. In 2012 a pilot survey was conducted in NSW and revealed a number of misperceptions of timber use as a substitute for concrete and bricks in new home builds [21]. The survey results showed that 69% of participants would chose brick and concrete homes over timber for reason of low maintenance, thermal comfort, and structural adequacy followed by durability, termite fear, acoustics, cost, and capital growth [21]. Some of these negative perceptions conflict with recent research into timber performance in areas of durability, fire and acoustic and thermal performance [22–24]. Structural performance and termite resistance of Australian housing are governed by building codes and standards and these dictate minimum performance for all housing regardless of building material selection [5, 25]. The pilot survey revealed that most respondent's agreed that an increased use of sustainable building materials in housing is required, timber was chosen as the most sustainable material and home purchasers would pay a premium to use the most sustainable building material [21].

3 Research method

The purpose of the research was to obtain data that reflected NSW resident's perception of timber use in regards to the sustainability and other timber performance attributes in residential building, their understanding of timber as an environmentally beneficial material and their inclination toward its use. The survey results would be analysed and results used to compare the perception with a test case study between timber and concrete and brick house design. The results from the research would be used to develop strategies to increase the acceptance of timber as an environmentally sustainable material alternative for the current new home construction options with time advantages and thermal performance that matches the heavy materials. Recommendations will also be made to reduce the cost of timber housing design in Australia.

3.1 Questionnaire survey method

Online questionnaire surveys were used for reasons of distribution efficiency and wider coverage and to increase the effectiveness of data collation and analysis. The sample group was chosen to provide a mix of residents occupying and/or owning units or detached dwellings and having a background of either construction or non-construction related employment. Construction related participants were contacted through construction companies, industry associations and professional affiliations. Non-construction workers were accessed through friends, family and work colleagues and snowballing technique was used to increase the size of this group. The survey was distributed via a link embedded in an email sent to participants to enable completion of the surveys at

their own convenience and to maintain anonymity. The potential participants were then reminded 2 weeks after initial distribution by email, phone and personal contact except in the case of surveys distributed through industry associations and snowballing. Final response rate was estimated at 15% with 310 responses received. The questionnaire included sections on demographics, attitudes to sustainable construction, material thermal performance and preferences for housing as well as timber performance. Survey participants were given 3 months to participate ending in March 2013.

3.2 Comparative case study method

The trial case study used a completed house design from a volume homebuilder that was materially based on a typical home constructed out of reinforced concrete slab, internal timber frame with a brick veneer and a concrete tile roof on a structural timber frame. The alternate timber design was created with the same room layout, dimensions and orientation as the brick design and was generated with the assistance of Australian building codes and standards [5, 25]. The timber redesign used concrete blob footings, galvanised steel piers, structural timber floors, structural timber walls and timber cladding with the same concrete tiled structural timber roof as the brick home. There were four areas of comparison that included operating energy, life cycle cost, embodied energy and time. Additional timber products such as timber frame windows, solid timber floor finishes, joinery and timber piers were not included as these are usually premium client-based preferences and not common options in Australia's project home market due to price and/or common building practices. It is acknowledged these inclusions would further reduce the embodied energy of the timber home option.

3.2.1 Energy analysis

The building code of Australia requires minimum thermal insulation and this can be achieved through acceptable construction practice set out in the code or use house energy rating software [5]. The case study comparison used the brick home as the base case upon which operating energy and embodied energy was compared. The brick house was analysed for operating energy with the use of an approved energy simulation program called AccuRate and an operating energy efficiency rating of 3.6 stars was achieved once the all required inputs were entered (Star rating ranges from 0-10 with 1 representing inefficient and 10 representing high efficiency). Inputs included house orientation and dimensions, envelope materials, floor and ceiling linings, external openings, roof coverings, insulation, external glazing and doors. In order to ensure that the redesigned timber had comparable operating energy rating to the base case the building envelope was altered by removing the concrete floor and brick veneer and replacing it with an elevated timber floor structure and timber wall frame. Other changes included insulating the floor structure, increasing the external timber wall frame dimensions, providing extra wall insulation and having 38mm air gap between the wall frame and timber cladding. The timber redesign achieved a star rating of 3.8 stars, which is marginally more efficient than the base case. The

change in design from the base design to the timber redesign had impacts on time of construction, cost of materials and embodied energy in the timber structure.

Embodied energy analysis was limited to the structural envelope of the homes for the same reason as the life cycle costing. Recurrent embodied energy associated with internal churn of finishes and fixtures and fittings would be identical in each design therefore excluded from the study. The only external envelope component requiring maintenance/replacement was the windows and doors, timber wall cladding, fixings, and painting. The 'Inventory of Carbon & Energy (ICE) Version 2.0' was used to calculate embodied energy with the coefficients multiplied by the weight of materials in each structure to provide totals in Mega joules (MJ). Carbon storage in timber is also not included in this case study however based on previous research it would provide the timber design with an advantage over the brick home [26]. Carbon storage will be included when multiple case studies are conducted as further part of the current research.

3.2.2 Life cycle cost

The life cycle cost of the building envelope comparison was carried out excluding the recurrent costs of internal finishes, fixtures and fittings of the buildings in the case study. It is acknowledged that the churn of internal finishes such as painting and carpets is quite high over the life cycle of a residential home. However due to both designs being identical in its layout and wall and floor coverings it is assumed that the cost will be the same across each design and will not affect the final dollar comparison. External maintenance costs of painting and cladding, window and door replacement were included in the costs. A fifty-year life cycle has been allocated to this initial case study to reflect recent literature examining house life cycle periods [27].

3.2.3 Construction time

Construction time was compared to evaluate any benefits in the use of timber as a structural material over the concrete and brick design. Construction time was measured from construction start until envelope completion. Microsoft project was the software program used to allocate individual tasks in the redesigned timber project, as it is a commonly used construction industry time management program. Industry standards and expert advice was sourced in the assembling of the building schedule. Industry experts were in the fields of carpentry, plumbing, electrical, roof tiling and building. Most experts had experience of greater than 20 years and/or managed subcontracting business in residential construction.

4 Observation and analysis

4.1 Residential housing survey

The survey group was composed mainly of homeowners and occupants living in home and apartments in the inner city areas of Sydney (50%), a smaller group

lived in the outer Sydney suburbs (34%) and the remaining participants resided in regional areas of NSW. There was an even split between construction industry professionals (48.5%) and non-construction industry employees (51.5%). The age distribution of survey respondents closely matched the state's population in the 18-64 year age range [28].

4.1.1 Sustainable materials for housing

Three questions were asked regarding environmental sustainability and building materials and questioned if there should be a greater society focus on sustainability, whether sustainable materials should be used in home building and if timber was considered a sustainable building material. There was almost full agreement that society should focus more on sustainability and sustainable materials should be used to build new homes with percentages of 90% and 93% scored respectively. Undecided votes for these questions were 7% and 4% respectively with negative responses for each question totalling just 3%. Two thirds (65%) of participants favoured timber as an environmentally sustainable building material with 29% unsure and 6% rejecting the proposition. Age. gender, employment background or the type of residence that participants lived in reflected no significant difference in responses.

4.1.2 Pay extra to use sustainable building material

Participants were also asked about their willingness to pay a premium for the most sustainable building material in a new home build worth A$300,000. 77% would pay more in the new home scenario and the percentage premiums ranged from less than 1% to greater than 10% and these are shown in Figure 1. Increasing age correlated with increasing willingness to pay a premium and females (86%) showed a greater likelihood to pay extra for sustainable materials than males (70%). There was also a reasonable difference between the construction and non-construction participants' propensity to pay extra for sustainable materials in new homes and renovations. Construction professionals were 15% less likely to pay more for sustainable materials than non-construction professionals.

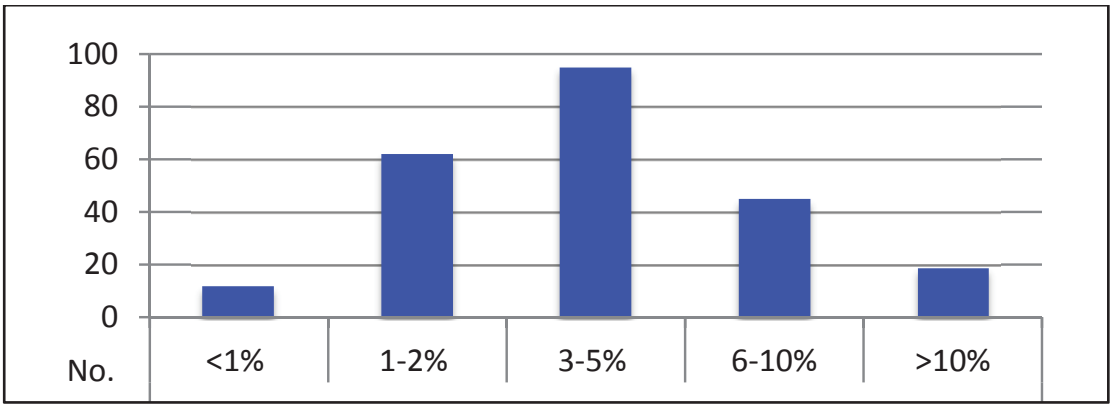

Figure 1: Premium paid for sustainable materials in new home purchase.

4.1.3 Perception of building material thermal performance

Perception of thermal performance was investigated with survey participants questioned about the current material performance on their homes, their view of best performing materials and their choice between timber and concrete/brick if timber was insulated to the equivalent thermal performance of concrete/brick. 65% of the occupants of the brick veneer residence were satisfied with the year round comfort levels followed by those living in double brick (64%), timber (54%) and then concrete (45%). Timber had the largest percentage of occupants that were dissatisfied with year round comfort levels (38%) whereas the heavy materials received less dissatisfaction levels (14-17%) with the remaining occupants neutral. When participants were asked to rank their top choice of new home materials for thermal wall performance double brick was the highest with 55% followed by Hebel (22%), timber (20%) and brick veneer (3%). Floor thermal performance was chosen in the following order from greatest to least popular, waffle pod concrete (48%), standard reinforced concrete (25%), insulated timber (24%) and traditional timber (3%). When participants were asked if they would build a new home out of insulated timber floors and walls in preference to concrete floor and brick walls (if it provided greater insulation) 79% answered yes as is depicted in Figure 2. Out of those who would choose the insulated timber option 66% would pay extra if it outperformed the concrete floor and brick wall option.

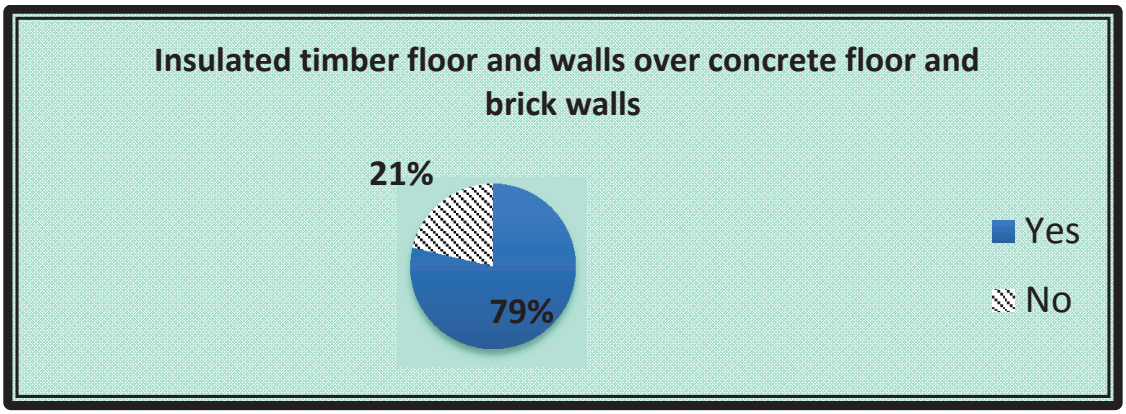

Figure 2: Preference for timber envelope if it outperformed concrete and brick.

4.1.4 Timber performance in housing

Specific questions related to the use timber in housing included the maintenance time and cost issues with timber cladding, fire concerns, aesthetics, speed of construction, building cost and resale value of timber homes. The majority (52%) viewed the maintenance of timber cladding as an issue with 35% unsure and the remaining perceiving no issue. 69% of people surveyed were concerned with fire in timber homes with 18% unsure but only 13% not viewing this as a problem.

The aesthetic characteristics of timber was affirmed by 82% with only 3% in disagreement and 15% unsure. The speed of building timber homes was seen to be quicker than concrete/brick homes by the majority (55%) with 39% unsure and 6% disputing this claim. Cost of timber home construction was perceived as

being cheaper than brick by 37% of participants whereas 45% where not sure and 18% disagreed. Only 4% of people surveyed thought that timber would have a better resale than brick compared to 58% that disagreed and 38% who were neutral.

4.1.5 Choice between brick and timber new home purchase

Towards the end of the survey participants were asked if they would ultimately choose brick or timber when purchasing a new home and 68% chose brick over timber (32%) This is similar to results in the pilot study conducted in Sydney in 2012 [21]. Men (73%) were more likely to select brick than women (60%) and construction workers (73%) more likely to choose brick than non-construction employees (63%). Regarding age the highest preference for timber over brick was from the 40-49yrs group (42%) followed by 50-65yrs (37%), 30–39yrs (32%) and the least proportion of timber selections was from the 20–25yrs and 25–29yrs with 25% and 20% respectively. The reasons for the selection of either timber or brick included a variety of reasons from being a traditional material to being easily adjusted. The reasons for selections are displayed in Figure 3. The reasons for brick are mainly for low maintenance, structural, and thermal performance followed by durability, fire resistance and aesthetics. The least chosen attributes of brick are cost, acoustics, traditional material, environmental and alterable. Timber is mainly chosen for its aesthetics, environmental sustainability, alterability and thermal performance followed by preferences for its cost, traditional material, structural and acoustic performance.

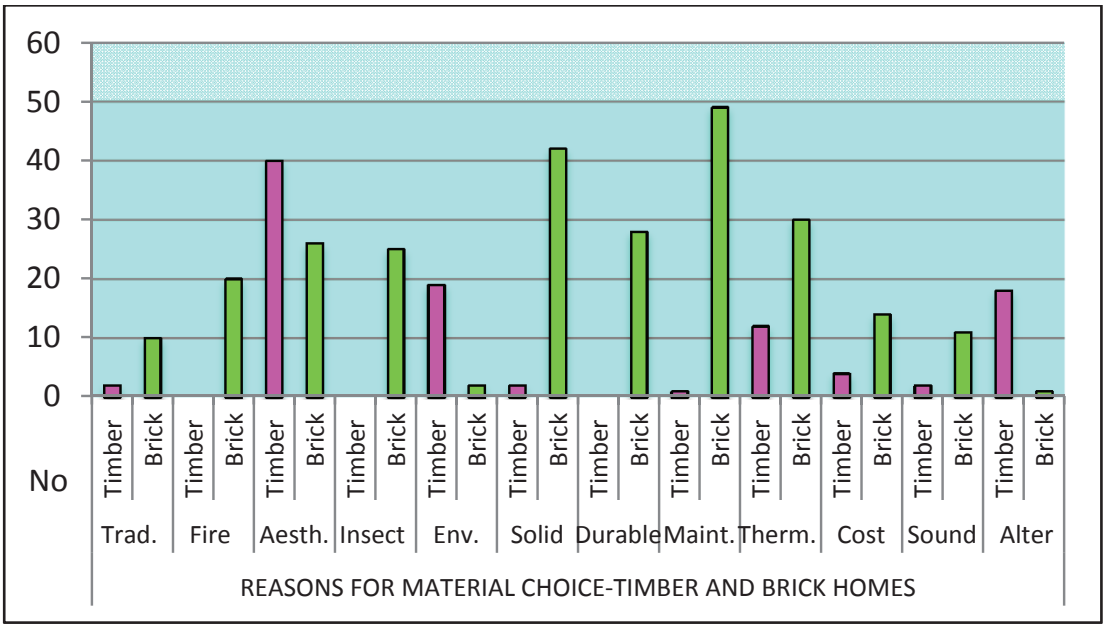

Figure 3: Reasons for choosing timber or brick homes.

4.2 Timber and brick house comparative case study

The comparative case study used a completed house and all the actual costs involved in the construction of the entire house and calculated envelope

maintenance over 50 years. The operating energy star rating was evaluated through inputs of orientation, envelope materials, internal linings, openings, windows and door sizes and materials. Embodied energy calculations excluded materials that were common to each home. Time is worked out on the entire construction process until contract completion.

4.2.1 Preliminary comparative case study results

Embodied energy was measured for the building envelope only and is measured in Mega joules/m^2 for the initial materials installed and the replacement timber cladding, hardware, doors, windows and painting for the cladding. Timber cladding, windows and doors are calculated to be replaced after 25 years and painting every 15years [29, 30]. The brick house envelope had embodied energy of 2288 Mega Joules/m^2 compared to the timber house envelope of 1831 Mega Joules/m^2. Cost comparison in the two house envelope designs resulted in the timber house price being \$637/m^2 compared to the brick home that cost \$525/m^2. The majority of additional costs were comprised of labour and material for upsizing the wall and floor structure to obtain a similar thermal performance of the brick envelope and the recurring labour and material costs of repainting and replacing the timber cladding. The timber home was more time efficient to build than the brick design with 7 days less and the time difference was mainly due to bricklaying and concrete slab preparation.

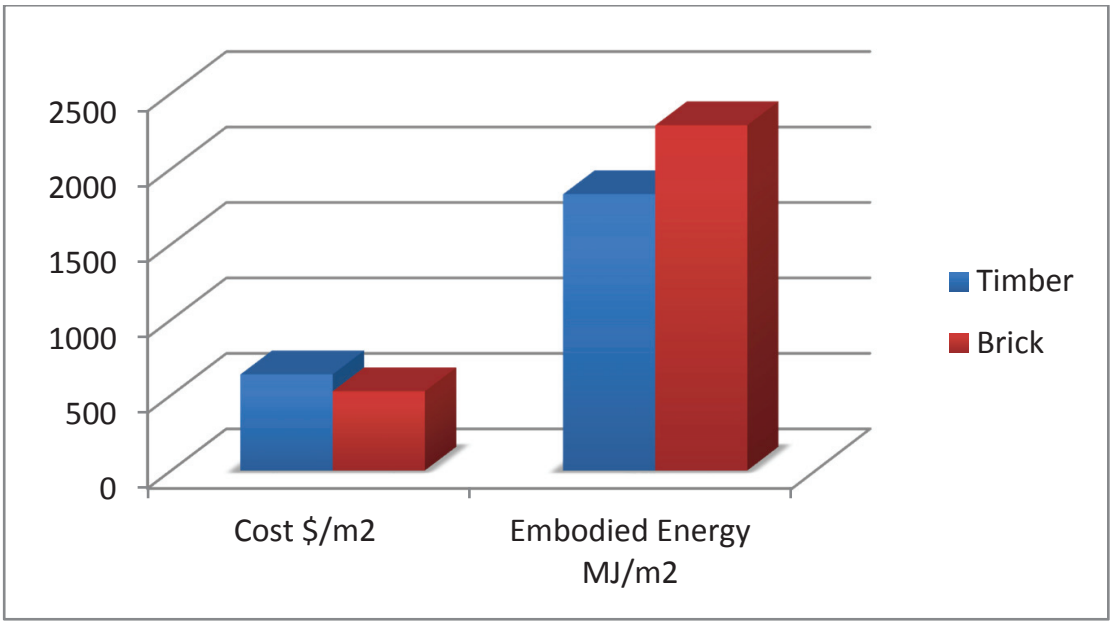

Figure 4: Comparative case study-Timber versus brick.

5 Discussion

Sydney housing occupants have expressed the awareness of building with sustainable building materials and the majority believe that timber has environmental advantages over heavy materials such as concrete and brick,

which are the materials that currently dominate new home construction. There is however a willingness to pay premiums for the sustainable materials and for timber house envelopes if they are shown to perform thermally equivalent to concrete/brick homes despite some confusion regarding the current perception of timber thermal performing sub optimally to heavier materials. There are still concerns regarding durability, maintenance and fire performance of timber but aesthetics, speed of construction and cost was perceived to be advantageous for timber housing. The popular opinion held is that brick homes returned a greater resale value compared to timber and when given the choice most people would select brick. Perceived structural benefits, durability, maintenance, thermal, fear of insect attack and cost are persuading home occupants to select brick over timber. A preliminary case study has found that achieving timber thermal performance equal to brick is possible however additional costs are incurred in the timber design. Speed of construction was an advantage identified in the timber design in addition to a significantly lower embodied energy.

The ideals of home purchasers owning a sustainable timber home that is cheaper, quicker to build and has comparable thermal quality to the current popular Australian house design built of concrete and brick has a few obstacles. The main hurdles are cost efficiencies and perception and there are some strategies suggested to address these issues:

1. Increase marketing to educate consumers regarding the actual durability (insect and rot resistance), structural, fire, and thermal performance of timber.
2. Consider the potential for the use of low maintenance heat and chemically modified timber in residential building construction.
3. Generate a strategic model for volume home builders to offer a timber house design which provides customer value in terms of cost, speed and sustainability whilst maintaining profit margins and gaining competitive advantage over competitors.
4. Investigate the increased speed and cost advantages of timber construction through the use of timber cassette fabrications for wall, floor and roof elements that are in their infancy in the Australian housing market.

These strategies aim to increase the use of timber in residential housing in order to reduce the carbon impact of Australia's construction industry, produce a sustainable product to prepare for future tightening of environmental regulations and offer a cost and time efficient product alternative to the heavy material housing design which is currently dominating the new house market.

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