Pro-environmental behaviours in improving energy performance of the Australian housing

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Abstract: The residential sector is the main energy consumer in the Australian building sector and has significant impact on greenhouse gases emission in this country. The sector confronts a number of non-technological barriers, e.g., diversity of products and stakeholders, which detract from the leverage of mitigation plans in this area of building industry. This paper aims at explaining the application of occupants' pro-environmental behaviour in overcoming such barriers in the Australian housing industry. Accordingly, the main objectives are to explain the housing characteristics, and then to find out to what extent pro-environmental behaviour is capable of moderating the barriers. Looking at the housing characteristics is a proper source for explaining the housing preferences, which are indicators of end-users' environmental perceptions and attitudes. Conducting graphical analyses on secondary data compiled from a number of online sources by Excel software resulted in drawing graphical profiles from the Australian housing, explaining the occupants' preferences. The results showed that the occupants' preferences are strictly responsible for the current direction of housing development; hence, their environmental attitudes and perceptions should gain centrality in future planning.

Keywords: Australian housing; end-users' perceptions and preferences; energy consumption and demands; emission mitigation; pro-environmental behaviours; efficiency; Australia.

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1 Introduction

The building sector is responsible for almost 39.4% of total energy consumption, as well as the generation of approximately one-third of greenhouse gases (GHG) and carbon dioxide (CO_2) emission (Desmarais et al., 2013). The sector interestingly has exceptional potentials for cost-effective CO_2 and GHG mitigation (Allwood et al., 2012; Desmarais et al., 2013). The existing insufficiencies in the implemented mitigation policies, using top-down fixed rules with low flexibility, along with a number of multiple non-technological barriers prevent the estimated mitigation baselines from becoming achieved in the industry (Cheng, 2010; IPCC, 2007; C2ES, 2015). In the small sized residential buildings, the problems are more complicated because of the diversity of housing products; complexity of spatial, functional, and physical characteristics; complexity and diversity of stakeholders; as well as the spread and magnitude of energy use activities; which reduce the leverage of the mitigation action plans in this area of the building industry (Asad Poor and Jusan, 2012; Cheng, 2010; Levine et al., 2007).

The spatial, functional, and physical characteristics of dwelling units influence substantially the range and amount of their energy usage, and CO_2 and GHG production (UNEP SBCI, 2009). End-users' environmental perceptions, attitudes, and behaviours also have centrality in the building energy consumption, and CO_2 and GHG emission, especially in the small size residential buildings whereby the end-users have a substantial role in influencing the marketing trends, and affecting all other stakeholders in the field (Levermore, 2008). It is believed that without end-users' positive attitudes, enhancing mitigation performance cannot be effectively and significantly achieved in the area of the building industry (Kwami et al., 2015). In small-scale residential buildings, for a long-run practical mitigation plan, the occupants' spontaneous involvement is a prominent element. Hence, their pro-environmental behaviours are essential in enhancing this spontaneous environmentally friendly involvement (Ramkissoon et al., 2013; Jin, 2013).

This paper intends to explain the existing potentials and challenges in overcoming these multiple non-technological barriers in the Australian residential sector, especially the diversity of the housing products and the stakeholders, which have the centrality in mediating the other barriers. The central questions are: what are the Australian housing characteristic, how they impact the diversity of the housing products and stakeholders, and eventually to what extent a mitigation action plan through pro-environmental behaviours is practically fruitful in reducing the impacts of these barriers. The main effort indeed is to find out the behaviours, the factors, and finally, the interventions that might be practically fruitful for mediating the berries.

This paper initially overviews the literature conducted on the impacts of building spatial, functional, and physical types and characteristics, and the diversity and characteristics of the stakeholders on the energy consumption in the residential sector. It then discusses the conceptual framework of the study by stressing the role of the pro-environmental behaviours in the successful emission mitigation in the Australian housing sector. The paper later draws profiles from the spatial, functional, and physical characteristics, as well as energy consumption of the Australian housing sector. Finally, the discussion on the characteristics assists in visualising the existing challenges and opportunities for emission mitigation in the residential sector, and the role of the occupants' pro-environmental behaviours in developing an operational mitigation plan for this are of building industry.

2 Literature review

According to Levine et al. (2007), regarding long lifetime of buildings and their equipment and serious market barriers in residential sector, existing cost reduction incentives have not resulted in an effective implementation of energy efficient technologies in this sector. Some of the market barriers are high costs of gathering reliable information on energy efficiency measures; lack of proper incentives as well as the distance between and the separation of the efficiency costs paid by owners or builders and the advantages received by buyers or occupants; limitations in accessibility of finances, subsidies on energy prices; widespread and magnitude of energy use activities; and the fragmentation of the building industry and the design process into many professions, trades, work stages, and industries (Levine et al., 2007).

There are also barriers other than market barriers, including lack of accessibility and cost-effective technologies, an integrated design process with the involvement of architects, designers, engineers, contractors, and clients with special concentration on the existing passive energy saving opportunities, and slow turnover of retrofitting and replacing the energy using equipment in the existing buildings (IPCC, 2007). That is why although a variety of mitigation policies have been developed, e.g., adaptation of appliance standards and building energy codes and labelling, energy pricing measure and financial incentives, utility demand-side management programs, public sector energy leadership programs (procurement policies, education and training initiatives as well as the promotion of energy saving companies), the implemented strategies do not have enough leverage in the emission mitigation (Levine et al., 2007).

UNEP SBCI (2009) also mentioned a number of non-technological barriers (e.g., economic and financial barriers, hidden costs and benefits, market failures, behavioural and organisational barriers, information barriers, political and structural barriers), which prevent the estimated mitigation baselines from becoming true. In sum, the non-technological barriers were categorised into four categories including financial; institutional and administrative; awareness, advice, and skills; and separation of expenditures and benefits (Illikainen and Sirviö, 2015).

Among varied multiple barriers that exist in the residential sector, two of them have critical priority compared with the other factors, including the functional, physical, and spatial diversity of the housing products as well as the diversity of stakeholders and socio-demographic characteristics of the occupants. The spatial, functional, and physical characteristics of the dwelling units influence substantially the range and amount of their energy usage, and CO_2 and GHG production (UNEP SBCI, 2009; Levermore, 2008). However, the diversity of the housing products alongside the geographical disparity of the products decreases the opportunity of monitoring the impacts of the housing physical characteristics on the energy performance of the products.

The diversity of the stakeholders in the residential sector (e.g., landlords, investors, buyers, occupants, real estate, builders, and other housing industry professionals) also decreases the leverage of the emission mitigation plans by intensifying the complexity of the distance and separation of the efficiency costs and benefits, and the fragmentation of the industry. Among the different stakeholders, end-users' environmental perceptions and attitudes have centrality in the energy consumption, and CO_2 and GHG emission of the residential buildings due to the direct impacts of the end-users' behaviours as well as their roles as key driving forces in animating the marketing trends, affecting all other stakeholders of the industry (Levermore, 2008; Kwami et al., 2015). That is why it is believed that in the residential sector, a long-run mitigation plan depends strongly on end-users' spontaneous sustainable involvements and their pro-environmental behaviours (Ramkissoon et al., 2013; Jin, 2013).

Traditionally, it was believed that regarding carbon mitigation plans, large and medium scale buildings should gain priority (UNEP SBCI, 2009) because the opportunity of energy saving from a large number of small sized units (such as single dwellings) is too small. It was also believed that regarding the diversity of the housing products and stakeholders, developing a practical approach to the emission mitigation in this area is quite complicated, and the final outcomes of the operated mitigation plan would not be practically achievable. However, recent studies revealed that although the energy saving amount in a small size unit is supposed to be low, the total capacity of the aggregated emission mitigation in the entire sector is quite high, so that the overall achievement would be far greater than for large and medium size buildings (Cheng, 2010).

According to Laustsen (2008), the residential sector is responsible for 27.1% of the energy consumption worldwide, and the major part of this consumption is in buildings. Levine et al. (2007) also stressed that there is a potential to cost-effectively mitigate almost 29% of the globally projected baseline emissions by 2020 in the residential sector. In the group of the International Energy Agency (IEA), which includes Australia, the energy consumption of the residential sector in 2010 was almost two-thirds of the total energy usage of the building sector, while the energy consumption of the residential sector in the rest of the world was up to 90% of the total energy consumption of the building sector (Zeiss, 2015). Nasrollahi (2009) revealed that a well-designed dwelling unit is able to cut down and improve the energy performance of a building up to 65%. Richard (2014) stated that regarding the current benchmark compared with the sustainable level of energy consumption, there is a high capacity of energy saving in the Australian residential sector.

Over and above the whole existing energy saving opportunities in the residential sector, the diversity and complexity of the building types and characteristics, and the diversity of the stakeholders are the remaining factors that make the emission mitigation in the small size dwelling units practically complicated and problematic. Though there are theoretically significant advantages in the emission mitigation in the sector, the question is how to put the theoretical findings into practice. The effect of the rarely implemented plans is insufficient and is mostly that the quantitative and qualitative direction of the housing development substantially overrides the outcomes of the action plans (BZE, 2013). Morrison (2011) believes that meeting the 2050 carbon emission target baseline depends strongly on the possibility of improving the energy efficiency of existing housing through pro-environmental behaviours as will be discussed briefly in the next section.

3 Conceptual framework

It is believed that any mitigation action plans without end-users' positive attitudes are not able to achieve successful outcomes, even though proper technological mitigation measures and facilities are employed (Kwami et al., 2015). The concept of attitude is defined as an individual's tendency to express certain responses towards a concept or an object and includes three different domains, i.e., affective, cognitive and behavioural realms (Ramkissoon et al., 2012). Accordingly, the first realm addresses the emotional responses; while the second realm refers to beliefs, perceptions, and thoughts; and eventually, the third realm is about behavioural commitments. Accordingly, places as the main platforms for the expression of the emotions, cognitions, and actions are reliable sources in studying human attitudes.

To address the aim of the study, the central question is how the places are capable of reflecting human attitudes and perceptions. In this regard, it is necessary to refer to the origins of human behaviours, which might be goal-oriented related to the utilitarian meanings, or value-directed related to symbolic contents (Collen and Hoekstra, 2001). Unlike utilitarian meanings, symbolic contents are abstract concepts, which are created through individual's affective judgments rooted substantially in the associational values, and might be related to denotative inferences, i.e., style and function, or connotative judgments, i.e., like and dislike (Collen and Hoekstra, 2001). The utilitarian and symbolic contents that are also addressed as overt and latent functions are directly or indirectly derived from the concrete attributes of the places, including formal cues related to visual composition, e.g., form, proportion, height, size, density, rhythm, and complexity as well as sensory cues related to appearance characteristics, e.g., colour, texture, transparency, and material (Allen and Ng, 1999; da Luz Reis and Dias Lay, 2010). Accordingly, formal cues have substantial responsibility in the creation of spatial order and geometrical adequacy, dealing with the structure of the form. Sensory cues play significant roles in the pleasurableness of the sensations perceived from the environments which are related to a collection of built and natural morphological elements alongside the aspects associated with maintenance and cleanliness (da Luz Reis and Dias Lay, 2010). In this regard, the referral to physical, functional, and spatial characteristics of places would be a reliable methodology in explaining human's environmental attitudes and perceptions (e.g., Rapoport, 2000; Beckham, 2007; Loeb, 2007; Norberg-Schulz, 1985; Oliver, 2006).

Rapoport (2000) developed a theoretical framework, which describes the mutual and progressive interrelationships between human motivations (e.g., values, ideals, dreams, traditions, schemata, beliefs, norms, and standards) and the physical characteristics of their built environment. Accordingly, any particular socio-cultural groups and ethnicities are able to create special environmental characteristics with respect to the values of their communities. Oliver (2006) revealed the linkage between the housing type, spatial organisation, and spatial layout characteristics and occupants' motivational tendencies and traits, e.g., family position, lifestyle, and socio-cultural values as significant factors affecting their housing decision making. Some other studies, e.g., Norberg-Schulz (1985), Beckham (2007), and Loeb (2007) focus on the role played by the physical features (i.e., location, geographical orientation, position in relation to other components, material, size, proportions, transparency, form and shape, colour) of the housing components (i.e., door, window, terrace, porch) in the creation of specific utilitarian functions and symbolic meanings for the places. This line of research stresses, over and above their different theoretical praxis and assumptions, the substantial role of the housing physical, functional and spatial characteristics in reflecting the occupants' perceptions and attitudes.

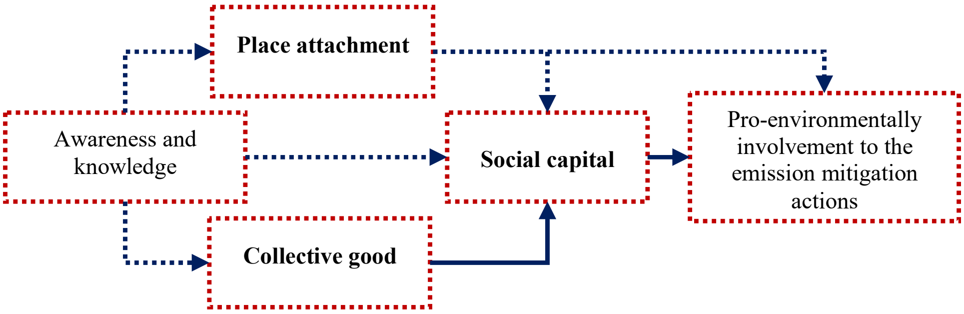
Having in mind that human behaviours are key driving forces in generating the environmental impacts, especially in the residential sector and regarding the capability of places in reflecting the human attitudes and perceptions, the remaining question is how it would be possible to enhance human attitudes and behaviours toward environmentally friendly behaviours.

It is believed that to increase the environmentally friendly behaviours, any actions related to the area of human values and motivations should be implemented based on a flexible down-up approach (Moser and Uzzell, 2003) which in the context of environmental sustainability means to improve people's pro-environmental behaviours (Ramkissoon et al., 2013). It is believed that the concept of pro-environmental behaviour is able to provide a substantial platform in enhancing the environmentally friendly behaviours (Ramkissoon et al., 2013). Pro-environmental behaviour that mostly depends on end-users' innate motivations and their spontaneous involvement in environmentally friendly activities is conceptually defined as behaviour that does not have harmful impact and may even improve environmental quality (Jin, 2013; Steg and Vlek, 2009). Berthoû (2013) believed that awareness of the climate change problems and intentions to live in a pro-environmentally friendly manner with the integration of the collective practical understanding would result in actual environmentally sustainable actions.

The concept of pro-environmental behaviour assists people in the selection of their housing requirements through a balanced integration of their real needs and environmental concerns. To provide more effective behavioural changes outcomes, the behaviour should be selected with respect to its effects on enhancing the environmental quality. It is then necessary to identify the factors that affect the behaviour, to develop well-tuned interventions that are capable of changing the behaviour and their related antecedents, and finally, to evaluate the effect of the interventions on the behaviours and their antecedents, as well as on the environment and people's quality of life (Steg and Vlek, 2009).

Ramkissoon et al. (2013) believed that place attachment has a significant role in promoting people's pro-environmental behaviours by empowering their social bonding, place dependency, and affection, as well as assisting them to look at the environment as an integrated part of their identity. On the other hand, social capital also affects positively pro-environmental behaviour, by changing the social level of the behaviour to the level of public everyday life activity and collective good (Berthoû, 2013; Jin, 2013). Figure 1 represents the interplay between factors assisting in pro-environmentally involvement to the emission mitigation actions.

Figure 1 The framework of mitigation action plan for small size units (buildings), i.e., residential sector (see online version for colours)



With respect to the discussion on emission mitigation in the Australian housing, Allwood et al. (2012) stressed the importance of the reduction in the consumption demand as one of the necessary actions for emission mitigation. Regarding the conceptual platform of this study, the reduction of consumption demand in the housing sector would rely strongly on the end-users' environmentally friendly and sustainable choice behaviours. The role of end-users' perception is crucial, not only due to the role of end-users as the main driving forces of the development but also due to their role in affecting the market trends and the various stakeholders alongside the building types and physical characteristics. Morrison (2011) stated that in improving the energy efficiency in the housing sector, the households' pro-environmentally friendly behaviours are the key parameters to the extent that the occupants' socially beneficial choices alongside their engagement in collective actions at the local level have capability of generating positive impacts on carbon emission at the national level.

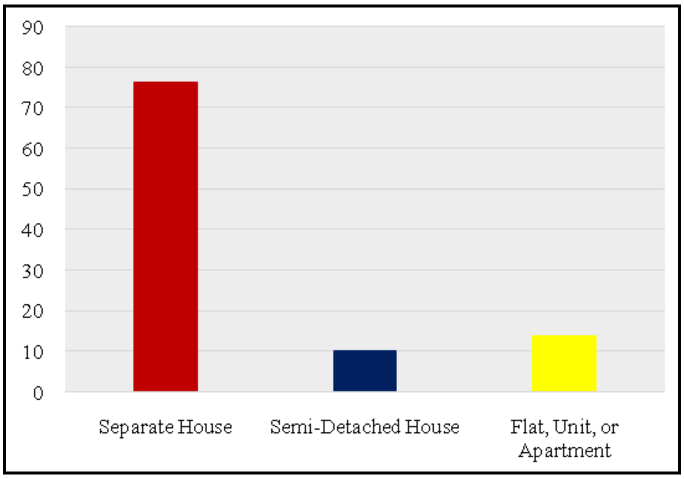
The main focus of this study is, therefore to explore the possible impacts of the occupants' perceptions and attitudes on the energy performance of the Australian housing by drawing profiles from the changes in the functional, physical, and spatial trends in the housing system. The study makes is fruitful for the identification of the factors that are the origins of the housing preferences and the impacts of these factors on the energy performance of the dwelling units. The outcomes of the study will assist in identifying the dwelling activities that are more critical in improving energy performance, and the interventions that make housing products able to improve the energy performance of the dwelling units.

4 Research methodology

Looking at housing preferences through the physical, functional, and spatial characteristics of their housing environments is a reliable methodology for explaining the occupants' perceptions and attitudes. In this regard, the main sources for the data collection are stated data based on the expressed preferences and revealed data based on the secondary data (Asad Poor, 2014). The nature of the stated data is hypothetical, and the process of the data collection and analyses might be affected by biases and prejudice generated by participants' and researchers' research activities (Kothari, 2009). Therefore, if the actual information is available, revealed data is a reliable and recommended method (Opoku and Abdul-Muhmin, 2010). Opoku and Abdul-Muhmin (2010) explained the economic performance of the residential sector to shed light on the housing purchase concerns of house buyers through employing a secondary data collected from a number of available sources.

In this study, the required data is compiled from a number of available sources, i.e., ABS (2012), Australian Institute of Family Studies (AIFS) (de Vaus and Qu, 2015), SA.GOV (2015) and BZE (2013). Employing Excel software, the graphical analyses conducted on the compiled data resulted in the extraction of the main components of Australian housing characteristics. Indeed, drawing graphical profiles from the Australian housing characteristics assists in visualisation of Australian housing preferences, which is substantially necessary for explaining the housing perceptions and attitudes. Addressing the occupants' housing perceptions and attitudes resulted in the explanation of the behaviours that are more crucial for improving the housing efficiency, the factors that may affect the behaviours, and the interventions that is necessary to change the behaviours (Steg and Vlek, 2009). The next sections will provide a platform for a brief discussion on the Australian housing characteristics, highlighting to what extent end-users' environmental perceptions are significant factors for improving the energy performance of the residential sector, and which aspects of their behaviours are more relevant to the emission mitigation in the Australian housing context.

Figure 2 Capital city households, by dwelling structure 2009 to 2010 (see online version for colours)



Source: ABS (2012)

5 Analyses and results

This section employs the data compiled from the online data sources to initially provide graphical representations of housing characteristics and occupants' preferences in Australia, and then to make a cross-comparison between residential and non-residential sectors to visualise the responsibility of the residential units and occupants' choice behaviours in improving the energy performance of the Australian building sector.

According to ABS (2012), in 2009 to 2010, 98% of Australia's population 8.4 million households) were living in private self-contained dwellings including houses, apartments, flats or units. Almost 6.636 million (79%) were living in separate houses (Figure 2). Typically, separate houses have three or four bedrooms. The three-bedroom house is the most common dwelling type in Australia (ABS, 2012). In 2009 to 2010, 40.5% of all households lived in three-bedroom separate houses, 30.5% lived in four or more bedroom separate houses, and within separate houses, almost 90% of the population lived in three or more bedroom houses (Table 1).

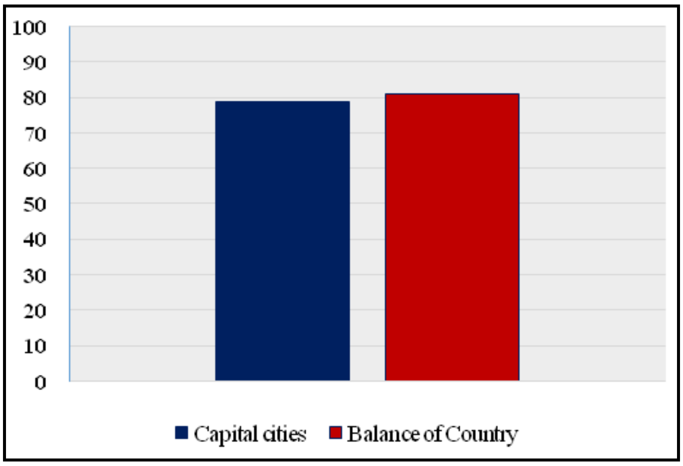
Table 1 All households, by dwelling structure and number of bedrooms 2009 to 2010

	Separate house '000	*Percent %*	*Townhouse/ flat/apartment '000*	*Percent %*	*All households '000*	*Percent %*
One bedroom	53.0	0.6	252.7	3.02	305.7	3.62
Two bedroom	618.8	7.4	904.8	10.83	1,523.6	18.23
Three bedroom	3,383.1	40.5	507.9	6.08	3,891.0	46.58
Four bedroom	2,544.6	30.5	89.7	1.07	2,634.3	31.57
Total	6,599.5	79	1,755.1	21	8,354.6	100

Note: *The table does not include other dwelling structure and housing types, i.e., bed-sits and dwelling with no bedroom.

Source: ABS (2012)

Figure 3 Households with one or more spare bedrooms 2009 to 2010 (see online version for colours)



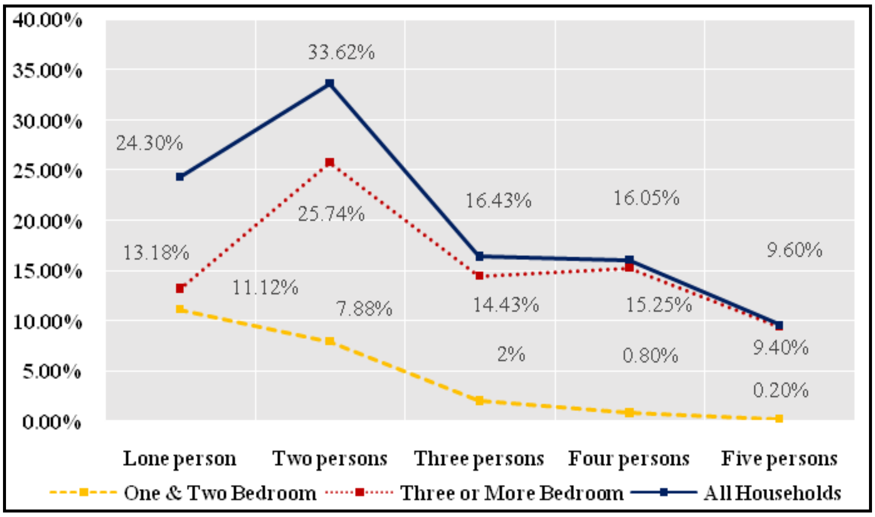
Source: ABS (2012)

Table 2 All households, by number of bedrooms and number of persons 2009 to 2010

	One and two bedroom '000	*Percent %*	*Three and more bedroom '000*	*Percent %*	*All households '000*	*Percent %*
Lone person	931.6	11.12	1,103.8	13.18	2,035.4	24.3
Two persons	659.9	7.88	2,155.6	25.74	2,815.5	33.62
Three persons	167.7	2.00	1,208.5	14.43	1,376.2	16.43
Four persons	66.8	0.80	1,276.8	15.25	1,343.6	16.05
Five persons	16.4	0.20	786.9	9.40	803.3	9.60
Total	1,847.8	22	6,531.6	78.02	8,374	100

Source: ABS (2012)

Figure 4 Number of households and number of bedrooms per dwelling 2009 to 2010 (see online version for colours)



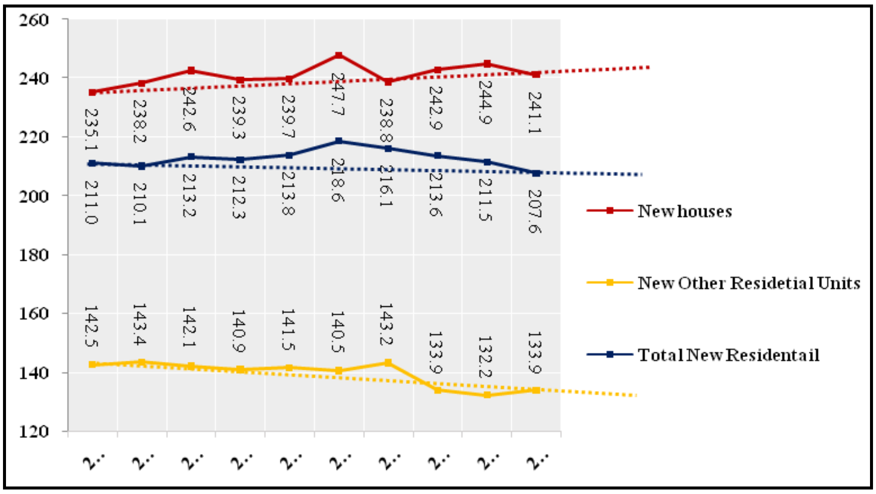
Source: ABS (2012)

The average number of Australian households' members and dwelling size between 1976 and 2009 to 2010 represented two contrary actions. While the average number of people per dwelling was decreasing from 3.1 to 2.6, the average number of bedrooms per dwelling has increased from 2.8 to 3.1 (ABS, 2012). In sum, in 2009 to 2010, most households enjoyed relatively spacious accommodation. According to ABS (2012), 79% of households had spare bedrooms, possibly associated with the proportions of separate houses, which means that the dwelling is not often fully utilised by accommodating a reasonable number of people, even though the spare spaces might be used for other purposes, e.g., study room, office room, play room, and store (Figure 3). In the three or more bedroom dwelling units, 38.95% of the units were occupied by households of less than two people (13.2% and 25.75% respectively for lone person and two person households) (Table 2, Figure 4). The amount of lone person households as a percentage of the Australian population had grown from 11% to almost 25% during the period of

1911 to 2011 (de Vaus and Qu, 2015). The number of lone person households is also estimated to substantially growth between 2011 to 2036 from 2,100,000 households to more than 3,300,000 households (1,300,000 households and more than 63% growth) (ABS, 2015), which means the lone person households as a percentage of the Australian population in 2036 would be more than 40%.

The average floor area of new residential dwellings increased continuously over the 28 financial years from 1984–1985 to 2012–2013 (ABS, 2013). The average floor area of all new residential dwellings increased from 149.7 m^2 to 207.6 m^2 (38.7%). Over this period, the average floor area increase for new separate houses was 48.5% (162.4 m^2 to 241.1 m^2) and for other new residential dwellings was 35% (99.2 m^2 to 133.9 m^2). Regarding the annual changes during the period of the last ten years of this period, the average floor area of new separate houses slightly increased during the period of 2003–2004 to 2012–2013, while the average floor area of other new residential units slightly decreased, especially after 2008–2009, when new other residential units experienced a relatively serious reduction compared with the fluctuation in the average floor area of new separate houses (Figure 5).

Figure 5 Average floor area of new residential dwellings, Australia (see online version for colours)



Source: ABS (2013)

Over the ten financial years from 2003–2004 to 2012–2013, the average floor area of new houses increased by 6.0 m^2 (2.6%), while the average floor area of new other residential types and total new dwellings units decreased respectively by 8.6 m^2 (6.%) and 3.4 m^2 (1.6%) respectively (Figure 5). Accordingly, the total average floor area of different types of new dwelling units over this period were almost 241 m^2 for separate houses, 139.4 m^2 for other residential types, and 212.8 m^2 for the total residential units (ABS, 2012). Considering the average number of people per household (2.6 persons per household), the average residential space per person in new dwelling units was almost 92.7 m^2 for separate houses, 53.6 m^2 for other residential units, and 81.8 m^2 for total residential units, which means that the total average floor area of new dwelling units increased almost 40 m^2 over the last 30 years.

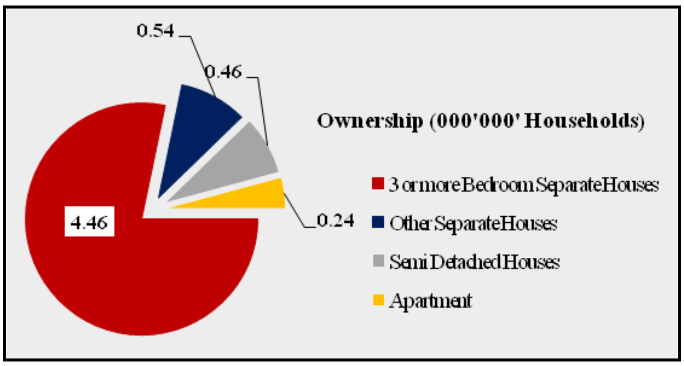
Since 1966 the rate of home ownership in Australia has fluctuated between 68% and 71% (Table 3). From the total households in the 2009–2010, an estimated of 33% (47.8% of the total owners) were the owners without a mortgage and 36% (52.2% of the total owners) were the owners with a mortgage (ABS, 2012) (Table 3). The ownership with a mortgage is somehow a sign of the uptake of flexible low-cost financing options that allow the households to spend their housing mortgages for other purposes (ABS, 2012). Australia's preference for a free-standing house on its own block of land is the most preferred ownership. Of the 5.7 million households that lived in owner-occupied dwellings in 2009–2010, 88% (five million households) were in separate houses (Figure 6).

Table 3 All occupied private dwellings, by tenure type

Year	*Owner without a mortgage '000*	*Owner with a mortgage '000*	*All owner occupied private dwellings '000*	*Renter*	*Other tenure*	*Total*	*Proportion of owner occupied private dwellings %*
1966	----	----	2,231.9	835.1	59.6	3,126.4	71.4
1971	----	----	2,468.9	1,001.3	119.3	3,589.5	68.8
1976	1,306.3	1,437.8	2,761.5	1,044.5	232.5	4,040.5	68.3
1981	1,548.9	1,542.9	3,178.9	1,164.5	190.6	4,534.0	70.1
1986	1,981.9	1,604.4	3,586.3	1,334.4	174.1	5,094.8	70.4
1991	2,362.0	1,561.3	3,923.2	1,560.6	210.3	5,694.2	68.9
1996	2,658.0	1,656.1	4,314.0	1,866.0	67.8	6,274.8	69.0
2001	2,810.9	1,872.1	4,683.0	1,953.1	101.3	6,737.4	69.5
2006	2,430.7	2,436.1	4,866.8	2,010.4	60.01	7,144.1	68.1
2011	2,488.1	2,709.4	5,197.6	2,297.5	70.07	7,760.3	67

Source: ABS (2012, 2016)

Figure 6 Owner and renter households, by dwelling type 2009 to 2010 (see online version for colours)



Source: ABS (2012)

The next stage of the analyses is to briefly compare the characteristics of residential buildings and non-residential buildings in the context Australia in terms of floor area and energy consumption. The comparison assists in visualising the capacity of energy demand reduction in the residential sector. Regarding the floor area of residential buildings, by considering the proportion of lone person households and the average number of people per household, it is assumed that the number of households is capable of representing the number of dwelling units; hence regarding the average floor area of the total residential units (212.8 m^2) and three or more separate houses (241 m^2), an estimation of floor areas based on ABS (2012) was calculated as follow:

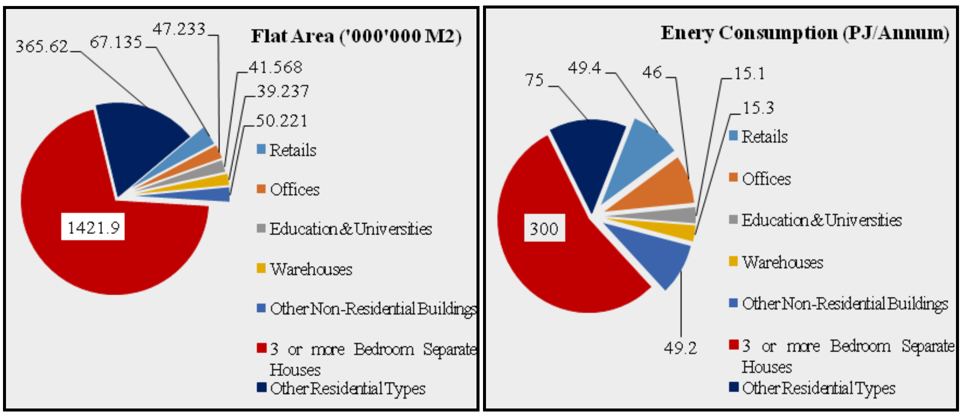
$$\text{Total number of households} * \text{Total average floor area of dwelling units}$$
$$8,400,000 * 212.8(\text{m}^2) = 1,787,520.000 \text{ m}^2 (\text{Total floor area of residential units})$$

$$\text{Number of three or more bedroom units}$$
$$* \text{Average floor area of three or more bedroom units}$$
$$5,900,000 * 241(\text{m}^2) = 1,421,900.000 \text{ m}^2$$
$$(\text{Total floor area of three or more bedroom Separate houses})$$

Regarding the total national floor area of non-residential buildings that was 245,311,000 m^2 (BZE, 2013), the total national floor area of the Australian building sector in 2012 would be:

$$\text{Total floor area of residential units} + \text{Total floor area of non-residential buildings}$$
$$1,787,520,000 + 245,311,000 = 2,032,831,000$$
$$(\text{Total national floor area of Australia})$$

Figure 7 Floor area and energy consumption of the Australian residential and non-residential buildings (see online version for colours)



Source: BZE (2013) and ABS (2012)

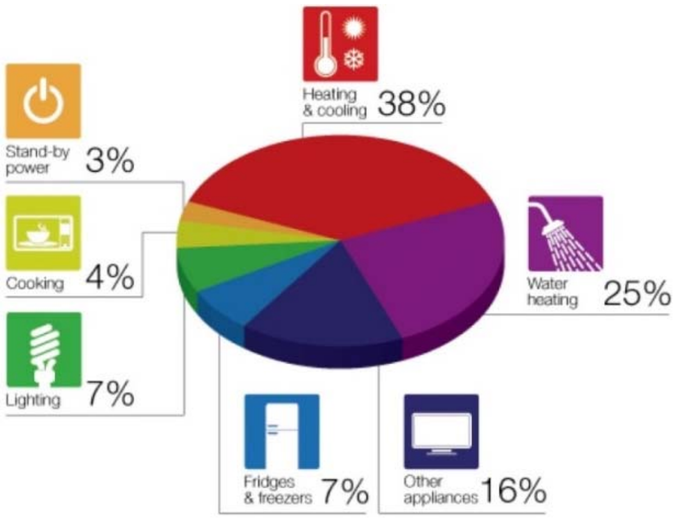
Table 4 National residential and non-residential building characteristics

Building category		*Floor area (m^2)*		*Percentage (%)*		*National energy use (PJ/Annum)*	
Residential	Three or more bedroom separate houses	1,421,900,000	1,787,520,000	70	88	300 (54.5%)	375 (68.2%)
	Other residential units	365,620,000		18		75	
Non-residential	Retails	67,134,855	245,311,000	3.3	12	49.4	175 (31.8%)
	Offices	47,232,731		2.3		46.0	
	Education and universities	41,568,034		2.04		15.1	
	Warehouses	39,236,929		1.93		15.3	
	Others	50,221,057		2.43		49.2	
		2,032,831,000		100		550	

Source: BZE (2013) and ABS (2012)

Regarding the total national floor area, the residential sector in 2012 represented 88%, and three or more bedroom houses represented 70% of the total national floor area of Australia compared with retails and office buildings that respectively represented 3.3% and 2.3% of the total national floor area (ABS, 2012; BZE, 2013). Regarding the national energy consumption of the Australian building sector in 2012, the total energy consumption of the residential sector was almost 375PJ/Annum (68.2% or more than two-thirds of the national energy consumption of the building industry). Considering the proportion of three or more bedroom separate houses, 300PJ/Annum energy (54.5% of the national energy consumption of the building sector) was consumed by this housing type, while this amount for non-residential sector was 175PJ/Annum (almost 31.8% of the total energy consumption of the building sector) (Table 4, Figure 7) (BZE, 2013; ABS, 2012).

Figure 8 The distribution of energy usage in the residential sector of South Australia (see online version for colours)



Source: SA.GOV (2015)

Finally, regarding the energy consumption distribution in the residential buildings of South Australia (Figure 8) and by assuming that it is possible to generalise the energy consumption distribution of South Australia to other regions of the country, from the total energy consumption of 3 or more bedroom houses, 114PJ/Annum (38%) was for heating and cooling purposes, and 75PJ/Annum (25%) was for water heating as the two main sources of energy consumption in the residential sector. The cumulative amount of energy consumption for heating and cooling and water heating was 189 PJ/Annum (63%) representing a significant proportion of energy consumption in this area of residential sector. The amount of energy consumption for heating and cooling purposes is highly crucial by considering the substantial capacity of energy consumption reduction in this energy consumption area of the residential sector (Nasrollahi, 2009; Richard, 2014).

6 Discussion

The graphical representations of the compiled data visualises the components of the Australian housing preferences, explaining the end-users' environmental perceptions, attitudes, and behaviours. Therefore, the graphical analyses are useful in explaining the potentials and challenges of the emission mitigation as well as the necessity of pro-environmental behaviours in the Australian residential sector.

The proportion of the national floor area and the energy consumption of the residential sector compared with the total building sector of Australia, make it evident that this sector has a substantial responsibility in the realisation of the mitigation baseline of Australia. The energy consumption for heating and cooling purposes as the first source of the energy consumption in the residential sector (Figure 8) highlights the substantial impacts of the housing spatial, functional, and physical characteristics, e.g., floor area, the number of floor, height, proportion, density, the number of bedrooms, spatial layout arrangement, and building materials. Regarding the capability of improving the energy performance of heating and cooling up to 65% in an efficiently-designed residential building (Nasrollahi, 2009), the capacity of energy consumption reduction in the most preferred housing type of Australia would be more than 74PJ/Annum that is substantially considerable compared with the energy consumption of the non-residential sector (Table 4). The energy usage for water heating purpose as the second source of the energy consumption in the Australian residential sector (Figure 8) also depends strongly on the occupants' choice behaviours rooted in their perceptions and attitudes.

The housing type and tenure alongside spatial characteristics (e.g., floor area, the number of bedrooms, and the number of household members per dwelling) explain the Australian housing preferences. Indeed, the most preferred housing type in Australia with 79% of the total households is a separate house standing on its own block of land. 70.3% of the total Australian households lived in 3 or more bedroom separate houses with the average floor area up to 241 m^2. In 2009–2010, 69% of people lived in owner-occupied houses, 33% of which (47.8% of the total owner-occupied houses) were without a mortgage. According to ABS (2012), the mortgage of the rest of the houses is not necessarily due to the original home purchase but is the evidence of the owners' interest in the uptake of the finances for the other purposes. Therefore, the most preferred housing type and tenure highlight the end-users' proper level of socio-economic capacity, facilitating the development of a suitable framework for the emission mitigation in the housing sector.

One of the interesting aspects of the most preferred housing type and tenure in Australia is the multiple roles of the end-user as a landlord, owner, and occupant, which impact on the complexity of dealing with the interrelationships among them, and the distance between paying for the efficiency costs and receiving the related benefits. The next point is the presence of the end-users during the different lifecycle stages of the houses. The end-users' presence along with their socio-economic characteristics increases the possibility of developing enhancement programs aiming at empowering the occupants' pro-environmental behaviours with respect to their household activities, which is essential for developing a flexible down-up approach to the emission mitigation, facilitating the production of energy-efficient new houses, the decrease in the consumption demands, and retrofitting the existing dwelling units.

The presence of the end-users and their socio-economic characteristics make their participation in the different stages of feasibility assessment and design process of the new houses practically possible, which can result in the enhancement of the energy efficiency of the housing product. The end-users' accessibility and presence provide an exceptional opportunity for proactive participatory design and construction, mediating the communication between designers, engineers, and builders (Israel, 2003). Hence, the accessibility provides good opportunity for reducing the fragmentation of the building industry and providing an integrated design and construction procedure. Their communication would be then capable of decreasing the embodied energy of the new residential units by facilitating the selection of the energy efficient technologies and materials during the design and construction. The design stage is moreover able to improve the spatial, functional, and physical characteristics by regulating end-users' housing preferences and mediating the interrelationships between the housing characteristics and the end-users' behaviours. The decrease in the complexity of owner-occupant interrelationships increases the reliability of the decisions related to the operation phase (Asad Poor, 2015), which results in the decrease in the post-occupancy interventions and a relatively higher level of stability in the household activities, reducing the operation energy of the dwelling units.

Looking at the housing characteristics over the last few decades (e.g., the increasing average floor area per person, the number of bedrooms per person, and the proportion of the lone and two person households, as well as the decreasing number of people per household) makes possible to visualise the direction of the occupants' preferences in the Australian housing. The housing trends show that the occupants' consumption demands in separate houses experienced a more rapid increase than the other housing types, indicating the significance of the occupants' level of socio-economic characteristics and affordability as well as the centrality of their environmental perceptions, attitudes, and behaviours for a sustainable energy usage plan. Within the period of 2003–2004 to 2012–2013, the increasing average floor in the new separate houses compared with the decreasing average floor area of the new other residential buildings strictly confirm the critical situation of the occupants' preferences in this housing type, and the centrality of their attitudes.

Regarding the most preferred housing type, the monotony of the dwelling type along with the proportion of lone and two person households highlight the lack of diversity and flexibility of the dwelling units with respect to the occupants' changing needs during their different lifecycle stages. The housing spatial, functional, and physical characteristics, e.g., floor area, the number of bedrooms, and the spatial layout arrangements should be designed in relevance with the households' size and socio-demographic characteristics, and the spatial layouts arrangements should provide flexibility with respect to the households' size and other living concerns during their different life cycle stages.

7 Conclusions

In general, over the last few decades, end-users' environmental attitudes and behaviours have been becoming more unsustainable, especially in the separate housing units. Considering the rapidly growing demands in the future housing development of Australia, a mere technological approach to the enhancement of the energy performance through up-down fixed rules would not be significantly effective and a flexible and comprehensive down-up approach that aims at reducing the energy demands by enhancing the housing spatial, functional, and physical characteristics through the enhancement of the occupants' pro-environmental behaviours would be highly critical. The Australian housing spatial, physical, and functional characteristics along with the direction of occupants' housing preferences are the main challenging factors against the enhancement of the energy performance of the residential sector. The characteristics also highlight the substantial capacity of the energy consumption reduction in the sector through the conceptual framework of pro-environmental behaviours. In this regard, reconsideration of housing development policies should gain priority to provide a flexible down-up approach, which is capable of inviting and encouraging occupants to take serious actions in improving the energy performance of their dwelling units by improving the functional, spatial, and physical characteristics of their dwelling units and enhancing their consumption preferences and activities. Regarding the population composition of Australia, the end-users' socio-economic characteristics provide a proper platform for pro-environmental behaviours through the concept of collective good. However, the multicultural nature of the population and the differences in the level of place attachment of the people are major challenging factors against the implementation of social enhancement programs, which should be considered further in the future research.

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