Low Carbon Residential Refurbishments in Australia: Progress and Prospects

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Abstract: Recognising both the recent surge in interest in low carbon refurbishments of residential buildings and the diversity of emergent terminology and perspectives, the authors set out definitions for key terms and frame a discussion of the phenomenon of refurbishments. The paper focuses on owner-occupied detached homes that dominate Australia's existing residential building stock.

In the context of both international and Australian conditions and initiatives, a review-based account is presented of factors that are (a) exogenous to the refurbishing household including technical, regulatory, economic and social factors, and (b) endogenous to the household, including social practices, goals, attitudes and behaviours. A set of intentional 'enabling' factors designed to facilitate the decision-making process and actions is considered. These include financial incentives, information tools, professional knowledge, voluntary labels as well as individual householder practices. Rebates, low interest loans and feed-in tariffs are proven incentives for retrofit actions. The capability of building professional and technical solutions may facilitate the execution of the homeowners' objectives. Trigger events, which may precipitate the decision toward comprehensive refurbishments, are identified. These may be the 'necessary' renovation of the home, a change in ownership, an energy audit or advice from a building professional.

The paper also reviews specific householder perspectives of living in 'near zero energy or carbon' homes. The neighbourhood and the functional aspects of the home are considered alongside energy efficiency. Conclusions are drawn in the context of decision-making processes, progress of low carbon residential refurbishments, and their future prospects.

243 words

Introduction

Buildings, which account for about a third of the world's greenhouse gas emissions (UNEP SBCI 2009), play an important role in strategies to mitigate climate change. Cutting carbon emissions from the building sector is promoted as "the cornerstone of every national climate change strategy" with potential benefits ranging from environmental to economic benefits (UNEP SBCI 2009, p. 2). As most of the emissions during the lifetime of a building are due to the reliance on fossil fuels during its operation, strategies to cut carbon emission typically target operational energy demand and upstream fuel sources. Technical options are often supplemented with initiatives aiming at changing occupant behaviours and social practices.

In Australia, energy used in residential buildings is estimated to be responsible for about 12 percent of the nation's energy consumption (Australian Government Department of Infrastructure and Transport 2013) and between 9 and 13 percent of Australia's greenhouse gas emissions (Australian Bureau of Statistics 2010c; Centre for International Economics 2007; ClimateWorks 2013). Action to substantially reduce the emissions from homes has been called for (UNEP SBCI 2009). The Australian Sustainable Built Environment Council (ASBEC), a peak body of key organisations committed to a sustainable built environment in Australia, believes that the "ultimate indicative goal should be zero emission buildings" (*Report of the Prime Minister's Task Group on Energy Efficiency* 2010, p. 148).

In Europe, many nations have set targets for zero or very low energy buildings at least for new buildings (*Report of the Prime Minister's Task Group on Energy Efficiency* 2010). In central Europe, there is significant concern regarding the improvement of the existing housing stock, and considerable activity in residential refurbishments to zero or near zero carbon standards has been observed. By comparison, in Australia, examples of such low carbon residential refurbishments are scarce (Sustainability Victoria 2012).

In 2012, Sustainability Victoria on behalf of ASBEC commissioned RMIT University's Centre for Design to review and analyse the drivers of demand for low carbon refurbishments (Sustainability Victoria 2012). This paper summarises those findings which pertain to owner-occupied detached homes and discusses the prospects for low carbon residential refurbishments in Australia.

Definitions

The improvement of a home in terms of energy efficiency invariably includes a range of measures, ranging from the enhancement of the energy performance of the building envelope, to the employment of more energy efficient fixed appliances, and switching to less carbon intensive fuel sources. Energy efficiency improvements may also vary in level of intrusion, costs and carbon savings. A plethora of terms are used to describe these widely varying activities and perspectives on the notion of improving the energy efficiency and quality of homes (Mansfield 2002). Although various attempts have been made to categorise these initiatives (Roberts 2008; Weiss, Dunkelberg & Vogelpohl 2012), there remains diverse understandings of the terms renovation, retrofit and refurbishment. A literature review of official definitions nationally and internationally yields that the terms may refer to changes in the appearance of a building, its size or the monetary value of the construction initiative with variations in scale and scope for different interpretations.

To clarify the terms used in this paper, a categorisation based on the extent of the measures and the use of renewable energy sources has been adopted, as illustrated in Figure 1. Energy efficiency initiatives which are limited to single or a few isolated measures are called 'retrofits', while those characterised by a comprehensive house-as-a-system approach are called 'refurbishments'. The use of adjectives distinguishes between activities targeting the building envelope, carrying the adjunct of 'thermal', and those involving a switch to renewable fuel sources, termed 'low carbon'. Hence 'zero carbon refurbishment' involves a comprehensive strategy that combines the improvement of the building envelope, the enhancement of the fixed operating systems and the choice of renewable fuel sources with the aim to balance the building's annual emissions with self-generated energy. The term 'upgrade' denotes the use of a more efficient technical appliance which still uses fossil fuels.

Deployment of renewable energy systems / Extent of measures	Restricted to building envelope	Use of renewable energy system is unknown	Inclusion of renewable energy system	Annual emissions are balanced by renewable energy generation
Single or few isolated measures	**Thermal retrofit**		**Low carbon retrofit**	
Comprehensive strategy	**Thermal refurbishment**	**Energy efficient refurbishment**	**Low carbon refurbishment**	**Zero carbon refurbishment**

Figure 1 Categorisation of energy efficient building improvements
Source: (Sustainability Victoria 2012)

This paper focuses on factors influencing low carbon refurbishments through a desktop review of academic and informal, national and international publications in English and German. Due to a dearth of information regarding low carbon refurbishments nationally, recourse was taken to exploring factors influencing retrofit activities in Australia. The potential validity of the findings of international studies for the Australian context is discussed.

Background

Like other developed nations, the Australian government has responded to the call for action by introducing increasingly stringent energy efficiency regulations. With regards to existing homes, energy efficiency regulations vary from state to state. In Victoria and New South Wales, energy efficiency requirements only apply to substantial renovations and alterations, defined by spatial (Building Commission 2011) or monetary thresholds (NSW Government 2009). In the absence of general retrofit or refurbishment obligations, actions to reduce building related emissions depend on voluntary actions by the decision makers, usually the building owner.

Despite the advertisement of the potential benefits of refurbishments to the householder, such as economic savings and increases in comfort, worldwide the rates of refurbishments are falling short of the rates expected by governments (Dyrbol & Aggerholm 2011; Weiss, Dunkelberg & Vogelpohl 2012). The lack of uptake of energy saving opportunities, sometimes called the 'energy efficiency gap', has also been detected in the Australian residential improvement market (The Allen Consulting Group 2004). As the implementation of energy efficiency measures in homes across the western world lags behind the expectations of some policy and program makers, (Gram-Hanssen 2013; Stieß & Dunkelberg 2013; Tovar 2012; Weiss, Dunkelberg & Vogelpohl 2012), interest in the householder perspective and decision making process is growing (Nair, Mahapatra & Gustavsson 2012; Stieß & Dunkelberg 2013; Swan 2013).

Approach

Various disciplines have proposed decision making models to explain choices in residential energy consumption. As explained by Wilson and Dowlatabadi (2007), common approaches centre on the individual as the potential key to the solution, yet the perspective is shifting towards a more contextual view. For example, the model of the 'rational actor' is rooted in the conventional economic utility theory and presupposes a conscious decision making process based on informed choices and perceived economic considerations. While this approach is challenged by behavioural economists who propose a heuristic or experience-based process which relies on the individual's emotions or responses, both concepts focus on the individual.

By contrast, Diffusion of Innovation theory (Rogers 1983), which sets out to explain the continuous spread of a novel idea or technology through a social system, introduces the social context into the decision making process. In this particular model the decision or choice of the adopter is attributed to the individual's attitudes, which are assumed to be shaped by various communication channels rather than on information. Similarly, the model developed by the disciplines of social and environmental psychology recognises contextual influences in the development of pro-environmental decisions and behaviour change in addition to the personal ones. Within the individual sphere, the model propounds that the individual's attitude or personal characteristics influence a person's beliefs which are internalised and change the perception of what is thought to be socially accepted behaviour. Contextual factors such as socio-economic status, regulations, incentives and market characteristics are seen to interact with the individual factors and to have the potential to induce behaviour change. A large-scale survey of German homeowners who had retrofitted their homes has confirmed the correlation of individual and contextual aspects in these decisions (Stieß & Dunkelberg 2013).

Building improvement projects are complex processes that involve various actor groups and are limited by temporal, technical, economic and social boundaries. For the purpose of this review, a model was developed which maps the key decision making variables on a project timeline. A low carbon refurbishment project is envisaged to pass through five consecutive stages: the attainment of knowledge of the concept, the process of persuasion, the point of decision in favour of the new standard, the implementation of the intent which starts with the design and planning phase in consultation with the architects and engineers, the construction process and, finally, the occupation of the building and the project evaluation. A schematic representation of the decision making model is provided in Figure 2.

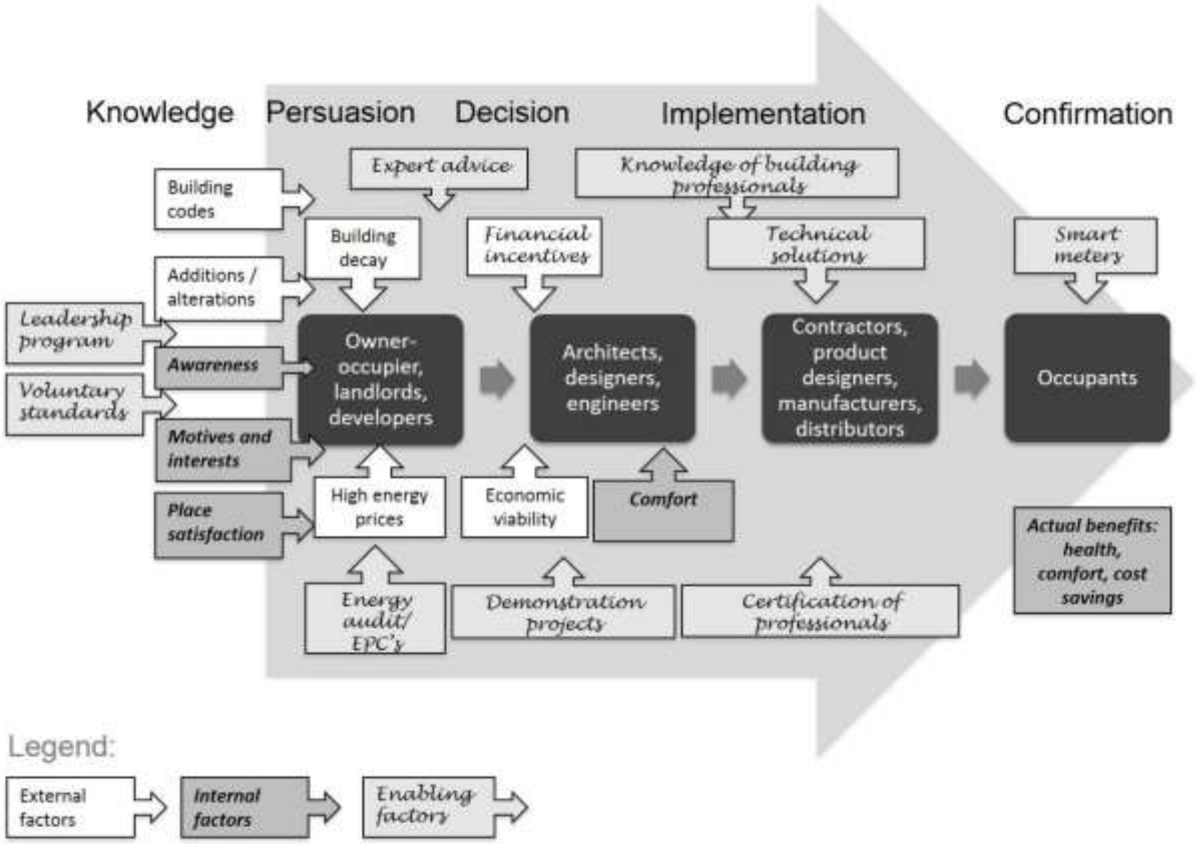

Figure 2 Schematic representation of decision model
Source: Adapted from (Sustainability Victoria 2012)

Based on the categorisation of exogenous and endogenous factors for renovation decisions by Jakob (2007) and Ott et al. (2005), the review distinguishes between external and internal factors. External factors may 'force' homeowners to undertake energy efficiency measures even though these might not be at the top of the priorities list. Internal factors are variables at an individual scale such as attitudes and beliefs. In addition, the review lists enabling factors that may facilitate or accelerate energy conservation decisions by helping to overcome barriers. For the purpose of this paper only the key factors are presented. For a comprehensive overview of all the factors and an analysis of their impacts, please refer to the full report (Sustainability Victoria 2012).

External factors

External factors are variables in the technical, regulatory, economic and social domains that have the potential to exert considerable influence on the choice of the decision maker. In general, external factors are tools of systematic persuasion, which appeal to logic and rational balancing.

Regulations

Building codes are considered to be one of the most cost and time efficient as well as effective external factors (Weiss, Dunkelberg & Vogelpohl 2012). While many European nations have adopted ambitious targets for the energy efficiency of new buildings, no country has yet implemented a very low or zero energy target for existing buildings. Sub-optimal energy efficiency mandates have been perceived as a "barrier to more radical change" (Vergragt & Brown 2012, p. 413), as they may 'lock-in' inefficient building performance for several years (Korytarova 2010; UNEP SBCI 2009). In addition, less ambitious regulations may be used as an excuse by contractors for resisting to change common construction practices (McGee et al. 2008). Nonetheless, it has been suggested that even the presence of very low or zero carbon mandates for refurbishments would not guarantee their effectiveness. Governments have been found to be limited in enforcing regulations in the existing building stock (Weiss, Dunkelberg & Vogelpohl 2012) and problems with non-compliant workmanship seem to be not uncommon (ClimateWorks 2013; Pan & Garmston 2012).

Regulatory obligations to improve the energy efficiency of existing homes are controversial as they may be perceived as interfering with property rights, (Murphy, Meijer & Visscher 2012; TrainRebuild 2011). In Australia, energy efficiency standards for existing homes have to be adhered to only when the buildings are substantially altered or extended. Analysis of renovations data in New South Wales reveals the widespread incorporation of thermal retrofits and solar hot water and heating systems in such projects (NSW Government 2009). In construction projects in which obligatory retrofits or refurbishments are necessary, the decision making process may shift from the homeowner to the architect or consultant. The homeowner may adopt a passive role if the decision about the extent and scope of the building energy performance improvement is left to his agent. The rationale for the decision made by the architect may be more based on economic considerations (The Allen Consulting Group 2004) than perhaps the decisions made by the homeowner.

In those cases in which the construction project remains below the regulatory thresholds or in homes where no improvement works are planned, regulatory requirements do not take hold. In the absence of refurbishment obligations outside of major construction work, energy efficiency initiatives in most existing homes in Australia remain voluntary. Nonetheless, energy efficiency building regulations create awareness of the new standards, the possibilities of fuel switching and may be associated with shifts in householder attitudes, knowledge and practice.

Economic factors

Economic factors are the cornerstone of the conventional economics decision model of the 'rational actor' (Wilson & Dowlatabadi 2007). Economic considerations include cost-benefit calculations, capital investment costs, maintenance costs and the risk of financial losses due to inaction (Nair, Gustavsson & Mahapatra 2010).

Evidence for the importance of economic considerations in the decisions making process about residential energy efficiency is inconclusive and a differentiation between refurbishments, low carbon retrofit activities and income groups may is needed. Internationally, research has found that economic concerns may be present but may not be the first priority for the householder when contemplating housing energy efficiency improvements (Mlecnik, Visscher & van Hal 2010; Schnieders & Hermelink 2006; Volkmer 2013). Similarly, in Australia, rising energy prices seem to cause concern among the population (Clean Energy Council 2011) and are believed to be the main driver for the demand of highly performing homes by key stakeholders in the building industry (Riedy, Lederwasch & Harris 2012) . Yet this does not seem to have translated into an increased uptake of thermal retrofits or refurbishments to date. In a survey conducted by the Australian Bureau of Statistics, rising energy prices have only been indicated by a small number of Victorian householders as the reason for installing insulation (Australian Bureau of Statistics 2010a). Householders may associate the prospect of lower energy bills with low carbon technologies rather than with thermal retrofits (IEA 2011). It has been suggested that the high uptake of solar photovoltaic panels among lower rather than higher income householders may have been due to the homeowners' desire to protect themselves against energy price volatility (ClimateWorks 2013; Eadie & Elliott 2013). It is not clear which energy price threshold will trigger a comprehensive low carbon refurbishment rather than isolated retrofit actions and how energy price rises may affect the retrofit and refurbishment activities of the various income groups.

Future energy prices are also the key variable in the calculation of the expected payback time of the investment costs. In Australia, research on capital costs and payback times of retrofit and refurbishment measures is scarce. Based on the findings of a recent Victorian refurbishment study, the payback time for a low carbon target is likely to be at least 30 years (Moreland Energy Foundation Limited 2010). Considering that four out of ten Australians move every five years (Australian Bureau of Statistics 2010b), the capital costs of achieving a high energy performance may only be recouped by homeowners who intend to stay in their home for a long time. The willingness to pay for highly performing homes or energy efficiency features in Australia is under-researched.

Technical factors

Lastly, internationally, the perceived physical deterioration of a home has been shown to be an important external factor in initiating energy efficiency improvements (Adjei, Hamilton & Roys 2011; Nair, Gustavsson & Mahapatra 2010; Novikova et al. 2011). The significant number of old, energy inefficient and decaying homes in Australia (Australian Bureau of Statistics 2002) present an opportunity for cost-effective low carbon refurbishments in the course of general comprehensive renovation works.

Internal factors

Internal factors are variables which are particular to the individual or household such as attitudes, common understandings, goals and beliefs. Evidence shows that people do not always make decisions based on reason, conscious analyses and expected benefits, but may rely on their individual preferences, habits and emotions (Wilson & Dowlatabadi 2007). In addition, decisions may not be made consciously but rather be the manifestation of practices which are based on habits and cultural expectations.

If we follow decision based reasoning, a glance at the schematic representation of the decision-making process shows a cluster of internal factors during the stage leading up to persuasion. Nonetheless, heuristic processes have also been observed in communication with energy auditors (Gonzales & Aronson 1988) and may be manifest in psychological barriers or drivers of the adoption of innovative technologies during all stages of the planning and construction process (Gifford 2011).

As heuristic decision making processes are dependent on prior knowledge, raising the awareness for the concept of low carbon refurbishments may be seen as an important step in promoting the concept. Although the Your Home Technical Manual, a guide to sustainability around the home developed by the Australian government and the building industry, contains introductions of the concepts of zero energy or low carbon refurbishments (Pipkop 2010), and Australians are becoming increasingly aware of resource conservation in the domestic context (McGee et al. 2008), key stakeholders in the Australian building industry believe that the concept of low carbon homes is not well known locally (Riedy, Lederwasch & Harris 2012). International evidence suggests that as long as low carbon refurbishments are considered a technical innovation, ecological motivations and environmental convictions are a key factor in aspiring to this standard (ILS 2010; Ruetter et al. 2008).

Nonetheless, the prospect of increased thermal comfort may also leverage the adoption of low carbon refurbishments. Links with retrofit activities in Australia have been made especially in the cases of older buildings (Australian Bureau of Statistics 2010a, 2011; Dillon et al. 2010).

Enabling factors

Indirect policy instruments such as financial support or information tools are commonly advocated as enabling factors. As capital investment costs are often considered to stand in the way of substantial low carbon refurbishments, financial assistance through governments are a widespread measure utilised to incentivise comprehensive actions. These have been pursued both internationally (BPIE 2011) and in Australia (Australian Bureau of Statistics 2011; Riedy, Lederwasch & Harris 2012). While such market mechanisms are aimed to address financial barriers, they may create new distortions: depending upon how they are designed and implemented they may attract free-riders and not reach those who require assistance the most (Weiss, Dunkelberg & Vogelpohl 2012).

Low interest loans for retrofit initiatives have already been used in Australia (AECOM Australia 2011; Department of the Environment 2010). Experiences in Europe suggest that such loans offered on a staggered scale (Neuhoff et al. 2011) can be a useful tool as part of a mix of measures designed to promote low carbon buildings. However, the amount of financial support that is likely to be required to shift practice towards refurbishment to low carbon performance which exceeds regulatory standards is unknown (Neuhoff et al. 2011). This confirms that the influence of price and cost is not well understood and is unreliable in predicting rates of low carbon refurbishments.

Information campaigns are often used to create awareness of low energy refurbishments. These may focus on the condition of existing dwellings and the potential benefits of comprehensive energy improvement measures. Awareness campaigns may be in the form of online portals or individual home audits. The provision of demonstration homes and associated evaluation material have also been a feature of information provision. The role of building professionals, mediating between households and their retrofit plans, is often cited as an important factor in low carbon refurbishment uptake. This innovative concept is seen to require specialised knowledge (Ruetter et al. 2008), yet the current level of expertise of Australian building professionals in matters of residential low carbon construction may be considered low (Crabtree & Hes 2009; Riedy, Lederwasch & Harris 2012). Moreover, building professionals may be risk averse around new techniques and technologies (McGee et al. 2008).

There is evidence that the existence of widespread, well understood low carbon assessment tools and standards for homes may be a key factor in promoting low carbon housing. Mandatory energy performance standards, which allow quick appraisal of the energy efficiency performance of a building at the point of sale or lease are common in Europe. However, early estimates of their effectiveness on precipitating comprehensive building energy improvements suggest that their impact falls short of expectations (Amecke 2012; Backhaus, Tigchelaar & Best-Waldhober 2011; Novikova et al. 2011). In Australia, the experience with such mandatory declarations is limited. Although the production of energy certificates at the point of sale have been mandatory in the Australian Capital Territory since 1999 (Australian Government Department of the Environment 2008) and more recently a limited scheme has been introduced in Queensland (Queensland Government 2011), evidence of their impacts is under-researched. A national energy performance disclosure scheme for residential buildings has been proposed (DCCEE 2012).

By contrast, voluntary high performance building labels like the German Passive House or the Swiss Minergie standard have been found to stimulate the uptake of low carbon refurbishments. A worldwide search of built examples of residential low carbon refurbishments has yielded a concentration of projects in Germany, Austria and Switzerland (Sustainability Victoria 2012). A review of the history and development of the Passive House and Minergie standards revealed that these voluntary low carbon assessment tools have assisted in disseminating information about innovative building criteria. They seem to have contributed to creating acceptance or new social standards amongst householders, and indicated a pathway for mandatory standards. Supporting measures have been found to be important success factors: Uptake of voluntary low carbon labels can be facilitated if benefits are widely disseminated through independent information sources, if the information is kept simple, if access to trained professionals is facilitated and if governments provide a regulatory framework and financial assistance schemes which embrace the voluntary rating system (Mlecnik, Visscher & van Hal 2010).

Standards are often commonly based on mathematical models which calculate a building's energy performance under certain assumptions of householder behaviour. If actual, rather than modelled, performance is to form the basis of the low carbon assessment, then the focus of the intervention has to shift from the mere technological solution to householder practices and their influence on residential energy consumption. Shifts in lifestyle, heating practices and the use of consumer electronics can weigh against predicted energy and cost savings of retrofits and refurbishments (European Environment Agency 2008; Kagerer & Herkel 2011; Sanquist et al. 2012).

This raises a further critical factor in low carbon housing: the fact that houses are also 'homes' - the physical scene within which domestic life is played out in all its complexity. The experience of living in a low carbon home may be expected to influence domestic practices and vice versa. In the literature, insufficient attention is paid to this dimension of low carbon homes. While the technical parameters of low carbon refurbishments have been well described and analysed, information on householder perspectives and experiences deserve more investigation.

Our exploration of the scarce literature encompassing post-occupancy experience reveals that the householder places emphasis on qualitative living factors rather than on quantitative or technical outcome measures. The psychosocial meaning of the home, its appearance, the facilitation of lifestyle and the performance of social practice as well as the broader merits of the neighbourhood seem to be valued higher than energy savings or financial benefits (Mlecnik 2013; NHBC Foundation 2012; Schnieders & Hermelink 2006). Attitudes towards progressive building standards and technological systems may even be shaped by subconscious associations with the terms used to describe the innovations, such as the choice of 'comfort' ventilation rather than 'mechanical' ventilation. Occupants seem to expect the high tech systems to function but have been found to be complacent about learning how to use them for optimum performance (Crosbie & Baker 2009; Schnieders & Hermelink 2006).

A further observation of the refurbishment decision making process relates to the importance of the timing of home improvements within the continuum of household living. The review found trigger events which are occasions when the decision in favour of a comprehensive energy improvement initiative seems more likely. The need for comprehensive construction works to ensure the structural or functional integrity of the building, the purchase of the home and the recommendation of a building energy professional have been found to be such trigger events (Jakob 2007; Mach et al. 2011; Neuhoff et al. 2011). Energy retrofit and refurbishment policies are already targeting these trigger events to increase the possibility of low carbon outcomes.

Progress and Prospects

This review has summarised our current knowledge on the uptake of low carbon refurbishments internationally and in Australia. While the shift towards low carbon refurbishments is slow, encouraging developments are taking place especially in Europe. Progress towards low carbon refurbishments in Australia is lagging behind some central European countries and a framework to accelerate the uptake of this novel concept is needed. Low carbon refurbishments involve multiple actors, including the owner, the household, the architects, the contractors and building product manufacturers as well as the broader industry, civil society, energy industries and government policy makers, who provide the context and form of external, internal and enabling factors. The economic market perspective assumes that demand for low carbon refurbishments may be created, householders may be manipulated to engage, and a list of interventions may promote pro-environmental choices. Common measures such as information and economic policy tools both implicitly or explicitly assume that demand for low carbon retrofitting is latent or will materialise once awareness and price barriers are removed. This approach exemplifies “the desire for single narratives and simple, one-dimensional story lines that explain behaviour and specify what should be done to change it” (Shove 2011, p. 263). However, in reality, there is no clear evidence that such measures addressing the individual consumer and specific barriers are successful in shifting demand.

The review shows that social and cultural factors influence retrofit or refurbishment activities towards low carbon homes. Decisions are seen to take place in the social and contextual sphere rather than in the personal one. Even within the domain of the individual homeowner motivations to invest substantially in home improvements depend on numerous factors beyond notions of economic considerations. These include neighbourhood satisfaction, plans to remain, and competing time and cost considerations (Amecke 2012; Australian Bureau of Statistics 2002; Ruetter et al. 2008).

This means that attempts to create demand for low carbon refurbishments by persuading the homeowner can only succeed if a wide range of systemic mechanisms are in place. Even then, the outcome may be unpredictable as the numerous social and technical factors are dynamic and prone to change. Evidence shows that even the importance of the decision making variables may change during the course of a refurbishment project (Novikova et al. 2011). Moreover, the multiplicity of actors in the construction process points towards a need for collaboration towards a common goal (Vergragt & Brown 2012). In this context the low carbon refurbishment process may be seen as an ‘arena of development’, which relies on the collective learning and performance of actors within a network (Jørgensen 2012).

Linked to this is the importance of standards. The literature shows that a residential low carbon standard, be it mandatory or voluntary, facilitates systemic learning, the articulation of common goals and understandings amongst the actors and the engagement of industry stakeholders. While the improvement of the energy efficiency of existing office buildings has been supported by the presence of nationwide assessment tools such as NABERS and Green Star (ClimateWorks 2013), both of which allow for the certification of zero or towards zero emission ratings, at present, a comparable low carbon standard for housing is missing in Australia. While the concept of low carbon refurbishment is based on the premise that the building is captured as a system, current energy efficiency regulations in Australia are centred on the building envelope and fall short of accounting for interactions of heating and cooling systems and fuel sources. This current assessment method may be replaced by performance-based ‘whole of building’ regulations as proposed in the *Draft National Building Energy Standard - Setting, Assessment and Rating Framework* (DCCEE 2012). In addition, organisation such as ASBEC (ASBEC 2012) and the Australian Passive House Association (APHA 2013) have ambitions to develop voluntary low carbon standards for the Australian context.

Furthermore, the review has revealed that the wider social and cultural meanings associated with low carbon refurbishments are important. The aesthetic significance of the home extends to the visibility of innovative technology and prestige, comfort and convenience (Grabler-Bauer et al. 2002; Schnieders & Hermelink 2006) supporting the notion that homes have symbolic and affective values rather than just instrumental ones (Dittmar 1992). These findings may shape strategies to create demand for low carbon refurbishments which are based on a cultural and broader social scale.

Conclusion

Low carbon refurbishments are innovative construction projects which are currently only conducted on a voluntary basis. While numerous examples are found in Europe, examples in Australia are less available. A systemic view of the low carbon refurbishment process indicates a broad range of actors involved in such a project, around which it is possible to posit a range of external, internal and enabling factors. The literature available to support such a systemic view suggests a complex decision making process which is rarely linear. A successful low carbon refurbishment project has been shown to depend on the collaboration between the actors and a broader sociotechnical framework which compliments and underpins the endeavour. Thus, in contrast to strategies only targeting the individual homeowner, a wide range of measures designed in unison and across traditional policy and disciplinary domains is more likely to promote the desired uptake of low carbon refurbishments (Horne 2012; Maller, Horne & Dalton 2011). A comprehensive strategic framework which incorporates both a view of the ‘house’ as a technological and material entity, and of the ‘home’ as a social and cultural site of domestic practice, is needed to accelerate the uptake of low carbon refurbishments in Australia.

4886 words

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References

Adjei, A, Hamilton, L & Roys, M 2011, *Deliverable 5.2. A study of homeowners' energy efficiency improvements and the impact of the Energy Performance Certificate*, IDEAL EPBD.

AECOM Australia 2011, *Green Loans: Review of Householder Perspectives*, AECOM Australia Pty Ltd, Fortitude Valley.

Amecke, H 2012, 'The impact of energy performance certificates: A survey of German home owners', *Energy Policy*, vol. 46, pp. 4-14.

APHA 2013, *Australian Passive House Association*, viewed 25 July 2013, <http://passivehouseaustralia.org/>.

ASBEC 2012, *Net Zero Emission Homes: An Industry Roadmap*, Australian Sustainable Built Environment Council.

Australian Bureau of Statistics 2002, *4102.0 Australian Social Trends 2002*, Australian Bureau of Statistics, Canberra.

---- 2010a, *1367.2 - State and Regional Indicators, Victoria, Jun 2010. Featured article: Water and energy effciency elements of households in older and newer dwellings*, Australian Bureau of Statistics, Canberra.

---- 2010b, *Australian Social Trends 2010*, Australian Bureau of Statistics, Canberra.

---- 2010c, *Year Book Australia 2009-2010*, Australian Bureau of Statistics, Canberra.

---- 2011, *4602.0.55.001 - Environmental Issues: Energy Use and Conservation, Mar 2011. Dwelling characteristics and insulation*, Australian Bureau of Statistics, Canberra.

Australian Government Department of Infrastructure and Transport 2013, *State of Australian Cities 2013*, Department of Infrastructure and Transport, Major Cities Unit, Canberra.

Australian Government Department of the Environment, W, Heritage and the Arts 2008, *Energy efficiency rating and house price in the ACT. Modelling the relationship of energy efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006.*, Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

Backhaus, J, Tigchelaar, C & Best-Waldhober, Md 2011, *Key findings & policy recommendations to improve effectiveness of Energy Performance Certificates & the Energy Performance of Buildings Directive*, Improving Dwellings by Enhancing Actions on Labelling for the EPBD (IDEALEPBD).

BPIE 2011, *Europe's buildings under the microscope*, Buildings Performance Institute Europe (BPIE), Brussels.

Building Commission 2011, *6 Star for new homes, home renovations, alterations, additions and relocations*, Building Commission, Melbourne, <http://www.buildingcommission.com.au/resources/documents/6Star_consumer_brochure_(web)2.pdf>.

Centre for International Economics 2007, *Capitalising on the building sector's potential to lessen the costs of a broad based GHG emissions cut*, Centre for International Economics, Canberra & Sydney.

Clean Energy Council 2011, *Clean Energy Australia Report 2011*, Clean Energy Council, Southbank.

ClimateWorks 2013, *Tracking Australia's Progress towards a Low Carbon Economy. 4. Buildings*, ClimateWorks, Melbourne.

Crabtree, L & Hes, D 2009, 'Sustainability Uptake in Housing in Metropolitan Australia: An Institutional Problem, Not a Technological One', *Housing Studies*, vol. 24, no. 2, pp. 203-24.

Crosbie, T & Baker, K 2009, 'Energy-efficiency interventions in housing: learning from the inhabitants', *Building Research & Information*, vol. 38, no. 1, pp. 70-9.

DCCEE 2012, *Draft Framework for Consultation. National Building Energy Standard-Setting, Assessment and Rating Framework*, Energy Efficiency Working Group Department of Climate Change and Energy Efficiency. Select Council on Climate Change, Canberra.

Department of the Environment, W, Heritage and the Arts,, 2010, *Review of the Green Loans Program. Final Report*, Department of the Environment, Water, Heritage and the Arts, Canberra.

Dillon, R, Learmonth, B, Lang, M, McInnes, D, Thompson, K & Bowen, K 2010, *Just Change Evaluation Report. Energy Efficiency for Low-income Renters in Victoria*, Just Change, Melbourne.

Dittmar, H 1992, *The Social Psychology of Material Possessions: To Have is To Be*, Havester Wheatsheaf, UK.

Dyrbol, S & Aggerholm, S 2011, *Implementation of the EPBD in Denmark*, Concerted Action Energy Performance of Buildings, viewed 11 October 2013, <http://www.epbd-ca.org/Medias/Pdf/2_CO_EPBD_DK.pdf>.

Eadie, L & Elliott, C 2013, *Going Solar: Renewing Australia's electricity options*, Centre for Policy Development (CPD).

European Environment Agency 2008, *Energy and environment report 2008*, European Environment Agency, Copenhagen.

Gifford, R 2011, 'The dragons of inaction: pychological barriers that limit climate change mitigation and adaptation', *American Psychologist*, vol. 66, no. 4, pp. 290-302.

Gonzales, MH & Aronson, E 1988, 'Using Social Cognition and Persuasion to Promote Energy Conversation: A Quasi-Experiment', *Journal of Applied Social Psychology*, vol. 18, no. 12, pp. 1049-66.

Grabler-Bauer, G, Guschlbauer-Hronek, K, Berger, M, Seidl, J & Krapmeier, H 2002, *Das Passivhaus in der Praxis. Strategien zur Marktaufbereitung fuer das Passivhaus im Osten Österreichs*, Bundesministerium fuer Verkehr, Innovation und Technologie, Vienna.

Gram-Hanssen, K 2013, *CALL FOR PAPERS: Special issue. Energy renovations of owner-occupied homes*, viewed 4 July 2013, <http://www.tandf.co.uk/journals/cfp/rbricfp.pdf>.

Horne, R 2012, 'Policies to Promote the Environmental Efficiency of Housing', in *International Encyclopedia of Housing and Home*, Elsevier, United Kingdom, pp. 286-92.

IEA 2011, *Technology Roadmap. Energy-efficient Buildings: Heating and Cooling Equipment*, International Energy Agency, Paris.

ILS 2010, *Leben im Passivhaus. Baukonstruktion, Baukosten, Energieverbrauch, Bewohnererfahrungen*, Institut für Landes- und Stadtentwicklungsforschung (ILS), Dortmund.

Jakob, M 2007, *The drivers of and barriers to energy efficiency in renovation decisions of single-family home-owners. CEPE Working Paper No. 56*, Centre for Energy Policy and Economics. Swiss Federal Institutes of Technology, Zurich.

Jørgensen, U 2012, 'Mapping and navigating transitions—The multi-level perspective compared with arenas of development', *Research Policy*, vol. 41, no. 6, pp. 996-1010.

Kagerer, F & Herkel, S 2011, '5.1 Concepts for Net Zero Energy Buildings in refurbishment projects', in S Herkel & F Kagerer (eds), *Advances in Housing Retrofit*, Fraunhofer-Institute for Solar Energy Systems (ISE), Freiburg.

Korytarova, K 2010, 'Energy efficiency potential for space heating in Hungarian public buildings towards low-carbon economy', Central European University.

Mach, T, Heimrath, R, Heinz, A, Droescher, A, Mueller, T & Fink, C 2011, '6. Implementation of Solar Thermal Systems in Renovation', in S Herkel & F Kagerer (eds), *Advances in Housing Retrofit*, Fraunhofer-Institute for Solar Energy Systems (ISE), Freiburg.

Maller, C, Horne, R & Dalton, T 2011, 'Green Renovations: Intersections of Daily Routines, Housing Aspirations and Narratives of Environmental Sustainability', *Housing, Theory and Society*, pp. 1-21.

Mansfield, JR 2002, 'What's in a name? Complexities in the definition of "refurbishment"', *Property Management*, vol. 20, no. 1, pp. 23-30.

McGee, C, Partridge, A, Carrard, N & Milne, G 2008, 'Mainstreaming sustainable housing: policies and programs that work', paper presented to sb08, Melbourne.

Mlecnik, E 2013, 'Opportunities for supplier-led systemic innovation in highly energy-efficient housing', *Journal of Cleaner Production*, vol. 56, pp. 103-11.
Mlecnik, E, Visscher, H & van Hal, A 2010, 'Barriers and opportunities for labels for highly energy-efficient houses', *Energy Policy*, vol. 38, no. 8, pp. 4592-603.
Moreland Energy Foundation Limited 2010, *On-Ground Assessment of the Energy Efficiency Potential of Victorian Homes. Report on Pilot Study*, Sustainability Victoria, Melbourne.
Murphy, L, Meijer, F & Visscher, H 2012, 'A qualitative evaluation of policy instruments used to improve energy performance of existing private dwellings in the Netherlands', *Energy Policy*, vol. 45, pp. 459-68.
Nair, G, Gustavsson, L & Mahapatra, K 2010, 'Factors influencing energy efficiency investments in existing Swedish residential buildings', *Energy Policy*, vol. 38, no. 6, pp. 2956-63.
Nair, G, Mahapatra, K & Gustavsson, L 2012, 'Implementation of energy-efficient windows in Swedish single-family houses', *Applied Energy*, vol. 89, no. 1, pp. 329-38.
Neuhoff, K, Amecke, A, Novikova, A, Stelmakh, K, Deason, J & Hobbs, A 2011, *Using Tax Incentives to Support Thermal Retrofits in Germany*, Climate Policy Initiative.
NHBC Foundation 2012, *Today's attitudes to low and zero carbon homes: Views of occupiers, house builders and housing associations*, NHBC Foundation, UK.
Novikova, A, Vieider, F, Neuhoff, K & Amecke, H 2011, *Beweggründe für Sanierungsentscheidungen – Eine Umfrage unter Ein- und Zweifamilienhausbesitzern*, Climate Policy Initiative Berlin, Berlin.
NSW Government 2009, *Alterations and Additions Outcomes BASIX*, NSW Government, Sydney.
Ott, W, Jakob, M, Baur, M, Kaufmann, Y & Ott, A 2005, *Mobilisierung der energetischen Erneuerungspotenziale im Wohnbaubestand (Mobilisation of the energy efficiency potentials of renovations in the existing building stock)*, Econcept, Zurich, and CEPE, ETH Zurich on behalf of the Swiss Federal Office of Energy, Bern.
Pan, W & Garmston, H 2012, 'Building regulations in energy efficiency: Compliance in England and Wales', *Energy Policy*, vol. 45, pp. 594-605.
Pipkop, J 2010, *Your Home Technical Manual. 1.4 Carbon Neutral*, Commonwealth of Australia, Canberra, <http://www.yourhome.gov.au/technical/fs14.html>.
Queensland Government 2011, *Sustainability declaration. Version 3. August 2011*, Queensland Government,,, <http://www.dlgp.qld.gov.au/resources/form/sustainable-housing/sustainability-declaration-form.pdf>.
Report of the Prime Minister's Task Group on Energy Efficiency, 2010, Department of Climate Change and Energy Efficiency, Canberra.
Riedy, C, Lederwasch, A & Harris, S 2012, *Net Zero Emissions Homes: An Examination of Leading Practice And Pathways Forward*, Prepared for the Residential Development Council by the Institute for Sustainable Futures, University of Technology. June 2012, Sydney.
Roberts, S 2008, 'Altering existing buildings in the UK', *Energy Policy*, vol. 36, no. 12, pp. 4482-6.
Rogers, EM 1983, *Diffusion of Innovations*, Free Press New York.
Ruetter, H, Rütter-Fischbacher, U, Hässig, W & Jakob, M 2008, *Praxistest Minergie-Modernisierung*, Bundesamt fuer Energie (BFE), Bern.
Sanquist, TF, Orr, H, Shui, B & Bittner, AC 2012, 'Lifestyle factors in U.S. residential electricity consumption', *Energy Policy*, vol. 42, pp. 354-64.
Schnieders, J & Hermelink, A 2006, 'CEPHEUS results: measurements and occupants’ satisfaction provide evidence for Passive Houses being an option for sustainable building', *Energy Policy*, vol. 34, no. 2, pp. 151-71.
Shove, E 2011, 'Commentary. On the difference between chalk and cheese—a response to Whitmarsh et al's comments on "Beyond the ABC: climate change policy and theories of social change"', *Environment and Planning A*, vol. 43, no. 2, pp. 262-4.
Stieß, I & Dunkelberg, E 2013, 'Objectives, barriers and occasions for energy efficient refurbishment by private homeowners', *Journal of Cleaner Production*, vol. 48, pp. 250-9.
Sustainability Victoria 2012, *Drivers of Demand for Zero and Towards Zero Emissions Residential Retrofits*, ASBEC, Melbourne.

Swan, W 2013, 'Adoption of sustainable retrofit in UK social housing', *Structural Survey*, vol. 31, no. 3, pp. 181-93.
The Allen Consulting Group 2004, *The Energy Efficiency Gap. Market Failures and Policy Options*, The Allen Consulting Group Pty Ltd, Melbourne.
Tovar, MA 2012, 'The structure of energy efficiency investment in the UK households and its average monetary and environmental savings', *Energy Policy*, vol. 50, pp. 723-35.
TrainRebuild 2011, *Deliverable D3.5: Conclusion reports from 'train the trainer' workshops for the trainers of WP4 and WP5*.
UNEP SBCI 2009, *Buildings and Climate Change. Summary for Decision-Makers*, UNEP DTIE. Sustainable Consumption & Production Branch, Paris.
Vergragt, PJ & Brown, HS 2012, 'The challenge of energy retrofitting the residential housing stock: grassroots innovations and socio-technical system change in Worcester, MA', *Technology Analysis & Strategic Management*, vol. 24, no. 4, pp. 407-20.
Volkmer, H 2013, 'Enhancing the energy efficiency in rural households through market development and consumer financing', *Appropriate Technology*, vol. 40, no. 3.
Weiss, J, Dunkelberg, E & Vogelpohl, T 2012, 'Improving policy instruments to better tap into homeowner refurbishment potential: Lessons learned from a case study in Germany', *Energy Policy*, vol. 44, pp. 406-15.
Wilson, C & Dowlatabadi, H 2007, 'Models of Decision Making and Residential Energy Use', *Annual Review of Environment and Resources*, vol. 32, no. 1, pp. 169-203.