INTERNATIONAL JOURNAL OF URBAN AND REGIONAL RESEARCH
DOI:10.1111/1468-2427.12453

CRITICALLY INTERROGATING ECO-HOMES

JENNY PICKERILL

Abstract

Eco-homes have only been researched in fragmented and partial ways, which fail to adequately examine their complexities and possibilities. Numerous myths about eco-homes persist in the public imagination and policy support has been mixed with, in practice, little change to the construction of contemporary homes. The ecological and social potential of eco-homes are being undermined by a technocratic focus, the capacity and behaviour of occupants, and a weakening of design as developments are scaled up. This intervention identifies five ways in which eco-homes need to be more robustly interrogated to strengthen their potential, through their breadth and diversity, dynamic nature, socio-material interdependencies, place, and understanding of their political economies. Crucially these interrogations need to be researched simultaneously to ensure that the full diversity of eco-homes is understood through their multiple interdependencies, multi-scalar practices and materialities.

Introduction

Eco-homes are houses designed, built and occupied to have less environmental impact than conventional homes. They are crucial sites of innovation in environmental sustainability, climate change adaptation and affordable housing provision, and they are invaluable as devices through which to examine the complex interdependencies between different scales of socio-environmental change (such as policy, construction industries and residents). In 2011 in the USA 17% of housing stock was eco-housing (McGraw-Hill Construction, 2014) and 41% of new buildings (mostly commercial) in 2012 were ecological compared with just 2% in 2005 (USGBC, 2016). In the UK it is forecast that 68% of construction firms will be building more than 60% of their work as ecological structures and as such 'green building is accelerating as it becomes viewed as a long-term business opportunity' (World Green Building Council and McGraw-Hill Construction, 2013).

Despite significant advances in the design and construction of eco-housing, the growth in the number constructed, and an increasing diversity and number of eco-homes being built, public understanding of and political support for eco-homes is limited. Conventionally an eco-house is understood as 'working' if it reduces the environmental impact of its occupants' daily lives. This has been measured in a variety of ways, including the amount of embedded carbon used in its construction and simple measures of energy efficiency during occupation. However, in many places eco-homes are not working: they are poorly understood, still too few in number (most new eco-construction is for commercial buildings, not homes), not sought after, and their functionality is impaired by occupants' practices.

Academics might assume that the case for more eco-homes is obvious and logical: they lower environmental impact and are cheaper to live in. But house builders, potential occupants and policymakers are not receiving these messages. Rather, many myths about eco-homes as being too expensive, unreliable and uncomfortable persist. Academically eco-homes have been too often considered sectorally, rather than as a vital part of the metabolism and circulations of places (Edwards and Bulkeley, 2017). There is a responsibility here for academics to generate new understandings of

 This research was funded by a Winston Churchill Memorial Trust Travel Fellowship 2010 (http://www.wcmt.org.uk/).

eco-homes, illustrate how they connect to many other important issues, intervene to counter these myths, and to popularize them.

A National House-Building Council (NHBC) Federation (2012) survey with UK occupiers, house builders and housing associations on perceptions of low-carbon homes identified occupants' lack of concern with energy efficiency, with few believing homes influenced carbon emissions. Few occupants in zero-carbon homes felt that they knew how to operate their renewable energy technologies and none completed maintenance. Knowledge of eco-homes' advantages and features is even lower amongst the general public, many of whom have never seen, let alone entered, an eco-home.

Policy support for eco-homes worldwide has been mixed (Walker *et al*., 2016). There are a growing number of ecological building regulations and codes that have been variously integrated into policy and legislation, or adopted at the municipal level. For example, in Europe the 2010 Energy Performance of Building Directive and 2012 Energy Efficiency Directive govern energy consumption standards, which are then enacted through national regulations, such as the German Building Code. These are gradually being tightened towards the goal of nearly zero energy buildings (Brilhante and Skinner, 2014). Policies have tended to take a technocratic approach, focusing on limited minimum standards of energy efficiency and water use, rather than more holistic notions of environmental impact, and thus they have encouraged the adoption of technological solutions. While there has also been a growth in the use of, and recognition for, rating tools, such as BREEAM (UK and Europe), LEED (the Americas), the Living Building Challenge developed by the Cascadia Green Building Council (USA and Canada) and Green Star (Australia, New Zealand and South Africa), they remain voluntary and predominantly adopted for commercial buildings, though some municipalities have made them compulsory for commercial and residential construction (Brooks and Rich, 2016). Indeed, in Britain the zero-carbon homes commitment introduced by the Labour government in 2006 had already been significantly weakened in intent and practice before it was abandoned entirely in 2015 (HM Treasury, 2015). In Australia and large parts of the USA the building of residential homes has not been significantly altered by policy interventions and a fear of market failure means that many construction companies are conservative and risk adverse, ignoring new innovation for tried and tested conventional methods (Pickerill, 2016).

As such, eco-homes have been largely neglected as a subject of research. This is especially the case by urban scholars who have tended to pay greater attention to broader-scale infrastructures, metabolisms and forms of governance, rather than individual buildings (Bulkeley *et al*., 2014a). Eco-homes are too often understood as a niche, a discrete sector, an 'other', or as an assemblage of sustainable practices that are only of value if 'mainstreamed'. Consequently there are several aspects of eco-homes about which there is relative silence. These absences are important because urban scholars are researching, and articulating findings, about only a narrow subset of eco-homes, often those with a technocratic focus and advocated by government policies, therefore ignoring much of eco-homes' potential.

While urban scholars have used analysis of socio-technical transitions, urban carbon governance, sustainable household practices, and architectural feelings and everyday practices to understand some elements of eco-homes, we know very little about the diversity of eco-home forms and why eco-houses are built using different methods, materials and technologies; how eco-homes are lived in and changed over time; how the design and materiality of eco-homes can alter the resource-using practices of residents and vice versa; the importance of place to eco-housing; and how the political economy of eco-homes is different or similar to, and supportive or hindering of, eco-house production. There has been little work on the spatiality and location of eco-homes already built, or the reasons why eco-homes are being built in some places but not others. Knowledge about eco-homes by the public, policymakers and

construction industries is partial and often inaccurate, with little research conducted on how such knowledge is gained and shared, or how knowledge could be better distributed (for an exception, see Faulconbridge, 2013). Although building processes are understood from a technical perspective, the reasoning behind choices made in the building, or what elements are taken into consideration, remains largely opaque. Despite some post-occupancy studies, how people's lives change in different types of eco-homes and how occupants change their eco-home remains little understood. Currently missing in understandings of eco-homes and eco-renovations is analysis of the many interconnections, relations and contexts in shaping how eco-homes are built (produced) and lived in (consumed). More work is required to understand to what extent eco-homes can reconfigure and reshape everyday social practices as part of the socio-technical assemblage of living with/in eco-homes.

These absences mean that we cannot fully comprehend the possibilities or consequences of eco-homes. The existing partial and fragmented approach blinds academics, and crucially policymakers and the public, to the full complexity and diversity of eco-homes. If we are to adequately understand how to make our cities, and other places, liveable then we need to critically interrogate eco-homes in holistic multi-dimensional and multi-scalar ways. Therefore, urban theorists should be interested in eco-homes because they offer potential solutions to some burgeoning climatic and affordability issues in housing.

The relative merits of filling the research gaps identified here depend on the issues researchers are most concerned with tackling; each enables the complex potential of eco-homes to be understood in different ways. Thus, it is necessary to examine the breadth and diversity of eco-homes in the search for better, cheaper, longer lasting, more effective build approaches for housing. There is a need to know how eco-homes are lived in and evolve to evaluate the extent to which they can reduce environmental impact, or whether their promise becomes 'undone' over the lifetime of a building. If some of the potential functionality of eco-homes is getting lost, then there is a need to identify the causes and find alternative processes. Likewise understanding the relationship between material and infrastructural changes and household daily practices is necessary to ascertain whether big shifts are required to housing stock in order to influence daily resource-hungry habits, or how such changes in practices might be possible without any redesign of housing. Knowing how eco-homes work differently in diverse places, and where innovation gets nurtured, is vital to encouraging more creativity. Finally, in all of these potentially dynamic relationships between homes and occupants, the political economies of eco-homes are vital to understand to ensure affordable homes are available to all. Each of these will now be examined in more detail.

Diversity and breadth

While there is an identifiable common function to eco-homes—minimizing environmental impact—there is significant diversity in eco-home forms (Pelsmakers, 2012; Pickerill, 2016). The breadth of ways in which an eco-home can be constructed and occupied is too often ignored in favour of concentrating on those forms which are either being 'mainstreamed' or are actively supported by policy, such as zero-carbon homes (Williams, 2012). Such an approach hides the extent of diversity of house forms and the different materialities implicated in them. For example, designing and building eco-homes requires attention to climatic conditions, cultural traditions, material availability, lifestyle needs and local skill sets (Wines, 2000). The term can include zero- or low-carbon houses, low-impact developments, sustainable housing, green building, passive houses (*passivhaus*), zero-net energy housing and energy-plus houses (Roaf *et al*., 2007). These forms of eco-homes can be understood in numerous ways; for example in the extent of their energy efficiency, in the environmental footprint of the materials used in construction or in their air tightness. There is as much variety in measurements

of eco-homes' functionality as there are different standards, certifications and awards (such as BREEAM, LEED and Green Star). The function of an eco-home can be achieved in many different ways: it might rely on natural materials (Figure 1) or technological systems (Figure 2).

There has been an academic emphasis on understanding technologically reliant eco-homes, often zero-carbon homes, rather than more diverse forms, driven in part by an emphasis on attending to how eco-homes can be mainstreamed and 'scaled up' within a narrow policy interest (Greenwood, 2012; Gibbs and O'Neill, 2014). Numerous assumptions are built into such a focus; for example, that carbon emissions are the most important measure of environmental impact, that low-tech natural-build approaches will forever remain niche, that consumers will only ever choose houses which conform to conventional aesthetics, and that self-building is not a viable alternative for housing provision. Crucially what is considered 'normal' or conventional in a home and as a norm in housing design is rarely analytically explored or defined.

These assumptions need unpacking. First, a carbon focus can result in odd distortions. A focus on carbon ignores other forms of environmental impact (water use, biodiversity, pollution, scarcity of materials and waste). Water use, for example, is largely ignored by a focus on carbon. Water does not absorb or produce a significant amount of CO_2. However, water supplies are likely to be disrupted by climate change; flooding mixes sewage into fresh water systems, temperature rises increase evaporation from reserves and increase demand for water for drinking and cooling. Therefore, building homes that conserve water is as important as reducing carbon emissions. Second, as illustrated in the work of Chatterton (2013; 2015), the use of low-tech natural-build approaches is expanding into the development of large-scale and public housing. LILAC in Leeds is a straw construction, council houses in Lincolnshire have been constructed from straw bales, and the use of cob as a construction material is also seeing a resurgence in Britain. In other words, it is not the case that low-tech natural-build approaches could not form part of future mainstream housing stock.

Third, for aesthetics, there is evidence that occupants do prefer traditional house designs (NHBC Federation, 2012), but also an assumption by residents that eco-homes will necessarily be of contemporary design. Actually eco-homes come in many different forms and little research has been conducted on the extent to which different aesthetics would be acceptable to residents, or how low-tech natural-build approaches can produce conventional-looking homes. In other words, if occupants are only asked what design of housing they like based on their personal experiences and a conservative housing market, it is not surprising that they will be cautious and choose 'traditional' forms. It is only through celebrating the diversity of housing types that residents' views might begin to shift. Finally, self-build could be more central to housing provision. In England less than 10% of new housing is self-built but still 'self-builders together now build more houses than the largest individual house-builder' (Broome, 2008). In France and Belgium self-build accounts for about 50% of all new building and in Sweden about a third of new house building is self-built (NaSBA, 2008; Dol and Haffner, 2010).

A narrow focus on only certain eco-home types precludes an understanding of where innovative ideas can emerge from, concentrates on ecologically weakened versions of eco-homes, and tends to exclude those forms of eco-home that require manual operation and lifestyle changes. It also limits the public and policy imagination of what an eco-home is, can do and what environmental actions are needed.

Homes as always evolving

Eco-homes are dynamic in that they are constantly in flux and being (re)made through everyday practices. Most research, however, focuses on the building phase of eco-housing, leaving us with, as Walker *et al.* (2015) note, little knowledge and understanding of what happens to eco-houses once they are occupied. Post-occupation

FIGURE 1 An eco-home that relies on the use of natural materials: El Valle De Sensaciones, Spain (photo by the author)

FIGURE 2 An eco-home that relies on technology to function: Leicestershire, England (photo by the author)

studies have tended to focus on how residents understand or resist ecological design features and systems, for example in misuse of mechanical ventilation systems, but not how residents adapt and change the home.

The dynamism of eco-homes has also been understood as the ways in which they can be 'mainstreamed'. Socio-technical transitions are used by Seyfang (2009; 2010) to argue that eco-housing knowledge innovation begins in a small niche environment which is protected from too much competition and small networks of actors support the evolution of these innovations within the niche. The innovations have to seize 'windows of opportunity' to break into the dominant culture (the regime which has a momentum which encourages the status quo, inertia and stability) and this is achieved through a particular innovation developing a singular discourse and then aligning with an aspect in the dominant regime, or being aided by government policy (Bergman *et al*., 2008; Lovell, 2008; Coenen *et al*., 2011; Goodchild and Walshaw, 2011; Greenwood, 2012). In this narrative elements of the mainstream culture then adopt successful innovation and the regime is altered.

Recently Gibbs and O'Neill (2014; 2015) have used this approach to understand the green building sector in England and Wales. Their findings question the simplicity of socio-technical transitions and they argue that green building niches are contradictory, fluid and contain contested practices. Therefore. attempts to 'protect' niches are problematic and unproductive. While a transitions approach might shed light on how knowledge of eco-homes translates and is replicated, it again focuses on the design and building of eco-homes, not their use.

Therefore, there is a need for closer attention to the temporalities of eco-homes across the whole process of making home—from inception, through building, to occupation, to renovation and potentially demolition. These temporalities should include a better grounding in the history of eco-building and, as discussed further below, the diverse places of eco-homes. Too many academics assert that the concept of eco-homes dates from the 1970s. Yet even a history of just technological eco-housing innovation would reach back to the Buckminster Fuller experiments of the 1940s, while a study of low-tech natural-material buildings stretches back much further by incorporating the history of vernacular architecture (Farmer, 1999; Hawkes, 2012).

There are as yet no longitudinal studies which trace the journey of an eco-home and the many ways in which those involved at each stage might understand and shape the home. Indeed most studies are snapshots of particular professionals' (often the architects and builders) views about the build process, rather than attempts to connect together how the eco-home itself as an entity evolves, is shaped and by whom, and is always in the making.

The interdependencies between houses and their occupants

The term eco-homes, rather than eco-housing, is used deliberately here to signal the need to incorporate the materialities of built form (and their attendant political and economic processes) into the socio-cultural understandings of how homes are constituted and always in the making (Blunt and Dowling, 2006). In recent years there has been increased interest in the new materialisms of everyday life and a need to understand architecture as spaces of 'ongoing social practices through which space is continually shaped and inhabited' (Lees, 2001: 51). In understanding the eco-home, such an approach recognizes how the material (the building, fabric, structure etc.) is inscribed with the social (the meaning, feelings, practices etc.), in what Walker *et al*., (2015) call 'socio-material interdependencies'. A home is a lived space that is created and made meaningful through the everyday practices of those using it (Jacobs and Smith, 2008; Dowling and Power, 2011). In practical terms, in a home, although architects have some agency in deploying scripts that configure everyday practices, this agency will always be circumscribed by occupants' actions that might work against

their design intentions. In even simpler terms, 'buildings don't use energy: people do' (Janda, 2011: 15).

In understanding socio-material interdependencies there is a need for greater acknowledgement of how the social operates through feelings, emotions and attachments about housing (Jones, 2009; Guy, 2010; Kraftl, 2006; 2010; Jacobs and Merriman, 2011). Living in eco-homes can transform how people relate, and feel about, their homes and consequently their identities. This has been expressed as positive, incentivizing collective changes in daily practices (Jones, 2014) but also, through the perceptions of children, in more negative ways where eco-homes were thought to be 'weird' and clashed with architectural conservatisms (Kraftl, 2014; Horton *et al*., 2015). The feelings and emotions that children had about eco-homes were articulated through misconceptions, myths and rumours, but ultimately involved the rejection of these homes as being liveable. Relatively little is known about how eco-homes impact occupants' social identities and how this might be stratified according to tenancy (Palmer *et al*., 2015), context (as in whether the homes are part of a broader eco-community, with Jones [2014] being one of the few to have explored this), and previous commitment to ecological practices.

Likewise, although there is a plethora of work examining environmentally sustainable behaviour change in the household (Hobson, 2006; Barr *et al*., 2011; Ellsworth-Krebs *et al*., 2015; Reid *et al*., 2015), it is the work on social practices that has best examined the interdependency between the materiality of a house and its social relations. Social practices are understood to be influenced, shaped and limited by the materialities of an eco-home, which are in turn shaped by social norms, government structures and commercial aims (Reckwitz, 2002; Warde, 2005; Shove, 2006). These practices become embedded in habit and routine, and are often implicit forms of consumption that people may not easily acknowledge as having significant environmental impact. Yet because such practices are inconspicuous, habitual and oft-repeated, their environmental consequences can be considerable. Moreover, there is the potential for past practices to be embodied, carried, remembered and performed through 'practice memory' as people change countries and experience new climates, thereby repeating practices which might be ill-suited (in terms of resource use) to new places (Fuller and Bulkeley, 2013; Maller and Strengers, 2013; Jones, 2014).

Existing research on sustainable households has explored a range of practices, particularly cooling (Shove *et al*., 2014), water use (Head and Muir, 2007; Strengers and Maller, 2012), comfort (Pickerill, 2015b) and eco-renovations (Gibson *et al*., 2010). So far there have been mixed findings. Maller *et al*. (2012) examined how eco-renovations were ineffective at reducing energy use because such aspirations clashed with existing habits and routines, and research on smart homes has identified that energy consumption feedback interfaces do not lead to long-term behavioural changes (Hargreaves *et al*., 2010; Wilson *et al*., 2015). However, Strengers and Maller (2011) examined how residents in eco-housing developed strategies for cooling without air conditioning and argue that a social practice approach to these strategies is productive for understanding the importance of adaptive cooling infrastructures in changing practices. Vannini and Taggart (2013; Vannini, 2014) identified significantly changed practices in off-grid eco-housing. Such analysis also suggests an opportunity to explore the potential of non-material transformational processes. In other words, whether homes become eco-homes simply through the transformed practices of its residents, and thus whether eco-homes could be created through changed practices alone, rather than the structural redesign of housing.

Although it is clear that existing infrastructures act to constrain and entrench unsustainable social practices, more work is required to understand to what extent eco-homes can reconfigure and reshape everyday social practices. The futility of smart homes feedback interfaces and the success of adaptive cooling infrastructures suggests, at this early stage, that it is the larger structural changes in eco-homes which facilitate

a shift in practices and that only these fundamental changes to how homes are designed and operate will have the necessary impact on reducing environmental impact. As such, radical changes are required to how we build new houses and our existing housing stock, rather than the technological tweaks encouraged by government policy and which receives the most academic attention.

Place

There is considerable work on carbon governance in response to the threats of climate change and low-carbon urbanism (Lovell, 2004; Bulkeley *et al*., 2012; Rydin and Turcu, 2013). Such carbon governance research explores the multiple scales of political decision making, the fragmented and blurred roles of state and non-state actors, the experimentalism of many climate change projects, and the deeply embedded nature of many of the processes that lead to emissions of carbon in everyday processes of consumption and production (Bulkeley and Jordan, 2012; Bulkeley and Castán Broto, 2013).

Eco-homes in this context are just part of the broader infrastructure of urban spaces (Bulkeley *et al*., 2014b). Eco-homes' presence in cities is understood in several ways: as innovative urban experiments by grassroots activists (Wendler, 2014), prefigurative experiments in post-carbon living (Chatterton, 2013; 2015), the outcome of government carbon policies generated through transnational social learning and policy mobility (Derk, 2011; Faulconbridge, 2013; Affolderbach and Schulz, 2015), the consequences of eco-building certifications producing a certain type of built environment (Cidell, 2009), or as spaces for social learning (McFarlane, 2011). Urban carbon governance analysis facilitates transnational comparisons enabling acknowledgement of the influences of different political, socio-cultural and economic contexts, and analysis of policies alongside other encouraging or hindering factors. It also enables analysis of the spatial heterogeneity of eco-housing, though so far this has only been mapped for commercially produced eco-homes (Faulconbridge, 2013). Although a focus on the experimental city theoretically encourages analysis of diverse forms of eco-homes, only Wendler (2014) has explored self-built eco-housing in this governance context. Most work has focused on very technological, policy-driven forms of zero-carbon housing, on infrastructures and on a neighbourhood scale (Williams, 2012).

Predictably, urban scholars focus on urban spaces, but while there are good demographic reasons to examine where the majority live, the result is an obsession with urban eco-homes at the expense of rural examples. This emphasis also tends to assume that urban spaces are the only sources of cultural creativity and transformation. Pickerill and Maxey's (2009) research has previously identified that radical ideas and grassroots innovations often emerge from rural places. The concept of a socio-technical transitions niche, even if slightly problematic, also works, perhaps even better in rural than in urban spaces (Seyfang, 2010). There is thus a need to look beyond urban spaces and to take multi-place approaches to the analysis of eco-homes. As discussed above, it is problematic to focus only on high-tech eco-home forms, and it is problematic to examine only certain types of scales and places.

Economies of scale

Finally, one of the biggest myths about eco-homes is that they are necessarily more expensive than conventional dwellings. What is clear is that relatively little is known about how eco-homes challenge the existing political economies of house construction and house markets. Moreover, there are likely constraints in terms of mortgage lenders' willingness to support non-conventional constructions and there is a niche market for eco-homes. Consequently there are assumptions that eco-homes do not help provide much needed affordable housing.

There is an institutional and economic underpinning of building (producing) and living in (consuming) homes. An analysis of the main factors contributing to house costs (Table 1) identifies these different institutional factors (planning, professional and compliance fees), economic factors (labour, materials, market) and those that are produced through the interplay of these factors (land prices which are determined by demand, planning restrictions, location, and commercial activities such as land banking).

TABLE 1 Main factors contributing to house costs

Main Factors Contributing to House Costs	Includes
Land	Purchase costs
Planning	Applications, changes and appeals
Infrastructure	Material (or hard) infrastructures (roads, bridges, power lines and water supply networks) and social (or soft) infrastructures (economic and governance systems)
Professional fees	Architects' and designers' fees
Accreditation	Costs to secure certification and accreditation by green construction schemes
Compliance fees	Planning and building control fees and tax on materials
Labour	All labour costs
Materials	All material costs
Market	The financial circle through which housing becomes an investment
Occupation	Includes energy running costs, state costs such as council tax

SOURCE: Adapted from Pickerill (2016: 126).

Many eco-home developments have sought to reduce costs by altering some of these factors, such as reducing material costs by using reclaimed materials or reducing market influence by establishing a community land trust to own the land. For example, many in Crestone, a small rural town in south Colorado (USA) with a proliferation of eco-builders, have dramatically reduced the costs of their house construction by purposefully building in a remote location where land is cheap, where building codes are not overseen and numerous homes are constructed from reclaimed or natural materials (Table 2).

TABLE 2 Summary of changes made by eco-builders in Crestone, Colorado, USA to mitigate the main factors contributing to house construction and occupation

Main Factors Contributing to House Costs	Attempted Solution to Reduce Costs
Land	Remote location
Planning	No planning application or fees
Infrastructure	In part provided by Property Owners Association, but also owners developing their own off-grid systems
Professional fees	No professional fees required
Compliance fees	No building codes which require compliance
Labour	Self-build reduces labour costs
Materials	Use of reclaimed, local or natural materials
Market	Limited resale value given location and build practices
Occupation	Eco-construction designed to reduce energy costs, but maintenance costs of natural building can be high

SOURCE: Adapted from Pickerill (2016: 135).

While it is possible to identify examples of individual (or small clusters of) eco-homes worldwide being built in affordable ways, there is little research on how volume commercial house builders could replicate such approaches (Brooks and Rich, 2016). The current policy emphasis on technocratic solutions that invariably requires additional funding, rather than changes in orientation, materials or occupational practices which would cost less, limits the possibilities of building cheaper eco-homes on a commercial scale. This is compounded by the reliance on accreditation schemes which have helped promote green building, but are often costly, restrictive and technocratic in their criteria. When examining the political economies of eco-homes there is therefore a need to examine not just the outcomes of policy interventions but how commercial construction companies, planners and mortgage lenders could learn from self-builders, eco-communities and innovative eco-homes to build more affordable housing.

Conclusions

Eco-homes have the potential to radically reconfigure the environmental impact of our housing and everyday home-based practices. Yet they remain little understood and under theorized. Eco-homes need to be more purposefully interrogated to test the claims made about them and to improve future designs. For example, while social practice theories have identified that habits, norms and infrastructures are central to changing everyday environmental practices, it remains unclear to what extent infrastructure and home design change is necessary to trigger major shifts in behaviour, or indeed whether redesign is even required.

New methodological innovations are also needed to enable more vigorous interrogation of eco-homes: ethnographic, longitudinal and multi-scalar. Detailed ethnographic work with all of those involved in eco-homes is required, especially with builders and occupants (Sage, 2013; Goodchild *et al*., 2014). Too often researchers rely on architects and designers to confer meaning onto eco-homes without recognition that it is those who physically build and occupy homes that really inscribe and make a home. Longitudinal research is needed to be able to trace the journey of a design through construction and into a period of occupation. Little is known about how people change their eco-homes over time, just that many effectively 'un-do' the environmental functionality of their homes (Cole *et al*., 2010). Only longitudinal research would be able to examine intent alongside practice, explore the instability of an eco-home and how it changes and evolves as it ages, is lived in differently and is physically altered. Finally, there is an urgent need for multi-scalar research that facilitates the examination of national scale economic and political processes alongside attention to individual households' lived and embodied practices and experiences (Carr and Affolderbach, 2014).

For scholars who are interested in the interrelations and interdependencies of sustainability, environmental governance and carbon emissions, eco-homes offer a rich space of analysis. Eco-homes are shaped by a myriad of influences: place, policy, socio-materialities and economic market pressures. They are excellent examples of the scalar interplay of these influences and how progression at one scale (for example zero-carbon homes government policy) can be undermined by action of another (builders' weak interpretations and occupants' misuse). Yet beyond the insight they offer into academic quandaries, eco-homes are also hopeful and optimistic entities that offer opportunities to reshape our built environment in positive, low-impact and inclusive ways. This hope alone is surely worthy of robust interrogation.

Jenny Pickerill, Department of Geography, University of Sheffield, Winter Street, Sheffield S10 2TN, UK, j.m.pickerill@sheffield.ac.uk

References

Affolderbach, J. and C. Schulz (2015) Mobile transitions: exploring synergies for urban sustainability research. *Urban Studies* 53.9, 1942–57.

Barr, S.W., G. Shaw and T.E. Coles (2011) Times for (un) sustainability? Challenges and opportunities for developing behaviour change policy. *Global Environmental Change* 21.4, 1234–44.

Bergman, N., L. Whitmarsh and J. Köhler (2008) Transition to sustainable development in the UK housing sector: from case study to model implementation. Working Paper 120, Tyndall Centre for Climate Change Research.

Blunt, A. and R. Dowling (2006) *Home*. Routledge, London.

Brilhante, O. and J. Skinner (2014) European experiences of building codes for promoting sustainable housing. Institute for Housing and Urban Development Studies, Rotterdam [WWW document]. URL http://www.ihs.nl/fileadmin/ASSETS/ihs/Marketing/prospective_students_pages/ECO_and_MFUI/EU_Experiences_of_Building_codes.pdf (accessed 4 January 2017).

Brooks, A. and H. Rich (2016) Sustainable construction and socio-technical transitions in London's mega-projects. *The Geographical Journal* 182.4, 395–405.

Broome, J. (2008) *The green self-build book*. Green Books, Totnes.

Bulkeley, H., V.C. Broto and A. Maassen (2014) Low-carbon transitions and the reconfiguration of urban infrastructure. *Urban Studies* 51.7, 1471–86.

Bulkeley, H. and V. Castán Broto (2013) Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers* 38.3, 361–75.

Bulkeley, H., V. Castan Broto and G. Edwards (2012) Bringing climate change to the city: towards low carbon urbanism? *Local Environment* 17.5, 545–51.

Bulkeley, H.A., G.A.S. Edwards and S. Fuller (2014a) Contesting climate justice in the city: examining politics and practice in urban climate change experiments. *Global Environmental Change* 25.1, 31–40.

Bulkeley, H. and A. Jordan (2012) Transnational environmental governance: new findings and emerging research agendas. *Environment and Planning C: Government and Policy* 30.4, 556–70.

Bulkeley, H., A. Luque-Ayala and J. Silver (2014b) Housing and the (re)configuration of energy provision in Cape Town and São Paulo: making space for a progressive urban climate politics? *Political Geography* 40.1, 25–34.

Carr, C. and J. Affolderbach (2014) Rescaling sustainability? Local opportunities and scalar contradictions. *Local Environment* 19.6, 567–71.

Chatterton, P. (2013) Towards an agenda for post-carbon cities: lessons from LILAC, the UK's first ecological, affordable, cohousing community. *International Journal of Urban and Regional Research* 37.5, 1654–74.

Chatterton, P. (2015) *Low impact living: a field guide to ecological, affordable community building*. Routledge, Abingdon.

Cidell, J. (2009) A political ecology of the built environment: LEED certification from green buildings. *Local Environment* 14.7, 621–33.

Coenen, L., P. Benneworth and B. Truffer (2011) Towards a spatial perspective on sustainability transitions. *Research Policy* 41.6, 968–79.

Cole, R.J., Z. Brown and S. McKay (2010) Building human agency: a timely manifesto. *Building Research and Information* 38.3, 339–50.

Derk, J. (2011) Geographies of policy: from transfer-diffusion to mobility-mutation. *Progress in Human Geography* 35.6, 773–97.

Dol, K. and M. Haffner (2010) *Housing statistics in the European Union 2010*. Ministry of the Interior and Kingdom Relations, The Hague.

Dowling, R. and E. Power (2011) Beyond McMansions and green homes: thinking household sustainability through materialities of homeyness. In R. Lane and A. Gorman-Murray (eds.), *Material geographies of household sustainability in Australia*, Ashgate, Farnham.

Edwards, G.A.S. and H. Bulkeley (2017) Urban political ecologies of housing and climate change: the 'coolest block' contest in Philadelphia. *Urban Studies* 54.5, 1126-41

Ellsworth-Krebs, K., L.A. Reid and C.J. Hunter (2015) Homeing in on domestic energy research: 'house', 'home' and the importance of ontology. *Energy Research and Social Science* 6.1, 100–8.

Farmer, J. (1999) *Green shift: changing attitudes in architecture to the natural world*. Architectural Press, Oxford.

Faulconbridge, J.R. (2013) Mobile 'green' design knowledge: institutions, bricolage and the relational production of embedded sustainable building designs. *Transactions of the Institute of British Geographers* 38.2, 339–53.

Fuller, S. and H. Bulkeley (2013) Changing countries, changing climates: achieving thermal comfort through adaptation in everyday activities. *Area* 45.1, 63–9.

Gibbs, D. and K. O'Neill (2014) Rethinking sociotechnical transitions and green entrepreneurship: the potential for transformative change in the green building sector, *Environment and Planning A* 46.5, 1088–107.

Gibbs, D. and K. O'Neill (2015) Building a green economy? Sustainability transitions in the UK building sector. *Geoforum* 59.1, 133–41.

Gibson, C., L. Head, N. Gill and G. Waitt (2010) Climate change and household dynamics: beyond consumption, unbounding sustainability. *Transactions of the Institute of British Geographers* 36.1, 3–8.

Goodchild, B., F. O'Flaherty and A. Ambrose (2014) Inside the eco-home: using video to understand the implications of innovative housing. *Housing, Theory and Society* 31.3, 334–52.

Goodchild, B. and A. Walshaw (2011) Towards zero carbon homes in England? From inception to partial implementation. *Housing Studies* 26.6, 933–49.

Greenwood, D. (2012) The challenge of policy coordination for sustainable sociotechnical transitions: the case of the zero-carbon homes agenda in England. *Environment and Planning C: Government and Policy* 30.1, 162–79.

Guy, S. (2010) Pragmatic ecologies: situating sustainable building. *Architectural Science Review* 53.1, 21–8.

Hargreaves, T., M. Nye and J. Burgess (2010) Making energy visible: a qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy* 38.10, 6111–19.

Hawkes, D. (2012) *Architecture and climate: an environmental history of British Architecture 1600–2000*. Routledge, London.

Head, L. and C. Gibson (2012) Becoming differently modern: geographic contributions to a generative climate politics. *Progress in Human Geography* 36.6, 699–714.

Head, L. and P. Muir (2007) *Backyard: nature and culture in suburban Australia*. UOW Press and Halstead Press, Wollongong.

HM Treasury (2015) Fixing the foundations: creating a more prosperous nation [WWW document]. URL https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/443897/Productivity_Plan_print.pdf (accessed 5 January 2017).

Hobson, K. (2006) Bins, bulbs, and shower timers: on the 'techno-ethics' of sustainable living. *Ethics, Place and Environment* 9.3, 317–36.

Horton, J., S. Hadfield-Hill and P. Kraftl (2015) Children living with 'sustainable' urban architectures. *Environment and Planning A* 47.4, 903–21.

Jacobs, J. and S. Smith (2008) Living room: rematerialising home. *Environment and Planning A* 40.3, 515–19.

Jacobs, J.M. and P. Merriman (2011) Practising architectures. *Social and Cultural Geography* 12.3, 211–22.

Janda, K. (2011) Buildings don't use energy: people do. *Architectural Science Review* 54.1, 15–22.

Jones, L. (2014) Living-with others, living-with an 'eco-home': from frustration to transformation in an eco-development. *Journal of Environmental Policy & Planning* 16.2, 221–40.

Jones, P. (2009) Putting architecture in its social place: a cultural political economy of architecture. *Urban Studies* 46.12, 2519–36.
Kraftl, P. (2006) Ecological architecture as performed art: Nat-y-Cwm Steiner School, Pembrokeshire. *Social and Cultural Geography* 7.6, 927–47.
Kraftl, P. (2010) Geographies of architecture: the multiple lives of buildings. *Geography Compass* 4.5, 402–15.
Kraftl, P. (2014) Liveability and urban architectures: mol(ecul)ar biopower and the 'becoming lively' of sustainable communities. *Environment and Planning D: Society and Space* 32.2, 274–92.
Lees, L. (2001) Towards a critical geography of architecture: the case of an ersatz colosseum. *Ecumene* 8.1, 51–86.
Lovell, H. (2004) Framing sustainable housing as a solution to climate change. *Journal of Environmental Policy and Planning* 6.1, 35–55.
Lovell, H. (2008) Discourse and innovation journeys: the case of low energy housing in the UK. *Housing Studies* 20.5, 613–32.
Maller, C., R. Horne and T. Dalton (2012) Green renovations: intersections of daily routines, housing aspirations and narratives of environmental sustainability. *Housing, Theory and Society* 29.3, 255–75.
Maller, C. and Y. Strengers (2013) The global migration of everyday life: investigating the practice memories of Australian migrants. *Geoforum* 44.1, 243–52.
McFarlane, C. (2011) *Learning the city: knowledge and translocal assemblage*. *RGS-IBG Book series*. Wiley-Blackwell, London.
McGraw-Hill Construction (2014) Green multifamily and single family homes Smartmarket report [WWW document]. URL https://www.construction.com/about-us/press/green-homes-show-growth-in-a-recovering-market-according-to-new-sm-report.asp (accessed 4 August 2016).
NaSBA (2008) Selfbuild as a volume housing solution. National Self Build Association [WWW document]. URL http://www.brightgreenfutures.co.uk/wp-content/uploads/2016/10/NaSBA-Self_Build_report.pdf (accessed 10 October 2016).
NHBC Federation (2012) *Today's attitudes to low and zero carbon homes*. NHBC, Milton Keynes.
Palmer, J., L. Instone, K.J. Mee, M. Williams and N. Vaughan (2015) Green tenants: practicing a sustainability ethics for the rental housing sector. *Local Environment* 20.8, 923–39.
Pelsmakers, S. (2012) *The environmental design pocketbook*. RIBA Publishing, London.
Pickerill, J. (2015a) Bodies, building and bricks: women architects and builders in eight eco-communities in Argentina, Britain, Spain, Thailand and USA. *Gender, Place and Culture* 22.7, 901–19.
Pickerill, J. (2015b) Cold comfort? Reconceiving the practices of bathing in British self-build eco-homes. *Annals of the Association of American Geographers* 105.5, 1061–77.
Pickerill, J. (2016) *Eco-homes: people, place and politics*. Zed Books, London.
Pickerill, J. and L. Maxey (2009) Geographies of sustainability: low impact developments and radical spaces of innovation. *Geography Compass* 3.4, 1515–39.
Reckwitz, A. (2002) Toward a theory of social practices: a development in culturalist theorizing. *European Journal of Social Theory* 5.2, 243–63.
Reid, L.A., K. McKee and J. Crawford (2015) Exploring the stigmatization of energy efficiency in the UK: an emerging research agenda. *Energy Research and Social Science* 10 (November), 141–49.
Roaf. S., M. Fuentes and S. Thomas (2007) *Ecohouse: a design guide*. Third edition, Architectural Press, Oxford.
Rydin, Y. and C. Turcu (2013) Key trends in policy for low-energy built environments: a 20-year review. *Local Environment* 19.5, 560–6.
Sage, D. (2013) 'Danger building site-keep out!?': a critical agenda for geographical engagement with contemporary construction industries. *Social and Cultural Geography* 14.2, 168–91.
Seyfang, G. (2009) The *new economics of sustainable consumption*: seeds of change. Palgrave Macmillan, Basingstoke.
Seyfang, G. (2010) Grassroots innovations in sustainable housing: building a low-carbon future. *Energy Policy* 38.12, 7624–33.
Shove, E. (2006) Constructing home: a crossroads of choices. In I. Cieraad (ed.), *At home: an anthropology of domestic space*, Syracuse University Press, Syracuse.
Shove, E., G. Walker and S. Brown (2014) Transnational transitions: the diffusion and integration of mechanical cooling. *Urban Studies* 51.7, 1506–19.
Strengers, Y. and C. Maller (2011) Integrating health, housing and energy policies: the social practices of cooling. *Building Research and Information* 39.2, 154–68.
Strengers, Y. and C. Maller (2012) Materialising energy and water resources in everyday practices: insights for securing supply systems. *Global Environmental Change* 22.3, 754–63.
USGBC (US Green Building Council) (2016) Benefits of green building [WWW document]. URL http://www.usgbc.org/articles/green-building-facts (accessed 10 October 2016).
Vannini, P. (2014) *Off the grid: re-assembling domestic life*. Routledge, London.
Vannini, P. and J. Taggart (2013) Voluntary simplicity, involuntary complexities, and the pull of remove: the radical ruralities of off-grid lifestyles. *Environment and Planning A* 45.2, 295–311.
Walker, G., A. Karvonen and S. Guy (2015) Zero carbon homes and zero carbon living: sociomaterial interdependencies in carbon governance. *Transactions of the Institute of British Geographers* 40.4, 494–506.
Walker, G., A. Karvonen and S. Guy (2016) Reflections on a policy denouement: the politics of mainstreaming zero-carbon housing. *Transactions of the Institute of British Geographers* 41.1, 104–6.
Warde, A. (2005) Consumption and theories of practice. *Journal of Consumer Culture* 5.2, 131–53.
Wendler, J. (2014) *Experimental urbanism: grassroots alternatives as spaces of learning and innovation in the city*. PhD dissertation, Department of Geography, University of Manchester.
Williams, J. (2012) *Zero carbon homes: a roadmap*. Earthscan, Abingdon.
Wilson, C., T. Hargreaves and R. Hauxwell-Baldwin (2015) Smart homes and their users: a systematic analysis and key challenges. *Personal and Ubiquitous Computing* 19.2, 463–76.
Wines, J. (2000) *Green architecture*. Taschen, Koln.
World Green Building Council and McGraw-Hill Construction (2013) World green building trends [WWW document]. URL http://www.gbcsa.org.za/wp-content/uploads/2013/06/WGBC-Trends-Report_2013.pdf (accessed 1 November 2016).