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Zero carbon homes: Perceptions from the UK construction industry

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HIGHLIGHTS

- The strongest drivers were perceived to be in the legislative and economic themes.
- More barriers were identified than drivers or potential support mechanisms.
- Economic and skills and knowledge barriers were perceived as the most significant.
- Uncertainty in zero carbon homes policy is a barrier to zero carbon homebuilding.
- Proposed support mechanisms include zero carbon champions and self-build homes.

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ABSTRACT

The take-up of the many voluntary energy efficiency standards which exist in the UK and internationally has been limited. As a result, governments have recognised the need to introduce mandatory schemes through legislation, e.g. from 2016 all new build homes in the UK will be required to achieve zero carbon in regulated energy consumption. However, as 2016 approaches, very few zero carbon homes are being delivered. This paper explores the drivers and barriers for zero carbon homebuilding. The perceptions of the wider construction industry were gathered through a series of semi-structured interviews with professionals involved in commissioning, designing, constructing and regulating housing. The results show that, whilst drivers for zero carbon homebuilding exist, the barriers are currently perceived to be greater than the drivers. The barriers are categorised into five groups: economic, skills and knowledge, industry, legislative and cultural. Mechanisms for policy and industry support for the delivery of zero carbon homes are identified to address these barriers. The research findings highlight the need for a clear and robust policy framework for the forthcoming standard. The Government and industry must prioritise raising public awareness of the need for and benefits of zero carbon homes to help develop market demand.

1. Introduction

Globally, buildings represent around 40% of primary energy consumption (IEA, 2014). The building sector has been identified as the sector with the greatest potential to reduce consumption (IPCC, 2007; GhaffarianHoseini et al., 2013). The UK Government has committed to a legally binding target of reducing carbon dioxide (CO_2) emissions by 80% of 1990 levels by 2050 (HM Government, 2008). In 2012, the domestic sector accounted for approximately 29% of final energy consumption in the UK (DECC, 2013a), 82% of this energy was used for space heating and domestic hot water (DECC, 2013b). Therefore, new build housing has the potential to be a leader in meeting the CO_2 emission reduction target. In 2007, the UK Government formally announced their intention to move towards the requirement for all new homes to be *zero carbon* from 2016 (DCLG, 2007) ahead of the Europe-wide requirement for all new buildings to be 'nearly zero-energy' by 2020 (European Union, 2010). When it was announced, *zero carbon* was defined as 'over a year, the net carbon emissions from all energy used in the home would be zero' (DCLG, 2007 p. 5). As a means of encouraging the housebuilding sector to voluntarily improve the energy efficiency of new homes, the Code for Sustainable Homes (the Code) was introduced in 2007 (DCLG, 2013a). Since its inception, very few homes have been built to the higher levels of the Code (DCLG, 2013b) and of those that have, the vast

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majority have been public sector housing. The statistics are suggestive of a reticence from the private housebuilding sector to act voluntarily; a view supported by the literature (Peterman et al., 2012; Goodchild and Walshaw, 2011). Therefore, housebuilders are failing to deliver *zero carbon homes* in preparation for the 2016 Regulations. Previous research into why the private sector is failing to respond to the non-mandatory stimulus has been limited. The research that has been undertaken has focused solely on the views of the large volume housebuilders (Osmani and O'Reilly, 2009). This previous study is primarily quantitative in nature and predates the ongoing global financial crisis which has had a significant impact on housebuilding activity in the UK (Sharman, 2014).

The aim of this paper is therefore to explore the barriers to the mass development of zero carbon new build homes in the UK through an investigation of perceptions around zero carbon homebuilding from professionals involved in the commissioning, design, construction and regulation of housing. The objectives of the paper are to

- Establish the state-of-the-art in zero carbon homebuilding through a critical review of the literature.
- Evaluate the drivers for zero carbon homebuilding.
- Explore the barriers and challenges in delivering *zero carbon homes;* and
- Formulate mechanisms, for both policy and practice, to support the delivery of *zero carbon homes*.

The remainder of this paper is organised as follows: the subsequent section provides a background on the mandatory and voluntary context for the energy efficiency of new build homes in the UK and the wider context and also considers the diffusion of energy efficiency innovation within housebuilding. Section 3 sets out the methodology employed in the research. Section 4 presents the findings of the empirical research and Section 5 evaluates these in the policy context. Finally, conclusions are drawn and implications for policy and practice are identified in Section 6.

2. Towards zero carbon

2.1. Nearly zero-energy buildings

From 2020, there will be a requirement for all new buildings within the member states of the European Union to be 'nearly zero energy' (European Union, 2010):

> *"'nearly zero-energy building' means a building that has a very high energy performance… The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby"*

The Energy Performance in Buildings Directive (EPBD) places the responsibility for developing a legislative framework for the delivery of 'nearly zero-energy buildings' on the individual member states; *zero carbon homes* and *zero carbon buildings* are the UK's response to this Directive. Whilst flexibility is necessary to allow individual countries to develop their legislation with regard to their own contextual conditions, Mlecnik (2012) cites the confusion created by the diversity of definitions internationally as an obstacle to the implementation of the EPBD. Indeed, the fact that no common definition for zero energy buildings exists remains of concern internationally (Marszal et al., 2010; Torcellini et al., 2006). Thus, due to the tightening legislative backdrop, there has been much discussion with regards to definitions around zero energy buildings. A number of papers have considered definitions for zero energy buildings (Hernandez and Kenny, 2010; Marszal et al., 2011; Torcellini et al., 2006) and a broad range of issues in relation to the scope of a definition have been considered, including energy efficiency, renewable energy generation, grid connection and system boundaries *inter alia*. However, whilst there has been debate around definitions for zero energy buildings, there has been little debate about the definition of *zero carbon homes* within the academic literature. The definition of *zero carbon homes* in the UK has been discussed in the context of changes made since the standard was first proposed (McLeod et al., 2012). Heffernan et al. (2013) suggest that the proposed definition for *zero carbon homes* is limited and present energy balance options for consideration in the development of a holistic definition.

2.2. Zero carbon homes

Zero carbon homes is a standard first announced to the UK construction industry in 2007, at which point the UK Government expressed an intention to require all new homes to be *zero carbon* from 2016 (DCLG, 2007). The standard was originally ambitious, requiring not only the emissions from regulated energy (for heating, cooling, hot water, ventilation, auxiliary services and lighting) to be accounted for, but also those from unregulated energy (for cooking and plug-in appliances) (DCLG, 2007). The Zero Carbon Hub is a public/private partnership that has been and continues to be central to the development of the definition of *zero carbon homes* in the UK. Their 2014 proposals suggest the *zero carbon homes* standard will comprise three elements for compliance: a Fabric Energy Efficiency Standard (FEES); on-site energy generation using low or zero carbon technologies (Carbon Compliance) and 'allowable solutions' (Zero Carbon Hub, 2014). Allowable solutions provide for local, near or off-site carbon offsetting, such as a community renewable energy scheme (Zero Carbon Hub, 2011). Between 2007 and 2014, the proposed definition of zero carbon for the standard has been subject to two significant amendments; firstly, the introduction of allowable solutions in 2009 (Parliament UK, 2009) and secondly, the removal of the requirement to account for unregulated energy in the 2011 budget (HM Treasury and BIS, 2011) (Fig. 1).

The Government was initially criticised for the ambitious speed and scale of the zero carbon policy (Lowe and Oreszczyn, 2008) and recommendations were made to limit the targeted reduction

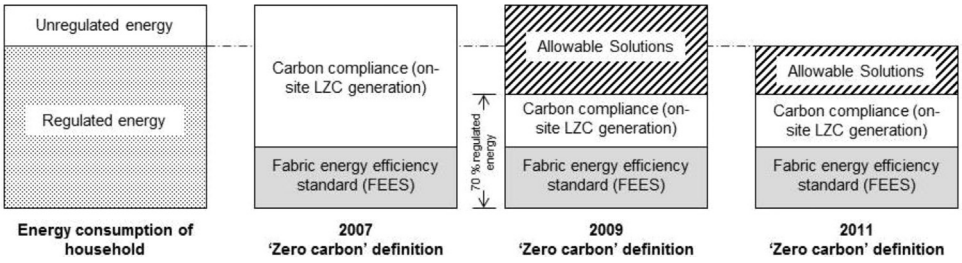

Fig. 1. The Evolution of the official *zero carbon* definition in the UK (developed from Zero Carbon Hub, 2011).

of CO_2 emissions. However, more recently, concerns have been expressed that the standard may be further 'watered down' before coming into force (UKGBC, 2014). There has been criticism within the academic literature that the proposed energy efficiency requirements of the *zero carbon homes* standard are weak because the requirement is too generous with regard to the allowance for the purchase of energy from off-site sources as opposed to conserving energy (McLeod et al., 2012).

2.3. The context for zero carbon homes

The Code for Sustainable Homes (the Code) (DCLG, 2008) is the most prominent voluntary sustainability label for housing in England. The Code is a holistic sustainability rating tool in which homes are rated against indicators in nine categories. Homes can be awarded a star rating between levels 1 and 6, with 6 being the most sustainable. The 'Energy and CO_2 emissions' category is weighted to account for 36.4% of the overall points available across the nine categories and increasing minimum standards for CO_2 emissions are mandatory for each of the six levels of the Code (DCLG, 2010). Private developments account for only 18% of post-construction certified homes under the Code (DCLG, 2013b) whereas they account for around 76% of all new build homes (Wilcox and Pawson, 2012). Fig. 2 illustrates this point; the proportion of all new build homes is shown by sector, as is that of all Code certified homes. It is evident that a very small proportion of the homes built by the private sector have voluntarily gained Code certification.

When it was first conceived, the *zero carbon* standard was equivalent to the highest level of the Code (level 6) in terms of energy and carbon emissions. The removal of the need to account for unregulated energy and the introduction of allowable solutions have reduced the on-site energy requirements for a *zero carbon home* to somewhere between those for Code levels 4 and 5. In 2014 a further exemption to the *zero carbon homes* standard was announced to the UK Parliament; small developments will not be required to meet the standard (Pearson, 2014). Although the detail of this exemption is unknown, it is of concern to 'green building' advocates as it represents another weakening of the forthcoming standard, thus reducing the potential carbon emission savings.

In England and Wales, the Building Regulations set out legal requirements for building work in relation to both new and existing buildings in order to ensure they are 'safe and accessible and limit waste and environmental damage' (DCLG, 2014a). Ways in which the Regulations can be met are set out within a series of Approved Documents. Approved Document Part L relates to 'Conservation of fuel and power' and is formed of four parts: Part L1A, new dwellings; Part L1B, existing dwellings; Part L2A, new buildings other than dwellings and Part L2B, existing buildings other than dwellings. It is anticipated that the *zero carbon homes* standard will be incorporated within a 2016 amendment to Part L1A of the Building Regulations.

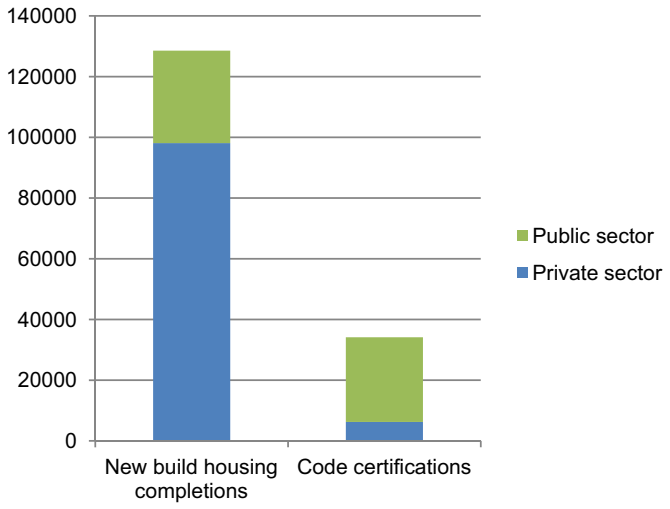

Fig. 2. Total new build housing completions and Code certifications 2011 (developed after DCLG, 2012; Wilcox and Pawson, 2012).

There have been recent moves to identify ways in which to rationalise non-statutory demands placed on new build housing through the planning process in the UK; initially through the Harman Review (Local Housing Delivery Group, 2012) and more recently through the Housing Standards Review (DCLG, 2013c). Subsequently, in 2014, a ministerial statement announced that the Code would be 'wound down' and many of the requirements under the Code consolidated into the Building Regulations (DCLG, 2014b). Although a consolidation of overlapping standards has been welcomed by industry, concerns have been expressed regarding both the potential negative effect on the quality of homes as a result of the removal of the Code and omissions in the transition to the Building Regulations—only approach (UKGBC, 2013). A technical consultation on the Housing Standards Review is in progress (DCLG, 2014c), when complete, a Planning Statement will be made and from that point it will no longer be possible for local planning policy to reference the Code. In light of concerns regarding the removal of the Code, BRE (formerly the Building Research Establishment, BRE is an independent consultancy which undertakes research in all aspects of the built environment in the UK) is planning to develop a new voluntary standard for housing in the UK to cover such issues as climate resilience, occupant wellbeing, efficiency of resources, biodiversity and energy efficiency (Roberts, 2014).

One further voluntary standard which is becoming more common in the UK is the Passivhaus standard. Established in Germany in the early 1990s (BRE, 2011), to date, over 30,000 buildings have been built to this voluntary standard. The standard requires buildings to be designed and constructed with extremely strict levels of airtightness, super insulation, limited thermal bridging and mechanical ventilation with heat recovery (MVHR). Together, these thermal efficiency measures typically reduce the heat demand of a house to such a level as to negate the need for a conventional heating system. It has been suggested that the Passivhaus standard could form a foundation for a more robust *zero carbon homes* policy in the UK, following a 'fabric first' approach (McLeod et al., 2012), although this is contested by the Zero Carbon Hub who state that this approach is not cost optimal (Zero Carbon Hub and Sweett Group, 2014). A comparison of potential *U*–values, level of airtightness and specific heat demand for *zero carbon homes* with those for the Passivhaus standard is shown here (Table 1).

2.4. Diffusion of energy efficiency innovation within housebuilding

The construction industry is formed as a complex supply-chain, through which the diffusion of new knowledge is not straightforward (Peterman et al., 2012). *Zero carbon homes* have been described as a form of socio-technical system (Goodchild and Walshaw, 2011); a socio-technical system being an interconnected network of social institutions and material technologies (Lovell, 2007). Mlecnik et al. (2010) state that the take-up and global diffusion of green building ratings systems has been slow and limited. The status of the economy and financial motives have been cited as contributing factors which result in the low levels of take-up of voluntary energy efficiency measures (Peterman et al., 2012). Goodchild and Walshaw (2011) also state that in the case of *zero carbon homes*, innovation has been discouraged by a lack of

Table 1
Comparison of fabric energy efficiency requirements: *Zero carbon homes* and Passivhaus (Heffernan et al., 2013 developed after BRE, no date and Zero Carbon Hub, 2009).

	Zero carbon homes	Passivhaus
Specific heat demand (kWh/m^2/yr)	≤ 39 (apartment/terraced) ≤ 46 (detached/end terrace)	≤ 15
***U*-Values** (W/m^2 K)		
Walls	0.18	≤ 0.15
Floors	0.18	≤ 0.15
Roofs	0.13	≤ 0.15
Windows	1.4	≤ 0.8
Airtightness (ach @ 50 Pa)	3	≤ 0.6

financial incentive. They assert that due to 'the inertia of design and production systems' these financial incentives would need to be large. A 2005 research study (Lovell) found that the housing market has failed to respond to increasing consumer demand for low energy homes and that the industry has a tendency to stifle innovation, due to the fact that decisions in housing are not just based on cost and the housing market has considerable momentum. Lovell concludes that economic supply and demand theory is too simplistic to apply to the more complex housing market with its myriad of socio-technical issues. The Callcutt Review (Callcutt, 2007) suggests there is a lack of demand for highly energy efficient homes due to home buyers being poorly informed, and that, despite some home buyers being cognisant of the benefits of energy efficiency, their preferences for the price, size and location of a home typically outweigh any preference for energy efficiency. The review states that with the lack of a strong market driver, the UK Government need to legislate. However, it was warned that, unless this legislation is credible, clear, sustained and enforced, it may act as a barrier (Callcutt, 2007).

In summary, the broader literature on diffusion of energy efficiency innovation cites financial barriers and the complexity of the industry as the primary reasons that change is slow and limited. The literature also highlighted divergent views as to the existence, or not, of market demand (Lovell, 2007; Callcutt, 2007).

Osmani and O'Reilly (2009) undertook a study using a questionnaire survey within which responses were received from 41 of the top 100 housebuilders in England. The study sought to identify the most significant drivers for and barriers to zero carbon homebuilding from the housebuilder's perspective. From the findings they categorise drivers for *zero carbon homes* into four groups:

- Legislative (environmental legislation, government policies, planning policies and home information packs).
- Cultural (innovation from within supply chain, corporate social responsibility and partnerships with local councils).
- Business (Business risk of future legislation, marketing benefits, customer demand and ecotown opportunities) and
- Financial (potential sales premiums, fiscal incentives, government grants and access to socially responsible investment funds).

They categorise barriers into a further four groups:

- Legislative (unclear definition of zero carbon, excess of government policies, lack of understanding of requirements).
- Financial (lack of cost data, no financial incentives and lack of sales data).
- Cultural (Current practices are built around current regulations, lack of confidence in emerging green technologies, lack of demand from customers and management is not pro-active) and
- Design (reluctance to vary traditional design, reduced amount of design data and aesthetics of renewable technologies).

This critical review has demonstrated that volume housebuilders are failing to respond to the voluntary stimuli for zero carbon homebuilding. Whether this is as a result of the changing definition of the forthcoming standard is unclear. However, despite the fact that zero carbon is now easier to achieve than when it was originally announced (due both to the progressive weakening of the proposed standard and technological advancement such as the decreasing cost of renewable energy generation systems), the private sector are not delivering *zero carbon homes* in preparation for the 2016 Regulations. Whilst there is a relative wealth of literature on the diffusion of innovation within construction, there has been very limited research on the drivers for and barriers to zero carbon homebuilding in the UK. The sole study identified by the authors (Osmani and O'Reilly, 2009) employed mixed methods but is primarily quantitative in nature and was undertaken at the start of the global financial crisis, at a time when the housebuilding industry was a very different environment and the *zero carbon homes* standard was still a distant prospect. The previous research also considered only the views of the volume housebuilders. As such, up-to-date research exploring the views of the wider construction industry using qualitative methods to gain a deeper understanding is warranted.

3. Methodology

The aim of this paper was to explore construction industry perceptions in relation to the delivery of *zero carbon homes*. A series of semi-structured interviews was carried out with professionals involved in the commissioning, design, construction and regulation of housing, primarily working within South West England. Purposive sampling, which involves the selection of participants based on their value to the research rather than at random (Rubin and Rubin 2005), was considered most appropriate. Interviewees with experience of the design and construction of low and *zero carbon homes* were initially selected using convenience sampling. Snowball sampling was also used, which Bryman (2012) suggests is well suited for use in qualitative research. Kvale (1996) comments that within interview studies, the number of interviews tend to be 15 ± 10 due to factors of time, resources and the law of diminishing returns. Warren (2002) states that, for the purpose of academic publication, between 20 and 30 interviews are required. A target of 30 interviewees was therefore sought due also to the heterogeneous sample group, in order to make it possible to identify any similarities and differences within and between the sample categories. In total, 34 interviews were conducted from the 45 professionals who were contacted to take part; this constitutes a response rate of 76%.

Hughes and Murdoch (2001) identify three overarching categories of roles within the construction industry: clients, consultants and constructors. They also identify the category of regulator for those *'involved by virtue of regulatory functions'* (p. 158). Within previous research in this area (Osmani and O'Reilly, 2009) only the views of volume housebuilders, who cross over the categories of client and constructor, were explored. Therefore, with the aim of gaining the views of the wider industry involved in the design, construction and regulation of new homes, professionals were selected from the following six categories: developer; contractor; architectural consultants; design

Table 2
Interviewee categorisation.

Organisation type	No. of interviewees	Private: Affordable	Position/Role
Developer	5	2:3	Development Manager/Developer
Contractor	5	1:4	Regional Director/Director
Architectural consultant	7	6:1	Architect/ Director/Sustainability Manager
Design consultant	7	1:6	Consulting Engineer/Quantity Surveyor
Local authority	5	–	Planning Policy/Building Control Officer
Government agency/ QUANGO	5	–	Policy expert/Design Manager
Total	**34**	**10:14**	

consultants (e.g. consulting engineers and quantity surveyors); local authority and government agency/quango (quasi-autonomous non-governmental organisation). The number of interviewees within each category is shown in Table 2.

The interviewees typically had experience of working on housing projects in both the private and affordable housing sectors, but with a majority of their workload within a single sector. The primary sector in which interviewees worked is indicated in Table 2 for all interviewees except those within the local authority and quango categories. Of the 24 interviewees in the remaining four categories, 10 worked primarily within the private sector and 14 worked primarily within the affordable housing sector. All interviewees had experience of working on multiple schemes of ten homes or more.

All interviewees were provided with the interview questions in advance of their interview to allow for preparation. The interviews comprised a series of open-ended questions developed for this research. The majority of interviews were conducted face-to-face (25) and the remainder (9) were conducted over the telephone. Notes were taken during the interviews and the majority (30) were digitally voice recorded with the consent of the interviewees. Each interview was transcribed and the data were analysed using NVivo 9 qualitative data analysis computer software.

A combination of thematic and matrix analysis was employed for the analysis of the qualitative data. Thematic analysis is amongst the most common methods of qualitative data analysis (Bryman, 2012). Within this study, the term 'theme' is used to represent a category or grouping identified and selected by the authors; the themes selected have all been identified by at least two interviewees, care has been taken to ensure that all themes are distinct from each other. The themes were developed both from the data and using an a priori approach (Ryan and Bernard, 2003); that is, from the literature and the 'characteristics of the phenomenon being studied' (p. 88) built upon the researchers' prior knowledge. Matrix analysis, as introduced by Miles and Huberman (1994), was used to support and strengthen the thematic analysis.

The coded data have been analysed and interpreted both overall and within and across the interviewee categories. Whilst not intending to rely heavily on quantifying the findings of this qualitative study, the themes identified in relation to each of the questions have been placed in order of significance. The significance of the themes has been rated both in terms of the number of interviewees who identified a theme or sub-theme and also in terms of the semantics used within the interviewees' responses (Rubin and Rubin, 2005). For example; within these three example quotes, the interviewees express different levels of certainty and importance in their responses:

*'The **one key** barrier…; it is cost'* [Public sector #4]
'The first one is Legislation and Regulation…. So, legislation is the biggest one…' [Quango #2]
*'Drivers: the fuel poverty. **I suppose** the environment'* [Developer #5]

In the first two quotes, the interviewees have expressed an opinion that something is important with certainty; whereas within the third quote, the language used shows an element of doubt in the opinion being expressed.

4. Results

4.1. Drivers for zero carbon homebuilding

The interviewees were asked to identify drivers for zero carbon homebuilding. The themes identified from the literature and data are: legislative, economic, social responsibility, individual and industry (Table 3). Under each of the themes a number of sub-themes have also been identified from the data.

Legislation was seen as the joint most significant theme of drivers for the delivery of *zero carbon homes* alongside the economic drivers. Under the theme of legislation a series of sub-themes was identified, of these the Building Regulations were seen as the principal driver for zero carbon homebuilding, being identified by 20 interviewees as a driver. Enhanced requirements in order to obtain funding, such as those for affordable housing, were also seen as a driver. This sub-theme of 'funding requirements' also sits under the economic driver theme.

Lower running costs for a zero carbon home were identified as a driver by 17 of the interviewees, across all of the interviewee categories. In terms of financial drivers for a developer however, there were divergent views amongst respondents regarding the existence, or not, of market demand for *zero carbon homes*.

Social responsibility was one group of drivers identified by the interviewees for the volume delivery of *zero carbon homes*. A significant minority of interviewees identified fuel poverty as a driver for the delivery of *zero carbon homes* (10); respondents from most interviewee categories identified this sub-theme, with a concentration in the contractor group.

The theme of individual (householder) drivers was identified as a secondary group of drivers within this study. These are perceived drivers, from the householder's perspective, identified by the professional interviewees. There are elements of cross-over between the social responsibility drivers theme and the individual drivers theme including sub-themes relating to moral drivers and environmental impact reduction. The strongest sub-theme identified by the interviewees was low running costs, which has an overlap with the primary economic driver of cost of energy. Respondents suggested that comfort, aspiration and public awareness were also all drivers for individuals.

The least significant theme of drivers was industry drivers; that is drivers from within the industry. There were very few references to drivers within this theme from the interviewees in comparison to the other four themes. However a small number of interviewees felt that there were drivers from the industry such as: being seen to be green, fashion and Housing Associations (leading by example).

Table 3
Identified themes – Drivers.

Theme	*Sub-themes*	*Example quote*
Legislative	• Building Regulations • Climate Change Act • Planning • Funding requirements • The Code for Sustainable Homes	*'I think unfortunately legislation is one of the few things that will actually get zero carbon building in; because people have to do it'* [Design Consultant #2]
Economic	• Cost of energy • Market demand • Need for affordable homes • Trialling • Funding requirements • Prestige • Incentives • Energy security	*'The next one then is market drivers so that's the demand, so if it's coming from the end users and the people who are going to buy my product or if there's a demand for it, or if I believe there is a marketing angle; the prestige of having the first ones, or moving the agenda on, if it's something that I can attract a premium for my development for the prestige of it'* [Quango #2]
Social responsibility	• Fuel poverty • Moral drivers • Imperative to act • Sustainable development • Limited resource use • Reduce environmental impact	*'Well, given the way the resources are being used up on the planet, I think we've got no choice but to look at these avenues and they'll probably get more and more efficient and improve'* [Developer #3]*'Drivers…the fuel poverty. I suppose the environment; I suppose those are the two big drivers to be honest with you'*[Developer #5]
Individual	• Low running cost • Public awareness • Positive action for the environment • Moral drivers • Comfort • Aspiration	*' I think in the last 2 or 3 years, we have started to experience homeowners starting to question now 'has the builder put the right insulation in?' whereas, a few years ago, they didn't really notice, didn't care, didn't bother, you know, not interested, whereas now people are more aware of it and I think it's the cost of fuel'* [Local Authority #5]
Industry	• Being seen to be green • Fashion • Housing associations	*'it is a driver in itself, we want to be seen as green, we want to be seen as building green houses'* [Developer #4]

4.2. Barriers and challenges for zero carbon homebuilding

The interviewees were asked to identify barriers and challenges for zero carbon homebuilding. The sub-themes of barriers identified have been grouped into five themes: economic, skills and knowledge, industry, legislative and cultural (Table 4).

Economic barriers were identified as the most significant theme by the interviewees. The capital cost of delivering *zero carbon homes* was identified as the strongest sub-theme within the study with 25 of the 34 interviewees identifying it as a barrier. The issue of scheme viability was another commonly identified sub-theme. Tying in with the sub-themes of land values and home valuations, interviewees perceived a tangible issue with how to make delivering *zero carbon homes* financially viable. There was a perception amongst the interviewees within this study that there is a lack of market demand for *zero carbon homes*. Although respondents held conflicting views in this respect, some interviewees felt there is an element of market demand, although they were generally unsure of the level.

A further primary group of barriers identified by the interviewees was skills and knowledge. Interviewees' perceptions were that knowledge gaps existed for all parties involved in the delivery of housing. The level of awareness of the public and knowledge of occupants were identified as a significant barrier. The barrier 'occupant knowledge' was identified by a significant majority of the interviewees (20), a higher number of references than were made to the knowledge of both the design and build team acting as a barrier.

Barriers and challenges themed around the nature of the housebuilding industry were identified by the interviewees. Amongst the sub-themes identified were the need to work more collaboratively, flexibly and in a place specific way. Interviewees within this study identified the current business model of the industry as a barrier. A further barrier identified in relation to the housebuilding industry was its inertia.

Barriers presented by legislation and government were identified by the interviewees. Amongst the respondents, there was a feeling that, although the government have affirmed their commitment to the *zero carbon homes* policy, the industry is reticent to make firm steps to prepare until there is legislation in place. The issue of the impact of changes in Government on legislation was also raised; one interviewee called for cross-party support for *zero carbon homes*. It was suggested that the industry cannot be expected to invest in designs, products and research if there is no certainty of future legislation.

The theme of cultural barriers was seen by the interviewees to be the least significant of the themes of barriers and challenges. Three sub-themes were identified under this theme: housebuilding industry culture, householder culture and aesthetic culture.

4.3. Support mechanisms for zero carbon homebuilding

The interviewees were asked to propose support mechanisms for the delivery of *zero carbon homes*. The support mechanisms identified have been grouped into four themes: education, training and awareness; legislation; financial and industry (Table 5).

Most of the ideas for the ways in which the delivery of *zero carbon homes* could be better supported were identified under the theme of education, training and awareness. The strongest sub-themes were increasing public awareness and occupant education; these address the most significant barriers identified under the skills and knowledge theme. Interviewees identified the need for improved awareness and education for a range of people involved in procuring and delivering new homes. One way of increasing awareness that was suggested by a number of interviewees was through the introduction of zero carbon champions within key organisations, such as local authority planning and building control departments.

Under the theme of legislation interviewees suggested clarity in the definition for *zero carbon homes*; a robust planning policy framework and stricter Building Regulations as ways in which to address the barriers previously identified. Interviewees stressed the need for the UK Government to go beyond confirming their commitment for *zero carbon homes* and provide the detail of the regulations in order that all those involved in the delivery of housing can prepare and progress. A number of ways in which the public sector could support the integration of zero carbon within the housebuilding process were identified, including design guides, design panels or legislation, but with an emphasis on the need for a clear and consistent approach.

Table 4
Identified themes – Barriers and challenges.

Theme	*Sub-themes*	*Example quote*
Economic	• Capital cost • Scheme viability • Lack of market demand • Perceived risk • Land values • Perceived cost • Home valuations • 'Green' overpricing • Section 106/CIL	*'Short-term, the big barriers are going to be the capital cost and the return on the investment. Simple pound shilling and pence, it doesn't make economic sense certainly not for developers because they're just not able to, at this moment in time anyway, recoup that in the cost of the housing'* [Quango #2]
Skills and knowledge	• Knowledge – occupants • Knowledge – build team • Knowledge – design team • Skills availability • Public awareness • Knowledge – maintenance team • Knowledge – planners • Fabric first • Moving from demonstration to mainstream • Awareness of workforce • Poor competency	*'We're going to have a problem where people eventually move into these houses and they're not going to know half of these systems and why they're there and how they work'* [Contractor #5]
Industry	• Availability of products • Lack of collaborative working • Unproven/inappropriate technology • Failing to be place specific • Hard to persuade people • Lack of drive from housebuilders • Volume housebuilding • Business models • Resistance to change • Design process • Complexity • Every project is a prototype	*'There's always a reluctance from developers I would say to do more than the minimum, not all I'm not going to tar all with the same brush, but some of the main ones, you know, it's about maximising profit and ticking the box, so that's still quite a challenge'* [Quango #5]
Legislative	• Uncertainty re ZCH policy • Planning agenda • Persuading Government sustainability will not stifle growth • Moving the goalposts • Current Building Regulations	*'I wouldn't say that lack of clarity over direction is a barrier…It is a reason for not making progress, so what we need is a clear definition for zero carbon and a clear definition for allowable solutions so that the housebuilders can invest in research and development and for their supply chain to do the same'* [Quango #3]
Cultural	• Housebuilding industry culture • Householder culture • Aesthetic culture	*'The culture of the industry is a barrier, but also the culture of the occupiers'* [Contractor #4]

Under the theme of financial support mechanisms, interviewees identified a number of sub-themes including: incentives, develop market demand, low cost solutions, funding and mortgage solutions. The provision of incentives was the most commonly identified sub-theme; interviewees' suggestions for incentives included reductions in council tax; incentives through the planning system; subsidies and tax incentives. Interviewees were not however supportive of the idea of financial disincentives. Some interviewees discussed existing initiatives such as the feed-in-tariff as a way to incentivise zero carbon homebuilding. Others returned to the issue of market demand, suggesting that when householders become aware of the benefits of *zero carbon homes*, demand for the product will start to develop.

A number of sub-themes were identified under the theme of industry support mechanisms, including: off-site construction, collaborative working, self-build and context specific design. A number of interviewees felt that the industry requires a more significant change than simply perpetuating traditional methods of construction but making it more energy efficient. They saw the need for a move towards more off-site manufacture for improved quality and attention to detail; others saw the need to reduce waste as a driver also guiding construction in the direction of off-site manufacture. A number of interviewees also suggested an increase in self-build methods of procurement which tend to complement off-site manufacture. The proposal to encourage more self-build methods of procurement is made not only as a means of tackling the barriers identified within the volume housebuilding industry, but also as a way of engaging occupants in the process of delivering new homes as a long-term solution.

5. Analysis and discussion

5.1. Drivers for zero carbon homebuilding

Overall, interviewees were able to identify an average of nearly five drivers each. Contractors were able to identify the most

Table 5
Identified themes: Support mechanisms for zero carbon homebuilding.

Theme	*Sub-themes*	*Example quote*
Education, training and awareness	• Public awareness • Occupant education • Industry education • Industry training • Low carbon champions • Design guides • Client awareness • Post build studies	*'education, it's understanding how you don't just put a PV panel and that's what makes it environmentally friendly, it's knowing the process and engaging with professionals'* [Architectural Consultant #1]
Legislation	• Building regulations • Robust planning policy framework • Clarity in definition for ZCH • Cross party support • Incentives • Stricter requirements for public land	*'I think there are a few things that are key and the first thing I think is around getting that definition nailed down and defined and the details of it defined and a commitment to translating that into Building Regs'* [Local Authority #4]
Financial	• Incentives • Develop market demand • Low cost solutions • Funding • Mortgage solutions • Payback mechanism • Economies of scale	*'I think the easiest way, if from a financial point of view, if the Government somehow sort of had a tax regime that made it beneficial. I think you will find a lot more people doing that.'* [Developer #5]
Industry	• Off-site construction • Collaborative working • Simple design solutions • Self-build • Standardised specifications • Context specific design • Availability of materials • Redesign & broaden standard housetypes	*'collaboration and understanding from the very earliest stages'* [Design Consultant #4] *'I will draw an analogy to the car industry – everything in car sales is now based on fuel efficiency etc. and the production process is efficient. We need to build modular homes, more custom housing, we need to change the way we build'* [Contractor #4]

drivers on average, followed by design consultants and architectural consultants. Developers were able to identify the fewest drivers on average (Table 6). The primary themes of drivers were legislative and economic; the secondary themes of drivers were social responsibility and individual. Industry drivers were identified as the least significant.

Interviewees within the contractor category held the strongest perception of legislation as a driver, whereas interviewees from the developer category held the weakest opinion of legislation as a driver. There was consensus amongst the remaining interviewee categories that legislative drivers are currently very significant; primarily the forthcoming changes to the Building Regulations, but also the impending European requirements within the EPBD. This view concurs with the literature; clarity of direction is seen as a necessity for pushing through the implementation of this challenging standard (Callcutt, 2007; Goodchild and Walshaw 2011; Osmani and O'Reilly, 2009; Peterman et al., 2012).

The divergence of the developer group in respect of failing to identify legislative drivers is not isolated to this theme of drivers; this interviewee category identified the fewest drivers overall when compared to the other interviewee groups. This is perhaps indicative of the fact that developers currently do not see significant motivation to deliver *zero carbon homes*. This is supported by a number of interviewees who expressed the view that until stricter legislation is in place, *zero carbon homes* will not be delivered in quantity.

The highest number of drivers was identified under the economic theme (Fig. 3). However, when semantics were taken into account, legislative drivers were perceived to be more significant (Fig. 3). Interviewees believed that the increasing cost of energy has started to make homeowners conscious of the energy efficiency of their homes. As a result, they suggested that this has the potential to act as a driver and develop market demand for *zero carbon homes*. This supports the literature which found that the cost of energy has begun to act as a driver in the case of homeowners choosing to make existing homes more energy efficient (Caird et al., 2008). However, within this study, there were divergent views as to the presence or absence of market demand for *zero carbon homes*. These divergent, and at times polar, views are symptomatic of the complexity of the housing market; when considering purchasing a home, homeowners prioritise a number of other criteria above its energy efficiency (Lovell, 2005). Osmani and O'Reilly's (2009) study of housebuilders' opinions identified financial drivers as the least significant theme, whereas, within this study economic drivers were seen as one of the most significant themes. The difference in the findings of these studies can perhaps be explained by the heterogeneity of the sample group within the current study, compared to the homogeneous group of private sector housebuilders within the previous study. When the views of the developers are isolated within the current study, the economic drivers are seen as the joint second most significant drivers amongst the interviewee category. However, it is noted that there is a low level of consensus amongst the developer group for any theme of drivers. The interviewee group with the strongest perception of economic drivers was the architectural consultants.

It is estimated that around 18% of households in England are

Table 6
Drivers – No. of sub-themes identified per interviewee from matrix analysis.

[a]	*Private/affordable housing sector*[b]	Legislative	Economic	Social responsibility	Individual	Industry	**Total**
Con 1	*P*	2	1	1	1	0	**5**
Con 2	*A*	2	2	1	2	0	**7**
Con 3	*A*	2	2	2	0	0	**6**
Con 4	*A*	3	1	3	1	0	**8**
Con 5	*A*	2	2	1	2	1	**8**
AC 1	*A*	1	1	1	1	0	**4**
AC 2	*P*	2	2	0	0	0	**4**
AC 3	*P*	2	1	0	0	0	**3**
AC 4	*P*	3	2	0	0	0	**5**
AC 5	*P*	2	3	1	3	2	**11**
AC 6	*P*	0	2	1	1	0	**4**
AC 7	*P*	0	2	1	1	0	**4**
DC 1	*A*	0	0	0	2	0	**2**
DC 2	*P*	1	0	3	0	0	**4**
DC 3	*A*	3	2	1	1	1	**8**
DC 4	*A*	1	1	0	1	0	**3**
DC 5	*A*	1	3	0	0	0	**4**
DC 6	*A*	2	2	1	1	1	**7**
DC 7	*A*	0	3	2	3	1	**9**
Dev 1	*A*	0	0	1	0	0	**1**
Dev 2	*A*	1	0	1	0	0	**2**
Dev 3	*P*	0	1	1	1	0	**3**
Dev 4	*P*	1	2	0	2	2	**7**
Dev 5	*A*	0	0	2	0	0	**2**
LA 1		1	1	1	0	0	**3**
LA 2		2	2	0	0	0	**4**
LA 3		1	1	0	0	0	**2**
LA 4		2	1	1	0	0	**4**
LA 5		1	1	1	1	0	**4**
Q 1		2	1	0	1	0	**4**
Q 2		2	3	0	0	0	**5**
Q 3		2	0	0	0	0	**2**
Q 4		0	1	0	1	0	**2**
Q 5		0	0	2	2	0	**4**
Total		**44**	**46**	**29**	**28**	**8**	**155**

Full matrices showing individual interviewee's responses per sub theme can be found in Heffernan (2013).

[a] Con=Contractor; AC=Architectural Consultant; DC=Design Consultant; Dev=Developer; LA=Local Authority; Q=QUANGO.

[b] P=Private sector; A=Affordable housing sector.

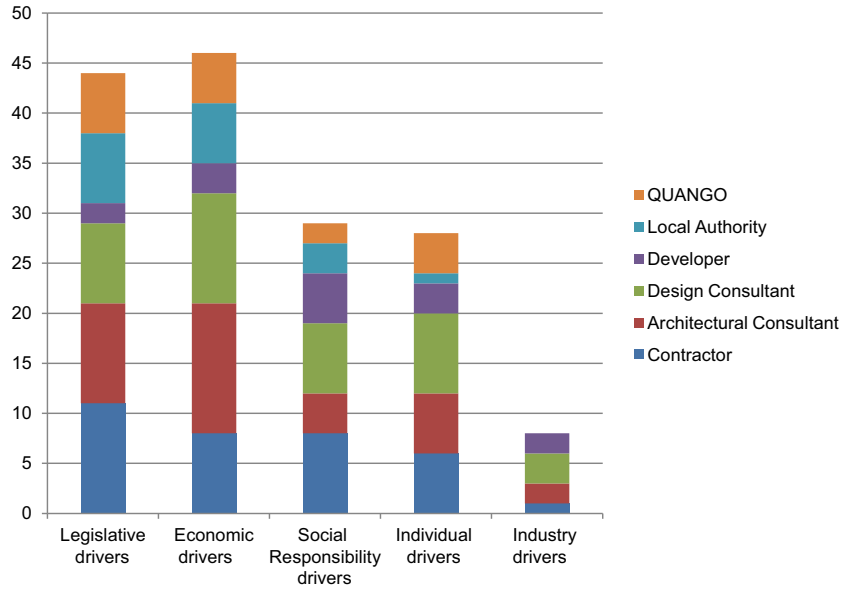

Fig. 3. Drivers – Sum of sub-themes from matrix analysis.

now living in fuel poverty (Guertler and Royston, 2013), this was therefore of concern to many interviewees and thus identified as a driver under the theme of social responsibility. Indeed, this was the strongest theme of drivers identified by the developer group. However, they were not the group with the strongest perception of social responsibility as a driver; the contractor group were able to identify the highest number of drivers in this theme on average. That this theme was perceived by the developer group as the most significant reason to start to deliver *zero carbon homes* is probably due to that group comprising a small majority from the not-for-profit housing sector (3 of 5) for whom addressing the issue of fuel poverty is of concern.

5.2. Barriers and challenges for zero carbon homebuilding

Interviewees were able to identify more sub-themes for this question than any other by a significant margin (Table 7). The overall average number of barriers and challenges identified was over eight per interviewee. Further, the barriers identified exceed the drivers not only in number, but also in magnitude, this is indicative that the interviewees perceive the delivery of *zero carbon homes* to be problematic at present.

There was a strong level of consensus across the interviewee categories for the theme of economic barriers and challenges; the group with the strongest perception of economic barriers was the contractor group and those with the weakest perception of the economic barriers were the Local Authority interviewees. Interviewees cited increased costs (real and perceived) of building a zero carbon home as a barrier to their delivery. However, a recent report (Zero Carbon Hub and Sweett Group, 2014) states that the increased cost of building a zero carbon home (over 2013 Building Regulations standards) is around £3700–4700 for a semi-detached or mid-terrace house. This is a significant reduction from the forecast additional costs when the standard was first announced of up to £36,000 per home (over 2006 Building Regulations standards and based upon the stricter anticipated definition at the time) (Savills, 2007). Osmani and O'Reilly (2009) found that the lack of financial incentive was seen as a major barrier by housebuilders. In the case of zero carbon homes, the perception of the interviewees is that housebuilders pay a premium to deliver homes that provide their future occupants with the benefit of reduced operational costs, but the housebuilder is then unable to attract a premium for their higher quality product. Some interviewees placed the responsibility for this impasse with the mortgage companies and the Royal Institute of Chartered Surveyors (RICS, whose role it is to provide 'Professional Standards' for the valuation of all financial assets, including homes). Together, they fail to acknowledge the value of energy efficiency, despite reports that low energy housing has been able to attract a premium of between 9% and 20% (Lovell, 2005) and that around a

Table 7
Barriers – No. of sub-themes identified per interviewee from matrix analysis.

[a]	*Private/affordable housing sector*[b]	Economic	Skills and knowledge	Industry	Legislative	Cultural	**Total**
Con 1	*P*	1	1	2	0	0	**4**
Con 2	*A*	4	4	5	0	0	**13**
Con 3	*A*	2	3	4	3	3	**15**
Con 4	*A*	3	0	1	0	2	**6**
Con 5	*A*	4	3	1	0	0	**8**
AC 1	*A*	0	1	0	1	0	**2**
AC 2	*P*	3	2	3	2	1	**11**
AC 3	*P*	2	0	2	0	2	**6**
AC 4	*P*	0	2	1	0	0	**3**
AC 5	*P*	4	2	5	1	0	**12**
AC 6	*P*	4	2	4	0	0	**10**
AC 7	*P*	1	2	1	0	0	**4**
DC 1	*A*	1	4	2	0	2	**9**
DC 2	*P*	2	3	2	0	1	**8**
DC 3	*A*	2	5	3	2	0	**12**
DC 4	*A*	2	5	2	1	2	**12**
DC 5	*A*	3	3	2	0	0	**8**
DC 6	*A*	3	3	2	1	1	**10**
DC 7	*A*	4	0	0	2	0	**6**
Dev 1	*A*	2	4	2	0	0	**8**
Dev 2	*A*	0	3	0	0	0	**3**
Dev 3	*P*	4	2	0	0	0	**6**
Dev 4	*P*	4	2	2	1	0	**9**
Dev 5	*A*	2	3	1	1	1	**8**
LA 1		1	2	0	0	0	**3**
LA 2		0	3	1	0	0	**4**
LA 3		1	0	0	0	0	**1**
LA 4		2	2	0	1	0	**5**
LA 5		1	3	3	1	0	**8**
Q 1		1	4	5	0	0	**10**
Q 2		2	7	1	2	0	**12**
Q 3		5	1	3	1	1	**11**
Q 4		4	5	0	2	0	**11**
Q 5		1	5	5	2	1	**14**
Total		**75**	**91**	**65**	**24**	**17**	**272**

Full matrices showing individual interviewee's responses per sub theme can be found in Heffernan (2013).

[a] Con=Contractor; AC=Architectural Consultant; DC=Design Consultant; Dev=Developer; LA=Local Authority; Q=QUANGO.

[b] P=Private sector; A=Affordable housing sector.

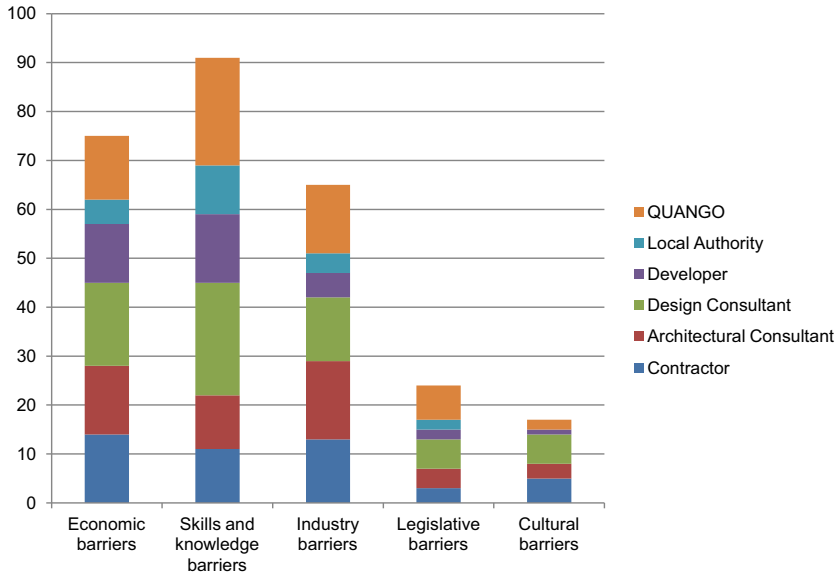

Fig. 4. Barriers – Sum of sub-themes from matrix analysis.

quarter of households would be prepared to pay more for an energy efficient home (Savills, 2007). Indeed, a study of transaction prices for homes in The Netherlands identified homes were able to attract a 10% premium with an 'A' rated EPC compared with the average 'D' rated home and a further 5% discount was evident for 'G' rated homes (Brounen and Kok, 2011). It is therefore surprising that homes cannot currently be valued at a premium to reflect the additional capital costs and that homeowners are not allowed to borrow more based on their reduced operational costs; if this were the case it is envisaged that housebuilders would start to build more *zero carbon homes*.

The theme of skills and knowledge barriers received the largest number of references when compared to the other themes (Fig. 4). However, the economic barriers were perceived to be of greater magnitude. Despite being identified as a primary theme of barriers within this study, skills and knowledge gaps were not identified as an issue within Osmani and O'Reilly's (2009) study of housebuilders . However, both Callcutt (2007) and Glass et al. (2008) found skills and knowledge to be an issue of concern for the implementation of enhanced standards in new build construction and for housebuilding in general, though not specifically for *zero carbon homes*. Of greater concern to the interviewees than the skills and knowledge of the designers, contractors and regulators was that of the building occupants. Interviewees had faced challenges in handing over homes incorporating new technologies to occupants and thus identified the need to educate the occupants of *zero carbon homes* in how to operate them effectively and efficiently. Interviewees also cited the need for potential purchasers to be made aware of the *zero carbon homes* standard and the imperative for change. The Attitude-Behaviour-Choice (ABC) model has been widely adopted within the literature on climate change in relation to lifestyle and behaviour (Shove, 2010), the potential purchase of a *zero carbon home* being one such behaviour.

Industry barriers were identified by interviewees from all categories (Fig. 4). Concerns were expressed that the overreliance on volume housebuilders in the UK is flawed as it fails to deliver homes that meet the occupants' needs. This supports the assertion of the RIBA (2009) that two thirds of homebuyers would not be prepared to buy a new home, because '*many volume housebuilders are only catering for the needs of a minority of prospective homebuyers*' (p. 6). Concern has been expressed regarding the lack of diversity in the UK housebuilding sector as this exacerbates the issue of lack of resilience in the housing market (Parvin et al., 2011; Wallace et al., 2013). The interviewees suggested that, in the UK, both homeowners and the housebuilding sector should learn from the self-build dominated housing delivery models in Europe to move forward. One interviewee stated that in mainland Europe, housing is '*seen as an object of choice and engagement rather than a market*'. This supports the current interest within both the literature and policy for the expansion of the self-build housing sector within the UK (DCLG, 2011; Parvin et al., 2011; Wallace et al., 2013). These barriers were not identified within the study into housebuilders' perceptions (Osmani and O'Reilly, 2009); with the previous study being based upon the views of housebuilders alone, whose interests lie in maintaining their market dominance, it is perhaps unsurprising that these differences in findings exist. The previous study identified a lack of confidence in green technologies and practice being based around current regulations under their corresponding theme of cultural barriers. The view of the interviewees that the housebuilding industry suffers from inertia is supported by the literature; Goodchild and Walshaw (2011) suggest there is a strong resistance to change in the design and production systems for new housing and as such, the incentives to change need to be of an equivalent magnitude.

The reluctance of the industry to take firm steps to prepare for zero carbon homebuilding until there is legislation in place is due in part to the Government's propensity to make unexpected changes to policy. One example of this was in 2011/12 with changes to the feed-in-tariff; these findings are supported by the literature (NHBC Foundation, 2012; Osmani and O'Reilly, 2009). Indeed, the lack of consistency across Europe has been cited as a barrier to the implementation of the EPBD (Mlecnik, 2012). The concerns of the interviewees over the lack of certainty and clarity of the standard have been proven well-founded by the recently announced exemptions from the *zero carbon homes* standard for 'small' developments (Pearson, 2014).

There was a commonly held opinion amongst the interviewees that the housebuilding industry habitually aims to meet and not exceed any regulations in place:

> *'I think typically as a national industry, we only ever do just what we've got to do – that's endemic, that is absolutely entrenched in the industry, so if there is a threshold, we will just pass that threshold and no more; and people will make a career out of*

making sure that we don't go too far beyond the threshold' [Contractor #2]

A number of interviewees concurred with this, stating that the requirements of the Building Regulations become a limiting factor, effectively restricting standards from exceeding that threshold. This supports the findings of the literature that the private housebuilding sector is reticent to act voluntarily (Peterman et al., 2012; Goodchild and Walshaw, 2011). Therefore, legislation was identified as both a driver for and a barrier to the delivery of *zero carbon homes*. The study into housebuilders' perceptions (Osmani and O'Reilly, 2009) concurred, identifying legislation as the primary driver and primary barrier for zero carbon homebuilding.

Culture was identified as a barrier by interviewees from all of the interviewee categories with the exception of the Local Authority category. Some felt the cultural barriers would be easy to overcome with time: *'When PC's first came out it was only geeks who had them, now everyone does and in 5 or 10 years' time it will be the same for energy efficiency for homes. And in terms of culture – it used to be very socially acceptable to smoke; now it is much less so due to the changes in the law and the same will be the case for being wasteful with energy'* [Contractor #4]. This quote illustrates the fact that owning an energy efficient home is not the social norm and this therefore acts as a cultural barrier. Other interviewees identified aesthetic cultural barriers; interviewees suggested that householders may need to be more flexible in terms of the aesthetics of new homes in the future. Cultural barriers within the industry were also identified; interviewees cited a need for a change in mindset for designers and contractors in order to deliver the quality required for zero carbon homes.

5.3. Support mechanisms for zero carbon homebuilding

The suggested support mechanisms for the delivery of *zero carbon homes* identified by the interviewees generally focused on addressing the themes they identified as barriers. However, interviewees were able to identify an average of less than five support mechanisms compared with over eight barriers, implying there is a perception that there are more problems than solutions at present. The interviewee group that identified the most support mechanisms on average was the Quango group and the group that identified the least on average was the Developer group (Table 8).

Education support mechanisms were most commonly identified by the interviewees by a significant margin (Fig. 5). The number of support mechanisms under the remaining themes was relatively similar, however, the distribution of these across the interviewee categories differs significantly. Contractors and architectural consultants identified more industry support mechanisms together than for any other theme.

The interviewees in this study were able to identify significantly more ways in which the delivery of *zero carbon homes* could be better supported than could be found in the literature. Proposed support mechanisms included collaborative working, zero carbon champions, mortgage solutions, self-build methods of procurement and industry training. The interviewees' call for clarity in the *zero carbon* standard substantiates the findings of Osmani and O'Reilly (2009) who make recommendations that the Government and industry take 'clear and concise action' in the implementation of legislation. Interviewees also identified the need for increased public awareness and market demand, for the development of cost effective solutions and the increased use of off-site construction; all of these recommendations for support mechanisms reinforce the findings of Osmani and O'Reilly (2009). The vast range of support mechanisms identified is indicative that there is no single solution to increasing the delivery of zero carbon homes, rather that it is necessary for Government and industry to work together to support the delivery in numerous ways.

Table 8
Support mechanisms – No. of sub-themes identified per interviewee from matrix analysis.

[a]	*Private/affordable housing sector*[b]	Education	Legislative	Financial	Industry	**Total**
Con 1	*P*	2	0	1	0	**3**
Con 2	*A*	0	3	0	0	**3**
Con 3	*A*	3	0	2	1	**6**
Con 4	*A*	0	3	1	2	**6**
Con 5	*A*	1	4	1	0	**6**
AC 1	*A*	0	0	1	4	**5**
AC 2	*P*	2	2	0	0	**4**
AC 3	*P*	1	1	1	2	**5**
AC 4	*P*	0	1	1	0	**2**
AC 5	*P*	0	3	1	5	**9**
AC 6	*P*	2	2	1	0	**5**
AC 7	*P*	1	1	2	0	**4**
DC 1	*A*	0	1	1	3	**5**
DC 2	*P*	1	0	0	1	**2**
DC 3	*A*	0	1	2	1	**4**
DC 4	*A*	2	1	1	4	**8**
DC 5	*A*	0	0	3	3	**6**
DC 6	*A*	0	0	1	1	**2**
DC 7	*A*	1	0	1	4	**6**
Dev 1	*A*	0	0	1	4	**5**
Dev 2	*A*	0	0	0	2	**2**
Dev 3	*P*	0	0	0	0	**0**
Dev 4	*P*	3	1	2	0	**6**
Dev 5	*A*	1	0	1	2	**4**
LA 1		0	0	0	2	**2**
LA 2		1	0	1	3	**5**
LA 3		1	0	0	4	**5**
LA 4		3	0	2	0	**5**
LA 5		0	0	0	5	**5**
Q 1		0	0	0	4	**4**
Q 2		3	0	0	3	**6**
Q 3		1	1	2	0	**4**
Q 4		3	2	0	1	**6**
Q 5		3	0	1	2	**6**
Total		**35**	**27**	**31**	**63**	**156**

Full matrices showing individual interviewee's responses per sub theme can be found in Heffernan (2013).

[a] Con=Contractor; AC=Architectural Consultant; DC=Design Consultant; Dev=Developer; LA=Local Authority; Q=QUANGO.

[b] P=Private sector; A=Affordable housing sector.

6. Conclusions

This paper has explored the perceptions from the wider construction industry in the UK of *zero carbon* homebuilding. The paper concludes that although drivers for the delivery of *zero carbon homes* exist, the identified barriers and challenges exceed the drivers in both number and magnitude. As a result, the diffusion of innovation for energy efficiency has been slow, and the private housebuilding sector is failing to respond to the non-mandatory stimuli for the delivery of *zero carbon homes*. The primary drivers were identified as being legislative, such as the Building Regulations and the Climate Change Act, and economic, such as the increasing cost of energy. The primary barriers and challenges identified were economic and skills and knowledge. These included the increased capital cost, scheme viability, public awareness, and knowledge of occupants. Industry barriers were also identified, including the nature of the housebuilding industry and resistance to change. There were divergent views amongst interviewees regarding market demand, however, it was agreed

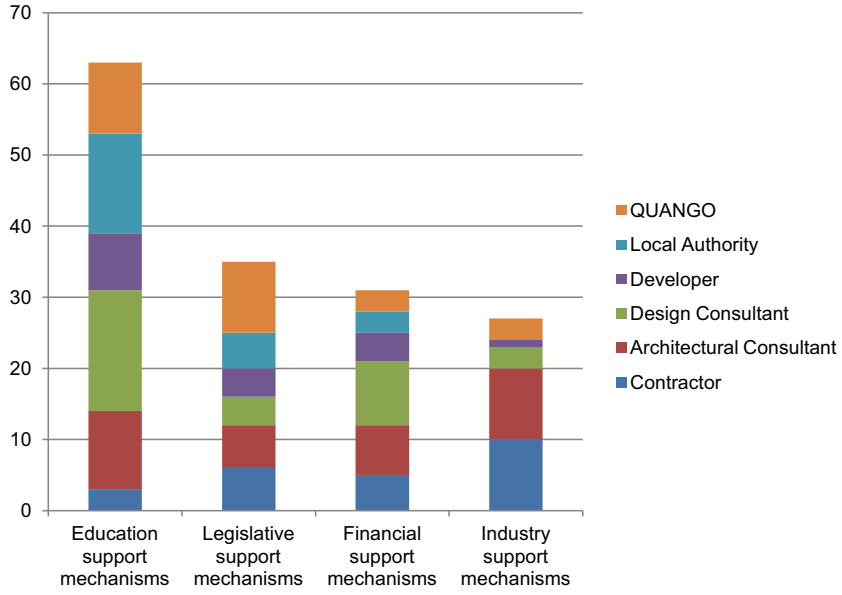

Fig. 5. Support mechanisms – Sum of sub-themes from matrix analysis.

that there is a need to stimulate greater demand as a mechanism to support the delivery of *zero carbon homes*. Uncertainty in the forthcoming legislation was identified as a barrier which needs to be addressed by the Government.

The paper has also formulated support mechanisms for the delivery of *zero carbon homes*, ranging from establishing a robust planning policy framework to encouraging the financial sector to support the delivery of *zero carbon homes* through mortgage lending which acknowledges the reduced operational costs of a *zero carbon home*. The Government and industry should work together to support delivery, as no single solution will independently suffice to increase the delivery of *zero carbon homes*.

The urgency to act is increasing as 2016 draws closer; it is therefore necessary for the Government and industry to prioritise raising public awareness of the benefits of and need for *zero carbon homes*. The over-reliance on the volume housebuilding sector for the delivery of the vast majority of homes should be addressed by encouraging alternative methods of delivery that are more likely to meet the *zero carbon homes* standard. Finally, certainty and clarity in the definition of the *zero carbon homes* standard should be provided to allow the industry to better prepare for this significant step to help reduce the impact of new build housing on climate change.

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