TWO APPROACHES TO DEVELOPING LOW CARBON DWELLINGS IN WEST WALES

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Abstract

In October 2010 Pembrokeshire Housing Association (PHA) completed a development of six residential units, in Pembroke Dock, in west Wales, as part of a Welsh Government pilot project to promote the development of low carbon housing in Wales based on the Code for Sustainable Homes (CfSH). In the same year, in the same town, a small scale developer undertook the design and construction of two houses based on ecological principles using strawbale construction. The houses built by this developer were designed and built outside of the requirements of the CfSH and utilised passive design approaches along with local and natural materials to reduce operational and embodied energy. Researchers from the Ecological Built Environment Research and Enterprise group, at Cardiff Metropolitan University, are working in collaboration with PHA to develop a best practice model for low carbon housing in rural areas of Wales and these two projects provide an opportunity for the researchers to investigate and compare two distinct approaches to low carbon design each with the aim to deliver sustainable, affordable dwellings. To evaluate these two schemes structured interviews were held with the design team of the pilot project and the designer/builder of the eco-house to understand their respective approaches; the influences and obstacles that affected the development of the schemes; and how they considered user behaviour. The paper concludes by considering the lessons that registered social landlords might learn from small scale ecological developers for the design and construction of low and zero energy housing in rural areas.

Keywords: *housing, sustainable development, affordable, rural, Wales.*

Introduction

Researchers from the Ecological Built Environment Research and Enterprise group, at Cardiff Metropolitan University, are working in collaboration with PHA to develop a best practice model for low carbon housing in rural areas of Wales. This paper compares and examines two housing projects in Pembroke Dock, west Wales, UK, each with the aim to deliver ecological, low carbon, affordable dwellings but designed and built using different principles to consider the following questions:

- In this case how did a CfSH based approach to affordable low carbon housing differ from a low carbon approach based outside of the requirements of the CfSH?
- What have been the significant influences on the approaches adopted by the two developers?
- What were the obstacles to development for these two approaches?

- What role did user behaviour play in the development of these two approaches?

Background

The first project was developed by Pembrokeshire Housing Association's (PHA) and consists of six four-person (two bedroom) houses on Britannia Drive, in Pembroke Dock built to Code for Sustainable Homes level four. The project was one of twenty-two schemes which used a portion of the Social Housing Grant programme to assess the implications of building to higher standards of the CfSH and inform the timetable for achieving the aspiration for all new homes to be zero carbon (Welsh Government 2011).

Figure 2: Britannia Drive pilot project house elevations: south elevation (top left) north elevation (bottom left) east elevation (top right) west elevation (bottom right).

Figure 1: Britannia Drive pilot project house plans: ground floor (left) first floor (right).

The six units in Pembroke Dock were built using timber frame construction, infilled with insulation, with a rendered blockwork outer skin and photovoltaic (PV) panels mounted on the roof. This construction represents a 'tried and tested methodology' of PHA and has been used on almost all of their house design over the past five years. The pilot project was not prescriptive about how each development should achieve the target of CfSH level four or higher, which allowed PHA to meet the requirements by using PV panels to upgrade a standard house design.

Figure 3: Britannia Drive - south elevation before installation of Photovoltaic panels: south east view (right) south west view (left).

The second project, less that a mile away, and also in Pembroke Dock, is by a self-builder who undertook the development of two five-person (three bedroom) eco-houses (see Fig. 4 and Fig. 5). A low carbon footprint and affordability were also the key aims of this eco-house project, but because the development numbered less than five dwellings it was exempt from the Welsh Government requirements to meet the CfSH (Welsh Assembly Government 2010).

Figure 6: Pembroke Dock strawbale eco-houses elevations: south elevation (top right) north elevation (bottom right) east elevation (bottom left) west elevation (top left)

Figure 5: Pembroke Dock strawbale eco-houses: ground floor plan (left) and first floor plan (right)

The two houses were built using strawbale construction with a structural timber frame and recycled or low impact materials wherever possible. A website on the eco-houses explains that they were designed around passive design principles so that the living spaces, such as the main bedroom and lounge face south, and have large windows to take advantage of passive solar gain. In addition, passive stack ventilation and 'breathable' walls provide ventilation to the houses without compromising the insulation (Howlett 2012).

Figure 6: Pembroke Dock strawbale houses – view of south elevation awaiting final render coat

Data Collection Methodology

The principle method for collecting data on the two projects has been through structured interviews. In the case of the eco-houses the data from these interviews was supported by email correspondence and by reference to a website on the project and in the case of the CfSH pilot project, as PHA is an industrial partner on the research project, it was possible to gain access to the contract documents and members of staff at their offices.

A combination of open and closed questions was used for the structured interview questionnaire, which was designed to last between forty minutes to an hour. The questionnaire was divided into five sections, which are as follows:

- the first section asked for contact information;

- the second investigated the participants general approach to low carbon housing design;
- the third section was specific to each project and asked about various influences on the low carbon design;
- the fourth was again specific to each project and asked about obstacles to the scheme's development;
- the final section asked about consideration for the building users in the design process.

Closed questions were used to establish the theme of each section and provide easily comparable results and open questions were used to provide more detailed answers. Interviewees were provided with opportunities to qualify their responses to the closed questions at the end of each section; however, as the interviews were recorded, the interviewees generally explained their answers as they responded to each question.

A seven point Likert item approach was employed for the closed questions with interviewees asked to rate various factors such as, for example, 'whether they saw planning policy as an obstacle to development' from 1("None at all") to 7 ("A lot") (Johns 2010). The open ended questions were generally related to the closed questions and asked questions such as 'Do you think that user behaviour will be a significant factor in the energy efficiency of the pathfinder houses since construction?' To overcome some of the problems of consolidating data generated by open and closed questions the software package NVivo was used to analyse the results.

A sample of seven key members of the design team for the CfSH pilot project and the sole designer/builder of the eco-houses were interviewed. The interviewees included the following professionals:

- Development Officer
- Quantity Surveyor
- Architect
- Mechanical Engineer
- Electrical Engineer
- Clerk of Works
- Contractor
- CfSH Assessor

How can a code based approach differ from an ecological approach based outside of the code?

Initial questions asked about the cost effectiveness of various approaches to achieving low carbon design highlighted that there was a considerable level of agreement with the members of the CfSH pilot project team and the designer/builder of the eco-house about the cost effectiveness of low carbon design strategies such as passive solar heating, natural ventilation, natural daylighting, improved insulation, thermal mass and improved air-tightness (see Fig. 7).

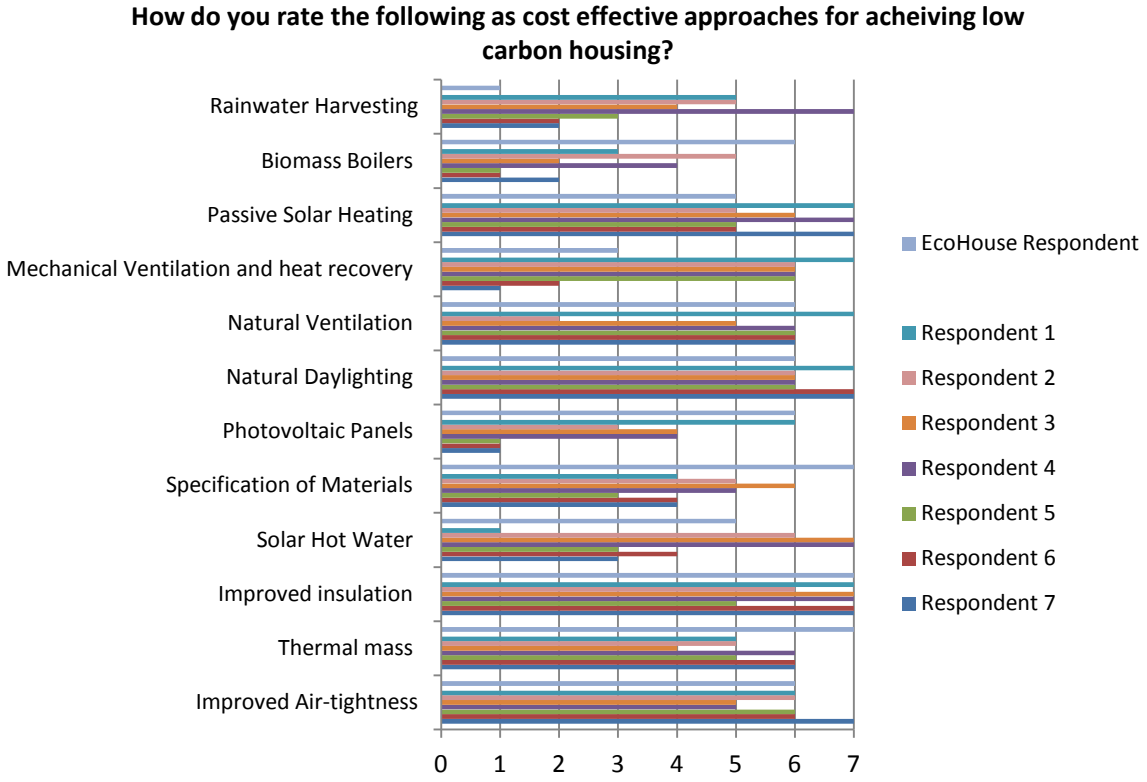

Figure 7: Perception of the relative cost effectiveness of various design approaches to achieve low carbon housing

Where the participants did differ was in answer to the question of whether they thought that their approach differed significantly from that of a conventional house. There was a consensus among most members of the design and construction team of the CfSH pilot project houses that it did not differ significantly from a conventional house of its type, as described below:

> *"I would say that it doesn't differ greatly… Which is in a sense a good thing because you haven't got to push the boundaries and do silly things. You can do the low carbon solution with just standard kind of approaches. Obviously the M&E isn't standard any longer – but the building form can be very similar."*

The mention of building form in quote above is interesting because building form was only mentioned in passing with reference to the pilot project. However, building form was described as being central to the low carbon strategy of the eco-house both in terms of reducing capital costs and but also for reducing operational energy, as explained below:

> *'In terms of things like design and keeping house form compact and relativley small you're minismising surface area relative to volume and reducing the build co;, keeping it affordable.'*

In addition to building form the designer/builder of the eco-house highlighted the way in which he approached the design as a significant way in which it differed from a conventional house; as described below:

‘Yes - partly in that it’s an ongoing process… as I started construction I've been experimenting and learning from it so its been a developing organic process rather then the fixed one you'd expect.’

The specification of materials as a low carbon approach drew a mixed response from the participants and this is significant because the comments highlighted it as one of the key differences in approach between the eco-house designer/builder and the developers of the pilot project. Comments by members of the pilot project development team explained that they perceived cost as barrier in the specification of materials with low embodied energy; as explained below:

‘If you’re building a house you're going to speak to Jewsons and they're going to give you the most cost-effective price on a material and are you actually going to ask the question of how much energy has it taken to produce that concrete block? I don't think you would. If you did you would probably end up paying a bit extra.’

Responses, such as the one above, were in contrast to those from the eco-house designer/builder who put the use of locally sourced, natural and recycled materials at the core of his approach. When asked about the role of material specification in his approach to the development of low carbon housing he gave the following reply:

‘Critical - It can make a huge difference to the fabric of a house. If you look at straw build you've got something that's carbon sequestering - you are locking up carbon for the lifetime of the building whereas you if you build in concrete or cement although it carbonates to an extent you are still taking up to a massive carbon footprint.’

These responses highlight that although there is a considerable level of overlap between the two projects there are some significant differences. The influences on the development of the low carbon approach that produced these differences are explored in the next section.

What have been the significant influences on the two approaches adopted?

The second section of the questionnaire investigating key influences in the development of the two schemes; responses to these questions described how the pilot project team considered planning regulations, building regulations and the standards set by the CfSH as major influences (see Fig. 8). However, the budget was highlighted by the pilot project interviewees as the single most significant influence. Comments by pilot project interviewees described how the restrictions of the social housing budget combined with legislative requirements to considerably influence the approach PHA took to development:

“Affordability is really at the forefront of thinking in most cases. We operate on very tight margins - I mean our main source of income is obviously the rent which is often bench marked… our grant funding comes conditioned with meeting DQR and the code... budget is really something which we...[it] is a big issue.”

Another significant influence on the development of the pilot project, explained in several comments, was experience on an earlier low carbon scheme that went significantly over budget. This earlier scheme appears to have contributed to a desire not to deviate from their typical approach in terms of building form and fabric. Thus, a micro-renewable led

design strategy was adopted to meet the pilot project's low carbon aspirations despite there being some debate within the construction industry about the merits of this approach (Energy Saving Trust 2010). Several respondents described the micro-renewable led approach adopted for the pilot project; including the interviewee below:

> *"I think the way we approached it [was] a little like stepping into the unknown - going from the BREEAM standard of Eco homes... we stuck with our traditional 140 stud so the fabric of the building and the general details didn't change too much. What we looked upon was the eco-bling… to achieve code four taking our standard unit and looking at… [adding] the PV system and an efficient gas boiler ... I think we probably did the right thing I don't think we did anything wrong we achieved the code in a cost effective way... maybe its not the way the assembly would like us to approach it.'*

The debate within the construction industry about the viability of a micro-renewables led approach were reflected in the responses of the design team of the pilot project and while some interviewees defended the approach (as above), others were more critical explaining that if the PV failed it would undermine the environmental strategy of the scheme, as explained below:

> *"But you think that it has achieved code four, it's just with the bolt-ons, with all the PV - it's not really the right approach - is it? Because if the PV fails the house doesn't perform with regard to code four and all the aspirations"*

Legislation and budget appear to be less significant influences on the approach of the eco-houses, at least when compared to the pilot project. This is evident in response to the how the CfSH was rated as an influence. Members of the pilot project design team all rated the CfSH as a significant influence (with a rating of five or more) (see Fig. 8); however, the developer of the eco-house chose not to adopt a development approach based on the CfSH, despite being a code assessor by profession. Through emails the eco-houses' designer/builder described his reasons for not adopting the CfSH, citing the way in which he perceived that it favours large developers using standardised solutions:

> "*The Code is set up to favour larger developers using standardised solutions and actively penalises smaller developers and low-tech, low energy solutions... The Green Guide gives rammed earth walls an A+ rating for having a low environmental impact, but you can also get an A+ rating for a concrete block wall built with cement mortar, despite the immense environmental cost of cement production."*

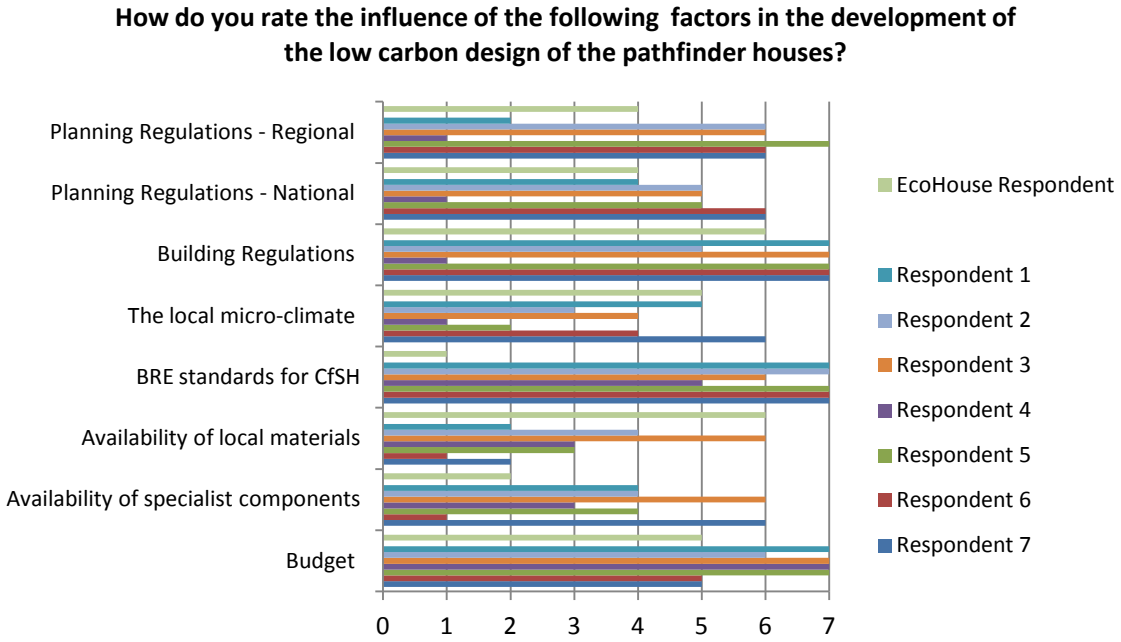

Figure 8: Perception of the influence of various factors in the development of the low carbon design of the pilot project houses.

Obstacles to the Development of the Pilot Project

With regard to the perception of obstacles it is apparent that the approaches of the eco-house and the pilot project produced quite distinct obstacles. In the case of the pilot project, there was a considerable level of difference about perception of obstacles among the development team based on each individual's professional role within the scheme (see Fig. 9). However, there was almost universal agreement that development costs were the most significant obstacle, as detailed in the comment below:

> *"I'd say development costs are often an obstacle on all schemes that we deal with. The problem we have, if I can elaborate on that, is that a lot of the land that we source tends to come predominantly from the local authority - former garage sites scrappy bits of land which have often not been developed for the reason that from time when the local authority used to develop housing it was often deemed to be undesirable. Consequently we have a lot of abnormal costs with developing these sites."*

With regard to the eco-house development costs were also identified as an obstacle but not to the same degree as the in pilot project (see Fig. 9). No doubt, part of the reason why development costs were not seen as such a significant obstacle on this project was because the designer/builder of the eco-house was able to draw on free and cheap labour and materials, as explained below:

> *'construction has been very cost-effective at approx. £60,000 to date (£30,000 per house) but there's a lot of free labour and time in that… I've found there is a wealth of materials available free or cheap; my clay plaster was dug from a neighbour's garden (about 10 tonnes of it!), there was some usable stone and slate on site and freecycle and neighbours renovations have been a godsend - free second hand kitchen cupboard doors, taps and bathroom white goods, left over insulation etc. have all found their way to my site.*'

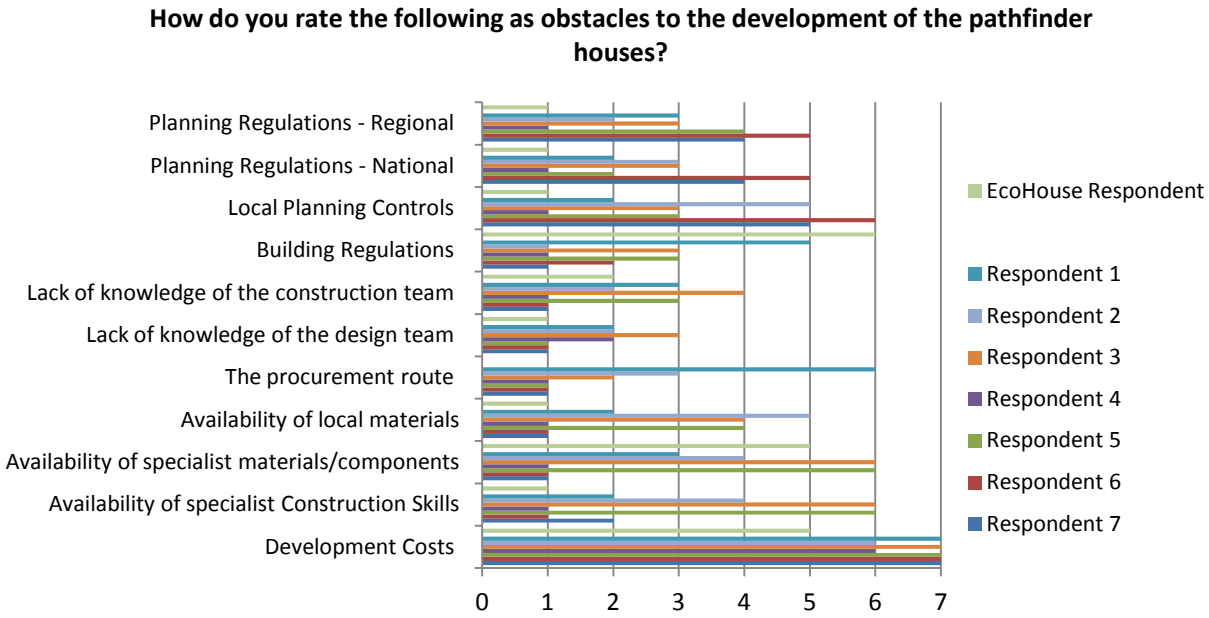

Figure 9: Perception of obstacles to the development of the pathfinder houses

The building regulations, was not perceived as an obstacle by the designers and builders of the pilot project; however, for the eco-house it was considered as one of the most significant obstacles, with a rating of six (see Fig. 9). The reason for the building regulations high rating by the designer/builder of the eco-house was described as follows:

> *'Basically I think that building regs although its not prescriptive; although it should really be about basic principles; building control officers, in my experience, are very heavily rooted in what they know and understand. What they like are standardised solutions… I think in terms of low impact development its a real sticking point. What's being imposed by the Welsh Assembly in terms of policy is completely unrelated to what is happening on the ground its a completely different approach and its not marrying up.'*

With regard to the pilot project and the role of the building regulations as an obstacle the low ratings (with six of the seven participants giving it a rating of three or less) (see Fig. 9) perhaps reflecting the fact that the 'tried and tested' solution adopted for this scheme was in keeping with the standardised solutions favoured by building control officers (as argued above). However, the low ratings also perhaps indicate that the stricter requirements set the CfSH have replaced building regulations as a legislative obstacle, as explained below:

> *'I mentioned earlier it was almost looked upon that the building regulations is something we tend to achieve as the norm. The code is the thing that seemed to focus attention... I didn't see building regulations as being a major obstacle.'*

With regard to the availability of specialist materials and the specialist skills it was only the Quantity Surveyor, the Development Officer and, to a lesser extent, the Architect who perceived a lack of skills and availability of specialist materials to be an obstacle on the pilot project. These participants cited the difficulties gaining an Micro-renewables

Certification Scheme accredited installer for the PV as the reason for their high ratings. But generally, it was felt by the pilot project team that the conventional nature of the house meant that the sourcing of specialist materials had not been a problem, as explained in the comment below:

> *'No - Because it was timber frame - a pretty standard construction… I'm just thinking more of the M&E whether that was influenced... [by a lack of materials] because we had the bolt-ons - it really wasn't... it wasn't an obstacle.'*

In contrast, to the pilot project, the sourcing of specialist materials for the eco-houses was rated alongside development costs as the second the most significant obstacle to the development. The reason for the high rating is explained below:

> *'Thinking back what I found was - was using ecological materials there is very much a right and wrong time of the year to be for looking for some things. So with straw its harvested in August - if you start looking in February after a hard winter it can actually be very difficult to get hold of it. Things like the hazel rods that you use for reinforcing the walls - coppicing stops at the end of March so if you're looking in April it can be a real job to find any significant quantities.... So yes availability of materials can be an issue.'*

With regard to the development of a best practice model for low carbon housing in rural areas of Wales, the fact that each scheme's obstacles appears to be addressed by the other scheme's approach indicates that there could be some merit in combining approaches. However, to successfully combine these two approaches a number of issues will have to be addressed: supply chain issues in the sourcing of local, natural materials; a issues around a lack of incentives for non-standard approaches, evidenced by PHA's decision to use a tried and tested methodology; and a lack of flexibility with regard to how low carbon buildings legislation is implemented at local level.

Consideration for the Building Users in the Design Process

There is evidence that the building users can play a considerable part in the energy efficiency of a project (Combe et al 2011) and also that design can be a tool to influence user behaviour (Lockton et al 2009); however, it was apparent from the answers in the final set of questions that, aside from provision of a home user guide, and to a lesser extent simplicity of control systems, that consideration of many aspects of user behaviour had been neglected in the design of the pilot project. Of the thirty-five answers provided by the participants involved in the pilot project in this section fifteen were given a one rating meaning that the interviewee believed that the particular item had not been considered (see Fig 10).

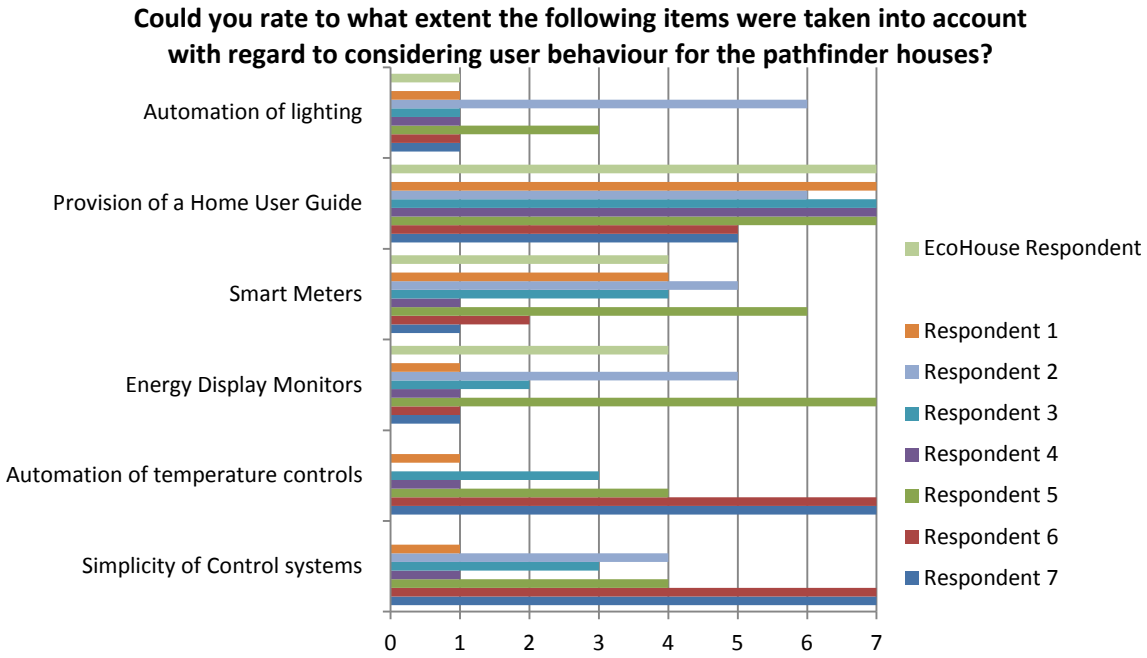

Figure 10: Consideration of user behaviour in the development of the pilot project houses

In the case of the eco-house the role of user behaviour on building performance was complicated by the fact that the designer/builder would be living in one of the properties and renting the other. Nevertheless there was a belief by the developer that the nature of the eco-house would influence its tenants though high levels of insulation which would reduce heating demand, although he conceded that he would be trying to rent the house to someone environmentally conscious; as explained below:

> *'I think that that you can influence user behaviour by increasing levels of insulation so that even if they do want it warmer it's not going to take that much energy to keep it warmer. But obviously if someone moves in and cranks up the thermostat so that it is 30 degrees all the time then obviously it is going to have a bearing on energy efficiency… I think also that it will tend to be someone more environmentally conscious who is going to want to rent a house like that and who I'd be more comfortable renting a house like that'*

The designer/builder of the eco-house explained the importance of choosing someone environmentally conscious in the quote below:

> *'I think it is a more sensitive type of housing - if you get water into the middle of a straw wall somehow that could cause a serious issue and you can't go slapping emulsion paint on the walls because that would stop it being breathable but yes it is sensitive house that needs to be treated properly but if you treat it properly it will look after you'*

The fact that the designer/builder of the eco-house is in a position to choose someone environmentally conscious contrasts with housing associations, such as PHA, who often had to contend with tenants who might have little or no interest in a particular house's energy saving features. One interviewee described how PHA often has to contend with tenants with little or no interested in a house's energy saving features:

> *'I think that the other issue is that because the tenants don't pay for this*

equipment to go on their building they're not that interested in it. If you were putting this on your house you would research it a little bit to see what benefits you're going to get from it, you would be keen to see that the system is set up to run in the most efficient way possible but because they have no financial commitment to it to be honest they're not that bothered with it.'

These two sets of responses highlight the important role that the building users can play in the development of approaches to low carbon dwellings. The fact that designer/builder of the eco-house had some control over the tenancy has provided a degree of freedom to develop a more 'sensitive' design while PHA tenant's meant that they were often limited to systems that require minimal engagement with the users, such as PV.

CONCLUSION

From the structured interviews it was apparent that by their respective aims both of these projects had been a success: the pilot project team successfully delivered a CfSH level four house within the social housing budget and the straw-bale eco-house was successful in achieving a low-impact home that was cheap to build. A detailed analysis of the embodied energy and cost of both projects is necessary to compare the effectiveness of specification of materials for reducing carbon emissions and either monitoring or dynamic thermal modelling analysis will be required to compare the operational energy of the two schemes.

This study suggests that the developer of the eco-house was able to use a degree of legislative freedom, at least when compared to PHA, to explore a holistic design that reflected his concerns about appropriateness of a CfSH based approach for small developers using low tech solutions. His concerns, and those of the some members of pilot project design team about the use of PV to raise the code rating of the scheme, raise questions about the appropriateness of the CfSH based approach adopted by the Welsh Government and echo unease among some sustainability consultants (including the eco-house designer/builder) that the CfSH favours standardised high tech solutions (Climate Works 2011). Questions about obstacles to the pilot project highlighted the problems associated with developing low carbon schemes on a social housing budget and suggest that even on exemplar schemes that affordability is the primary concern reflecting evidence that budget will be a significant factor in the development of low carbon dwellings in England and Wales (Osmani M and O'Reilly A 2009).

Regarding the development of a best practice model for affordable, low carbon housing in rural areas of Wales this study indicates that significant savings in capital cost could be achieved though the use of local materials and the adoption of a more compact form, as on the eco-house. It is questionable whether it would be appropriate for a social housing developer, such as PHA to replicate this strawbale approach due to sensitivity of the material to maltreatment by tenants and issues surrounding sourcing materials. However, this study indicates that the financial barriers, perceived by some members of the pilot project design team, to reducing the embodied energy in social housing can be overcome by a departure from the standardised approaches to construction used on the pilot project. However, this study also indicates that questions remain about whether the present legislative context, both at local and national level in Wales, provides suitable incentives and flexibility for developers to adopt non-standard low carbon building solutions within the social housing framework.

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