DEVELOPING POST-OCCUPANCY EVALUATION TECHNIQUES FOR ASSESSING THE ENVIRONMENTAL PERFORMANCE OF APARTMENT BUILDINGS IN WALES: AN ECOLOGICAL PERSPECTIVE

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ABSTRACT: Post-occupancy evaluation (POE) originates from "an interest in learning how a building performs once it is built, including if and how well it has met expectations and how satisfied building users are with the environment that has been created" (Vischer, 2002). The subject of this paper is a three-year PhD research project that is investigating the environmental performance of low-carbon apartment buildings in-use, including how users rate building performance. The drivers and barriers to making POE more routine practice in the UK are identified through a literature review, and a definition of environmental performance for building evaluation studies is proposed that encompasses both the degree to which the building supports the activities and aspirations of its users and the environmental impacts arising from its use. POE techniques employed in recent studies of housing in the UK and other parts of the world are reviewed, and the paper concludes by discussing the development of an overall monitoring strategy and an occupant survey questionnaire to be used in the research programme. The paper will be of interest to researchers investigating POE research and practice in low-carbon dwellings.

Keywords: post-occupancy evaluation, environmental performance, apartment buildings

1 INTRODUCTION

The UK Government has outlined an ambitious strategic policy objective for all new homes to be zero carbon by 2016 (CLG, 2007a). However, this target is defined according to design performance, not measured performance. The subject of this paper is a three-year PhD research project that is investigating how low-carbon apartment buildings perform in practice, including how users rate building performance. This type of investigation is normally described as post-occupancy evaluation (POE). A brief overview of the history and recent developments in POE research and practice is presented, and key literature is reviewed in relation to developing an overall approach and protocols for assessing the environmental performance of apartment buildings in-use. The paper concludes by discussing the development of an occupant survey questionnaire for the research.

2 BACKGROUND

2.1 Introduction to post-occupancy evaluation

The emergence of post-occupancy evaluation (POE) as a distinctive discipline traces its origins to studies of public and student housing in the UK, France,

Canada and the United States in the 1960s and 1970s (Zimring *et al.*, 2010). These early studies gathered information about the responses of occupants to buildings through questionnaires, interviews, site visits and observation, sometimes linked to physical assessment of the building, with the objective of understanding the performance of design elements, identifying best practice approaches and also what should not be repeated in future (Federal Facilities Council, 2002). This mixed-methods approach and investigative ethos principally focussed on user experience remains central to most contemporary approaches to POE. Recent developments are characterised by two trends: the creation of standardised POE methodologies for specific building types (e.g. offices, healthcare and educational facilities) and the extension of the scope of POE activities to incorporate evaluation and feedback at repeated intervals during the building delivery lifecycle (Stevenson, 2009). As the discipline has expanded and become more specialised, so too have the terms used to describe it, for example facility performance evaluation, environmental design evaluation, environmental audits, building-in-use assessment, building evaluation, facility assessment, and building performance evaluation (Zimring *et al.*, 2010). In recognition of this diversity of objectives and application, Vischer (2002) offers a loose definition of POE as “any and all activities that originate out of an interest in learning how a building performs once it is built, including if and how well it has met expectations and how satisfied building users are with the environment that has been created”.

2.2 Drivers and barriers for POE

The potential benefits of POE to the design, construction and operation of buildings include developing an understanding of the short- and long-term effects of design and construction decisions (in terms of costs, occupant satisfaction and building performance aspects such as energy management etc.) and improving the knowledge and practices of clients, designers, builders, facility managers and other built environment professionals (ibid.). In the UK context, POE has yet to become embedded as routine practice in the building delivery process (Bordass & Leaman, 2005). Typical barriers to more widespread adoption of POE cited by practitioners include cost considerations, time constraints, perceived challenge to professional judgement (including risk of litigation) and the availability of researchers and practitioners possessing the broad range of skills required for undertaking a successful POE study (Vischer, 2002; Stevenson, 2009). Government funding for the most significant coordinated programme of POE undertaken recently in the UK – the Post-occupancy Review of Buildings and their Engineering (Probe) studies comprising surveys of twenty buildings of technical interest between 1995 and 2002 – was discontinued in 2002 (Bordass & Leaman, 2004). However, the announcement in May 2010 that the Technology Strategy Board (TSB) would provide £8 Million funding in a competition to support building performance evaluation studies is likely to stimulate a resurgence in POE practice and research (TSB, 2010).

2.3 POE and zero carbon homes

The rationale for the TSB competition is specifically concerned with understanding how buildings perform in practice in terms of carbon emissions[1] (ibid.). This emphasis is directed by UK Government policy objectives for climate change mitigation as set out in the Climate Change Act 2008, which commits the UK to legally-binding targets for emissions reductions of at least 34% by 2020 and 80% by 2050 against a 1990 baseline (Offices of Public Sector Information, 2008). For domestic buildings, which are responsible for approximately 24% of total UK emissions (Department of Energy and Climate Change, 2010), achieving deep and rapid emissions reductions is a strategic priority if these targets are to be met (Boardman, 2007).

In response to this agenda, the UK Government has established a target for all new homes to be zero carbon by 2016 (CLG, 2007a). Zero carbon refers to the net level of carbon dioxide emissions resulting from all energy used in the dwelling as being zero or better, and is proposed to be defined according to a hierarchical approach in the UK as illustrated in Figure 1 below. It is expected that new dwellings will be required to meet a minimum energy efficiency standard for space heating and space cooling to satisfy the first level of the hierarchy, with the remaining emissions mitigated through a combination of on-site low and zero carbon (LZC) technologies, community heating and 'allowable solutions' comprising initiatives that support emissions reductions in other aspects of the development and a LZC energy infrastructure (Zero Carbon Hub, 2009).

Figure removed due to copyright restrictions *– the figure can be accessed from p.16, Defining a Fabric Energy Efficiency Standard For Zero Carbon Homes here:* http://www.zerocarbonhub.org/resourcefiles/ZCH-Defining-A-Fabric-Energy-Efficiency-Standard-Task-Group-Recommendations.pdf*.*

Figure 1. Hierarchical approach to UK Government zero carbon definition (following Zero Carbon Hub, 2009)

New, low-carbon homes will therefore "provide important exemplars to the community and general population" (Boardman, 2007) and help to develop a market and infrastructure for energy technologies that are not reliant on fossil fuels, and also for sustainable building materials. These benefits are likely to accrue more widely to the improvement of existing homes, which are more significant in terms of their contribution to overall emissions. New buildings also represent one of the easiest sectors of the economy to implement emissions reductions cost-effectively (Olivier, 2001; Levine *et al.*, 2007). Furthermore, there is an argument for demolition over refurbishment in the case of "hard to heat" homes, and also for political reasons, for example urban regeneration. Thus, the drivers for monitoring the performance of new dwellings using POE techniques include:

- Supporting product and process innovation for new, low-carbon design and construction methods and technologies;

[1] In this paper, 'carbon emissions' or 'emissions' refer more generally to anthropogenic (human-caused) greenhouse gas emissions.

- Developing knowledge and expertise in the development of low-carbon buildings through providing feedback to the clients and design and construction teams; and
- Informing the development of building design standards and regulatory instruments and thus connecting climate change policy aims with practice.

3 ASSESSING ENVIRONMENTAL PERFORMANCE IN DWELLINGS

3.1 Low-carbon homes in Wales

The preceding section of the paper has provided an overview of the history and development of POE as a "multifaceted tool" for assessing building performance (Vischer, 2002) and identified contemporary drivers for monitoring the performance of new, low-carbon homes. This section introduces the background, aims and objectives of a three-year PhD research project being undertaken by the lead author of the paper to investigate the application of POE techniques for assessing the environmental performance of new-build apartment buildings in Wales.

The Welsh Assembly Government (WAG) (the devolved Government for Wales within the UK) aims for the construction of new homes to move towards zero carbon as soon as possible (WAG, 2009). Initially, WAG announced an aspirational target for this to be implemented ahead of the UK timeline and for all new homes to be zero carbon by 2011 (National Assembly for Wales, 2008). In support of this objective, WAG provided additional funding within the Registered Social Landlord (RSL) Development programme in 2008 to pilot 22 'Pathfinder' housing schemes built to Levels four and five of the Code for Sustainable Homes (CLG, 2009; WAG, 2009).

The research project, which is based in Wales and commenced in February 2010, is investigating the environmental performance of apartment buildings to determine if, in practice, low-carbon design is translated into low-carbon construction and performance in-use. Four case study apartment buildings in Swansea (UK), designed to meet EcoHomes 'Good' and Level 4 of the Code for Sustainable Homes are to be monitored during the course of the research programme (Building Research Establishment, 2006; CLG 2009), including one of the 'Pathfinder' schemes. These apartment buildings are being developed by the industrial partner to the project; Coastal Housing Group Ltd. (an RSL based in Swansea), and will be used to test and develop POE techniques for assessing environmental performance. An expected output of the research will be the development of a guide for RSLs that explains how monitoring environmental performance can benefit RSL development programmes, the types of monitoring methods that can be employed and the equipment, personnel and cost involved, and how a monitoring programme can be built into the briefing and development process of low-carbon apartment buildings. This type of practical and non-technical guidance for an RSL audience is not currently addressed in existing literature within the UK.

3.2 Building performance: sustainability and uncertainty

The UK and WAG targets for the construction of zero-carbon homes are to be implemented through progressive strengthening of the requirements of Approved Document L1A (ADL1A) of Building Regulations (CLG, 2007b). In addition to establishing design targets for dwelling emissions the requirements

will raise minimum standards for building fabric insulation and air-tightness. Some specific risks to the sustainability of buildings designed to meet these regulatory requirements may be anticipated. For example, there is a tension between design objectives for minimising ventilation heat losses in winter and the need to maintain adequate ventilation rates to remove moisture and pollutants and maintain satisfactory indoor air quality. Both criteria have important implications for building performance; ventilation heat losses increase energy use and may further impact on the affordability of heating the building to an adequate level, whilst there is a strong association between ventilation and occupant comfort and health (Wargocki *et al.*, 2002).

Mechanical ventilation with heat recovery (MVHR) is, in principle, an energy-efficient solution to these conflicting objectives for compact building typologies such as apartments. However, occupant misunderstanding of how to operate the controls of MVHR systems can wholly undermine energy performance (e.g. Macintosh & Steemers, 2005). In addition, the longevity of the housing stock in the UK renders domestic buildings particularly vulnerable to the predicted effects of longer-term changes to climatic conditions (CIBSE, 2005). The overall trends expected in the UK climate during the 21st century are for warmer, wetter winters; hotter, drier summers; rising sea levels; and increasing frequency of extreme weather events (Jenkins *et al.*, 2008). For highly insulated air-tight buildings with MVHR, the impact of these trends will be to reduce the period when heat reclaim is of significant benefit (Gething, 2010). Thus, the example of MVHR highlights some of the uncertainties inherent in predicting the performance of new low-carbon technologies, strengthening the argument for more widespread uptake of POE during the current period of rapid reforms to UK Building Regulations. Furthermore, it illustrates that the assessment of building performance using techniques such as POE should be understood as "reflecting the *changing* nature of the relationship between people, the climate and buildings" (Nicol & Roaf, 2005).

3.3 Defining environmental performance: an ecological perspective

The previous section identified in the example of MVHR the potential problems that can arise when occupants are unfamiliar with the "correct" operation of building technologies (the problem is more accurately stated as being a shortcoming in the design intention not fully responding to user perception). More generally, occupant behaviour and lifestyles are highly significant in terms of their influence on the energy and carbon performance of dwellings[2]. Other environmental impacts, also determined by the occupant's use of the dwelling, are identified in the Code for Sustainable Homes – the national standard for the sustainable design and construction of new homes in the UK – for example, water use and household waste (CLG, 2009). With respect to sustainability objectives, it follows that the assessment of building performance is not only concerned with evaluating the physical aspects of building design and construction, but also implicates and is critical of occupant behaviour and lifestyles within buildings. The objective of such a critique should not be to "blame" occupants, but to identify opportunities for improving occupant understanding of how to use buildings more sustainably, and to recognise the cultural barriers that exist to more sustainable lifestyles (Lutzenhiser, 1992).

[2] This is coupled to physical building performance aspects e.g. fabric energy efficiency. The effect of occupant factors on domestic energy use is reviewed in Taylor *et al.* (2010) in more detail.

Furthermore, occupants have a central role in the assessment of building performance, since the users' physical, functional and psychological experience of the building environment is "a measure of its effectiveness – one might say, quality" (Vischer, 2008). As a corollary to this, any assessment will be contingent on the users consulted at a particular point in time, reflecting the nature of their activities and the disposition of their needs in relation to the building environment. Thus, two distinct relations emerge in the assessment of the environmental performance of buildings: the relationship of the building user to the built environment e.g. occupant health and well-being, the usability of controls; and the relationship of the built environment to the natural environment e.g. the carbon emissions of a dwelling in contradistinction to the regenerative and waste absorptive capacity of the biosphere (cf. Wackernagel, 2009).

In terms of learning from and improving buildings through POE, specifically in relation to reducing carbon emissions, too narrow a focus on monitoring physical performance characteristics, although strategically essential for delivering more energy efficient buildings, risks excluding the highly significant effect of occupancy characteristics on energy use and therefore providing an incomplete picture of the factors that influence actual levels of emissions. Also, there is a danger that giving priority to emissions accounting within domestic POE studies risks divorcing the evaluation of performance from the needs of users and the other significant environmental burdens that arise from the use of dwellings, and also more general debates concerning the status of housing provision within the UK (e.g. space standards. See Carmona *et al.* (2010) and Simmons (2010) for an exploration of some relevant issues).

For the research, the performance of a dwelling is therefore to be defined in relation to two aspects of its interaction with the environment:

1. The degree to which it supports the activities and aspirations of occupants, and other legitimate users of the building (cf. Vischer, 2008); and
2. The environmental impacts arising from the use of the building e.g. carbon emissions, finite resource depletion (Khasreen *et al.*, 2009).

These aspects correspond with the two relations identified above; the first being concerned with the relationship of the building user to the built environment, and the second with the relationship of the built environment to the natural environment. The definition of environmental performance posited here is intended to connect the policy objectives for reducing emissions from buildings to the context of the broader cultural influences that shape energy use in households and the market conditions under which housing is delivered. This theoretical standpoint may be described as an ecological perspective, viewing "energy and technology as key mediators between humans as social organisms and their natural environments" (Lutzenhiser, 1992).

4 DEVELOPING POE TECHNIQUES FOR ASSESSING ENVIRONMENTAL PERFORMANCE

4.1 A user-centred, ecological approach to POE

In summary, the preceding sections of the paper have presented an argument for more widespread uptake of POE in support of UK and WAG targets for all new homes to be zero carbon. A PhD research programme is being undertaken by the lead author of the paper to investigate the application of POE techniques

for assessing the environmental performance of new-build apartment buildings in Wales. Two important questions to be addressed in the research are as follows:

- Does low carbon design translate into low carbon construction and performance in-use?
- How do users rate building performance in low carbon apartment buildings?

A user-centred, ecological approach to POE is advocated, in which building performance is assessed according to two types of environmental relations: the relationship of the building user to the built environment (does the building support the activities and aspirations of building users?) and the relationship of the built environment to the natural environment (what are the environmental impacts arising from the use of the building?). The objective of this assessment is to engage with a wider environmental agenda than emissions accounting; one that recognises user needs and also the broader cultural influences that shape behaviour and lifestyles within domestic buildings. If the design performance of zero carbon dwellings is to be achieved in-use, then progress will need to be made in both improving the physical performance of dwellings and also in promoting environmentally-conscious behaviour from occupants.

This section of the paper introduces the POE techniques being developed as part of the research programme introduced in Section 3.1. The research methods employed in previous POE studies of housing undertaken in the UK and other parts of the world are reviewed and, in the context of the present research, on-going work to survey occupant perception and behaviour in one of the case study buildings is discussed.

4.2 POE methodologies for housing

A review of the development of POE methodologies for different building typologies is presented by Stevenson (2009) and a portfolio of established POE techniques is discussed in Bordass & Leaman (2005). In comparison to other typologies, POE practice and research in housing is less well-established (Stevenson, 2009; Leaman *et al.*, 2010). The Probe studies in the UK (referred to in section 2.2) focussed principally on commercial offices and educational buildings (Bordass & Leaman, 2004). Furthermore, Probe only reported on the performance of 20 buildings. The energy survey method developed for Probe is now published as a CIBSE guide (CIBSE, 2006). However, the occupant survey method is only available under licence from Building Use Studies (Building Use Studies, 2010). In recent POE studies of UK housing, research methods have incorporated detailed studies of physical building performance (e.g. Wingfield *et al.*, 2008), qualitative evaluation of occupant perception and behaviour (e.g. Stevenson, 2004) and a combination of these approaches (e.g. Stevenson, 2008). Other relevant literature includes an Energy Saving Trust (EST) protocol for monitoring the energy and carbon performance of new dwellings (EST, 2008) and a Commission for Architecture and the Built Environment (CABE) survey of residents' attitudes to the design of new housing (CABE, 2005).

In Canada, a building performance evaluation protocol has been developed by EcoSmart (EcoSmart, 2007). The protocol has been piloted on six buildings and is publicly available to the design community, including a version that has been adapted for multi-unit residential buildings. However, no details are provided on the costs involved (which are likely to be significant since the

protocol draws on the expertise of an acoustics consultant, an indoor air quality consultant, a lighting consultant and a controls and commissioning consultant). Also, the protocol calls for the use of a survey to assess occupant satisfaction, but the survey itself is not included in the scope of the protocol (ibid.). A significant body of experience and knowledge of POE also exists in the United States, and is documented in a report of the Federal Facilities Council (Federal Facilities Council, 2001). However, like Probe the focus of this work is directed towards the evaluation of non-domestic buildings. In Korea, a housing performance evaluation model has been developed for multi-family residential buildings (Kim *et al.*, 2005). However, the assessment criteria and weighting of the results have been derived for the specific Korean context.

What is currently absent from housing evaluation in the UK is an overall methodology for assessing energy and carbon performance and user satisfaction and a framework for making feedback routine within the briefing and development process (Leaman *et al.*, 2010). Progress has been made towards developing technical protocols for assessing the energy efficiency aspects of the built fabric (e.g. ATTMA, 2007; Building Research Establishment, 2008; Wingfield *et al.*, 2010). However, more mainstream acceptance and use of techniques to measure energy and carbon performance and user satisfaction is likely to prove problematic for some of the reasons cited in Section 2.2. As long as POE is perceived as costly and complicated, it is likely to remain confined to the margins of academic and technical discourse. In the RSL context, most Housing Associations regularly engage with their tenants through satisfaction surveys (e.g. STATUS – the Standardised Tenant Satisfaction Survey) and their housing stock through maintenance contracts (National Housing Federation, 2010). For POE to become routine practice, the assessment techniques will need to be transparent and accessible and complement the existing practices of RSLs. In addition, a significant issue in housing studies is privacy; such investigations are likely to be perceived as intrusive (particularly where the study involves installation of monitoring instrumentation) and occupant participation in such programmes involves a range of ethical considerations, including data protection. These issues are to be addressed in the research programme through the development of an RSL guide for monitoring environmental performance (see Section 3.1).

4.3 Identifying environmental performance criteria and developing assessment techniques

The overall approach and protocols for assessing the environmental performance of apartment buildings in Wales being developed for the research programme are expected to have three principal uses as:

1. A diagnostic tool to indicate how the environmental performance of study buildings may be improved;
2. A benchmarking tool to enable performance to be compared with examples of best practice; and
3. A learning tool to improve understanding of environmental performance in use and thus help inform future approaches to the design and construction of apartment buildings in the UK.

The assessment, which is being developed according to the principles of environmental management defined in BS EN ISO 14001:2004 (British Standards Institution, 2004), will provide an indication of how well the building is performing across a range of environmental performance criteria, and may be used as a basis for delivering feedback to the client and design and construction teams involved in the development, and also to inform guidance for encouraging occupants to adopt environmentally-conscious behaviour. Although the overall approach is being developed in the context of apartment buildings, it is anticipated that it will be more generally applicable to other dwelling types. An indicative structure of the performance criteria and techniques to be used in the assessment process are illustrated in Figure 2 below.

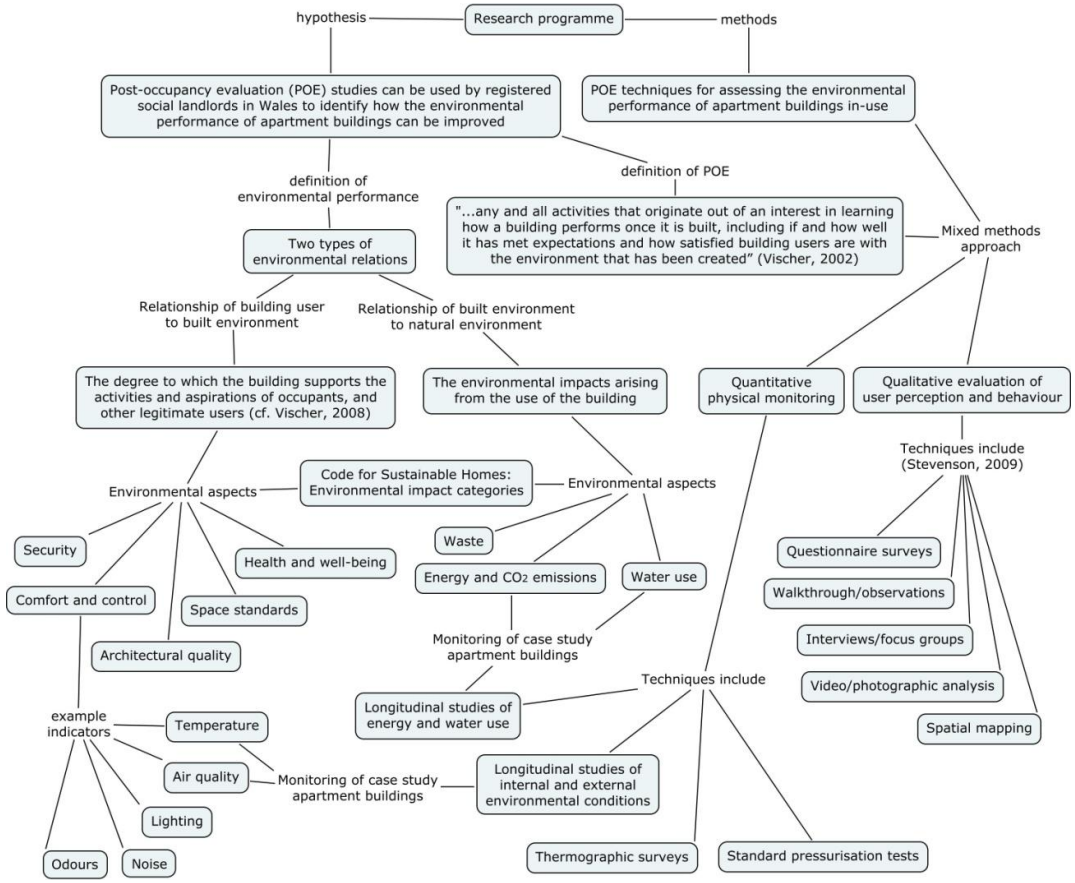

Figure 2. Conceptual diagram illustrating the environmental performance criteria and assessment methods to be used in the research programme

To test and develop the assessment process, a programme of monitoring activities is to be carried out at each of the case study apartment buildings comprising the following methods of data collection and analysis:

- Standard pressurisation tests: to measure the air-tightness of the building.
- Thermographic surveys: using infra-red camera technology to observe heat loss mechanisms.
- Longitudinal studies of internal and external environmental conditions: sensors installed in completed apartment units are to be used to record internal environmental conditions (e.g. temperature, humidity) over a period of at least one year. A weather station is to be installed locally to monitor local climate conditions.

- Longitudinal studies of energy- and water-use and occupant experience: a survey group of residents are to be followed over a period of at least one year to record energy- and water-use trends and document overall occupant attitudes towards the design and living environment of apartment units.

4.4 Development of an occupant survey questionnaire

Questionnaire surveys are a well-established research instrument in POE (Leaman *et al.*, 2010). A questionnaire has been developed and distributed by post to residents at one of the case-study apartment buildings being investigated as part of the research programme. The development consists of two blocks of apartments of timber-frame construction (one three-storey, one five-storey) comprising a total of 80 flats (79 two-bed, three-person flats and a one-bed, two-person flat). An image of the development and typical floor plan is shown in Figure 3 below.

Figure 3. Image and typical floor plan of one of the case study apartment buildings
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The objectives of the occupant survey questionnaire are as follows:

- To measure and characterise aspects of occupant behaviour that have a significant effect on the environmental performance of dwellings in use. This includes recording data and information on occupancy patterns for potential application in dynamic thermal simulation of building performance.
- To explore and describe aspects of the occupant's physical, functional and psychological experience of the environment in the housing apartments and surrounding development.
- To appraise how successfully certain aspects of the design criteria of EcoHomes and the Code for Sustainable Homes (CfSH) have been realised.

Specific themes to be investigated in the occupant surveys are listed in Table 1 below.

Theme	**Issues**
Occupancy patterns	Frequency of presence and activities of occupants in the apartment (do occupants work from home?).
Energy use	• Obtain consent for monitoring levels of gas and electricity use in the apartments. • Ownership and use of electrical appliances. • Room and hot water thermostat settings.
Water use	Obtain consent for monitoring water use in the apartments.

Affordability	Assess occupant attitudes towards the affordability of household bills.
Performance of systems and controls	Performance of heating and hot water systems, and effectiveness and ease of use of controls. Do occupants refer to Home User Guide (provision of such a guide is assessed in EcoHomes and the CfSH)?
Comfort and health and wellbeing	Occupant satisfaction with temperature, air movement, air quality, lighting and noise and perceived level of control over environment. Do occupants report symptoms indicative of building-related health issues? A specific point of interest with new dwellings is the possibility of increased incidence of discomfort relating to inadequate ventilation. A questionnaire template developed for the HOPE project (HOPE, 2005) is being adapted for use in the present research.
Architectural quality	Attractiveness of building and surrounding environment, enjoyment of views from windows and overall level of comfort.
Environmental attitudes and behaviours	Do occupants report being concerned about environmental issues, and does this influence their behaviour?
Ventilation	Investigate how occupants report using windows (ventilation heat loss in winter has a significant impact on heating energy use).
Space standards	Do occupants express satisfaction with space provision and the layout of the apartment? RSL developers are obliged to comply with the Lifetime Homes standard. For example, one point of interest is the space available for recycling bins. This is assessed in EcoHomes and the CfSH, but frequently reported to be inadequate in a recent study (HATC, 2009). The questionnaire used in this study is being adapted for use in the present research.
Security	Do occupants report feeling unsafe in the proximity of the building? Achievement of the Secured by Design award is assessed in EcoHomes and the CfSH.
Management	Investigate any history of complaints about building performance and the speed and effectiveness of management response.

Table 1. Themes and issues to be investigated in the occupant survey questionnaire

The questionnaire design has been presented to the Cardiff School of Art & Design Ethics Committee at the University of Wales Institute Cardiff for guidance and approval. Results will be presented in forthcoming publications to be announced on the EBERE website (EBERE, 2010).

5 CONCLUSIONS

This paper has presented a brief overview of the development of post-occupancy evaluation (POE) as a distinctive discipline in built environment studies and reviewed recent POE practice and research in housing in the UK and other parts of the world. In the context of UK and Welsh Assembly Government policy objectives for all new homes to be zero carbon, POE has an important role in:

- Supporting the development of innovative design and construction methods and technologies;
- Improving the knowledge and expertise of built environment professionals; and
- Informing the development of building design standards and regulatory instruments.

Achievement of these goals is also likely to have important implications for occupant behaviour. Housing evaluation studies therefore need to address both angles of this problem. A user-centred, ecological approach to housing POE is advocated in which building performance is assessed according to the degree

which the building supports the activities and aspirations of occupants and the environmental impacts arising from its use. Such an approach is compatible with both the need to demonstrate the technical efficacy of the building fabric and systems in new dwellings and also to promote environmentally-conscious behaviour.

An overall approach and protocols for assessing the environmental performance of low-carbon apartment buildings is being developed as part of a three-year research project based in Wales. The research team is studying the environmental performance of four case study apartment buildings to determine if, in practice, low-carbon design is translated into low-carbon construction and performance in-use. These apartment buildings are being developed by the industrial partner to the project; Coastal Housing Group Ltd. (an RSL based in Swansea), and will be used to test and develop POE techniques for assessing environmental performance. The project aims to address gaps in existing knowledge and practice, particularly in terms of collecting data on the actual environmental performance of dwellings, specifically apartment buildings, designed to meet EcoHomes 'Good' and Level four of the Code for Sustainable Homes, and in providing practical and non-technical guidance for RSLs that explains how monitoring studies can benefit RSL development programmes.

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