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Evaluating Retrofitted External Wall Insulation

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Appendix I: SB11 Conference Paper

Developing a methodology for monitoring and evaluating improvements to existing dwellings in deprived areas of Wales

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Summary

This paper sets the scene for a three year research project, which is investigating and evaluating the improvements being undertaken to existing deprived dwellings as part of a Welsh Assembly Government funded scheme in Swansea, Wales (UK). It seeks to determine how effective the improvements are at making energy and carbon emission reductions, whilst improving occupant comfort, health and wellbeing in the deprived dwelling. The research methodology includes thermography and occupant interview surveys. The expected outcomes of the research include guidance for owners of existing deprived dwellings by taking an ecological approach to improvements and also methods to monitor and evaluate reductions in energy use and carbon emissions and obtain occupant feedback.

Keywords: existing dwellings, energy use, carbon emissions, fuel poverty, occupant attitudes and behaviour, Wales

1. Introduction

This paper is focused upon a research project, entitled ‘A study to investigate and test traditional and ecological strategies to mitigate and adapt existing deprived dwellings for climate change in the UK’. The aim of the research is to investigate and develop an ecological approach for technical and social improvements to deprived dwellings in Wales. Through a review of existing literature, the paper examines the rationale, drivers and incentives for improving and adapting existing deprived dwellings. It then introduces and discusses the research project in terms of the research methodology and the current and expected outcomes.

2. Improving and adapting existing dwellings

The rationale for improving and adapting existing deprived dwellings is driven by requirements to reduce energy use, carbon emissions and fuel poverty and enhance occupant quality of life. Domestic energy use accounts for 27% of UK carbon emissions, which is the main greenhouse gas contributing to climate change. With predictions for global energy use to increase and the inevitable peak in oil and natural gas, there is likely to be impacts on energy security and costs. As a result, levels of fuel poverty are likely to increase. In the UK, domestic energy use accounts for nearly 30% of all energy consumed, with older and detached dwellings consuming more energy due to their poor environmental performance. For existing dwellings, the environmental performance is calculated using a reduced data version of the Standard Assessment Procedure (rdSAP). The results are given as a rating between A to G, with A representing the most efficient dwellings. In the UK, 11% of existing dwellings have the lowest ratings of either F or G, representing a significant risk to the health of occupants. Coupled with the requirement to improve the physical performance of existing dwellings is the issue of occupant attitude and behaviour. The differences in occupant behaviour can vary energy consumption by up to 300%. Research shows that providing occupants with direct feedback on energy use can have the most positive influence for changing behaviour to reduce consumption.

The main drivers and incentives for improving and adapting existing dwellings in the UK are in the form of: Building Regulations; Energy Performance Certificates (EPCs); energy supplier obligations; VAT (Value Added Tax) reductions; and a Feed-in-Tariff, paid for small scale electricity generation. Collectively these drivers and incentives have the potential for making some contributions to increasing the environmental performance of existing dwellings. However, without any monitoring and evaluation of the results, the outcomes of these are effectively just estimates. Related to this is the need for research on how effective the improvements are in relation to the techniques used and how occupant behaviour affects the results in terms of the expected savings made. In response, the Welsh Assembly Government have implemented the Strategic Energy Performance Funding Programme (Arbed), which has the aim of delivering mass adaptation to existing dwellings in deprived areas of Wales and includes conducting monitoring and evaluation of the results. However, there is no methodology or funding for this assessment, particularly for deprived dwellings.

3. Adaptation of existing dwellings in deprived areas of Wales

The first author of this paper is undertaking a three year research project within the Ecological Built Environment Research and Enterprise (EBERE) group at the University of Wales Institute Cardiff. Commencing in August 2010, the research involves monitoring and evaluating a sample of mixed tenure existing deprived dwellings, which are receiving improvement measures in Swansea, UK, through the Arbed scheme. The types of measures being undertaken include installation of external wall insulation, replacement space and water heating systems, real-time energy displays and micro-renewable technologies, such as solar hot water and photovoltaic panels.

The research methodology involves conducting a monitoring programme established in collaboration with fellow researchers within the EBERE group. The methods of data collection and analysis comprises: occupant interview surveys; thermography surveys; studies of internal and external environmental conditions; and recording of technical solutions for improvement methods undertaken. The surveys will be conducted before and after installation of improvement measures to allow comparisons to be made.

4. Discussion

The major findings of the research thus far has identified that adapting the worst performing deprived dwellings in terms of energy use and carbon emissions is a priority. This is evidenced by the strategies which have been implemented at both a European and UK national level. However, it can be argued that if overall targets are to be met then the scale of adaptation needs to extend far beyond what current measures address.

The study thus far has reviewed predominately UK published literature as a means of assessing the requirements, drivers and incentives for mass adaptation of existing dwellings. In addition, the literature review has provided grounds for monitoring and evaluation to determine if the improvements have the desired results and how these are affected by occupant behaviour patterns. To date (July 2011) the research has included the commencement of data collection in the form occupant interviews and thermography surveys, prior to installation of improvement measures. The next stage of the research is to record the technical solutions undertaken and conduct follow up surveys to obtain results for analysis. Following analysis of the results, guidance for future adaptation projects can be produced, based on the findings. This can be disseminated in the form of technical solutions and a monitoring strategy which can be implemented by Housing Associations across Wales and the UK.

Developing a methodology for monitoring and evaluating improvements to existing dwellings in deprived areas of Wales

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This paper sets the scene for a three year research project, which is investigating and evaluating the improvements being undertaken to existing deprived dwellings as part of a Welsh Assembly Government funded scheme in Swansea, Wales (UK). It seeks to determine how effective the improvements are at making energy and carbon emission reductions, whilst improving occupant comfort, health and wellbeing in the deprived dwelling. The research methodology includes thermography and occupant interview surveys. The expected outcomes of the research include guidance for owners of existing deprived dwellings by taking an ecological approach to improvements and also methods to monitor and evaluate reductions in energy use and carbon emissions and obtain occupant feedback.

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1. Introduction

This paper is focused upon a research project entitled ‘A study to investigate and test traditional and ecological strategies to mitigate and adapt existing deprived dwellings for climate change in the UK’. The aim of the research is to investigate and develop a best practice approach for technical and social improvements to deprived dwellings in Wales, taking an ecological focus to reduce energy use, carbon emissions and fuel poverty and increase occupant quality of life. The paper commences by discussing the rationale for improving some of the most deprived dwellings in the UK. It goes on to explore the environmental performance of existing dwellings and occupant behaviour in relation to energy use. This is followed by an examination of UK drivers and incentives for the adaptation of existing dwellings. In 2009 the Welsh Assembly Government (WAG) introduced and funded the “Arbed” scheme, which is a Strategic Energy Performance Funding Programme. The scheme aims to improve the worst 15% of deprived dwellings in Wales, UK across both public and private ownership and forms the basis of the research project. The next section explains the research methodology for undertaking a monitoring programme, which include thermography and occupant interview surveys to investigate fabric heat loss and energy use before and after improvement measures. The paper concludes by discussing some of the current and expected outcomes of the research project, which after only eleven months (July 2011) have started to occur and include an in-construction quality check for retrofitted external wall insulation.

2. Background and context

2.1 Rationale for improving existing dwellings

The requirement to improve existing dwellings is driven by three overarching objectives: mitigating and adapting to climate change, maintaining energy security and eradicating fuel poverty. Each objective poses specific challenges, yet there are possible synergies to be obtained from a unified approach to improvements.

2.1.1 Climate change

The climate change projections for the UK include hotter and drier summers, wetter winters and more extreme weather events. There is thus an urgent need to adapt existing dwellings for both the future climate and to reduce carbon emissions resulting from energy use [1, 2]. It has long been known that carbon dioxide (CO_2) is classified as the 'greenhouse gas' which has the largest volume and therefore contributes significantly to climate change [3]. In response to this, the UK government has set out legally binding targets within the Climate Change Act 2008 for a reduction in carbon emissions of 26% by 2020 and 80% by 2050 [4]. UK carbon emissions resulting from energy use in buildings account for approximately 45% of total emissions, with domestic buildings accounting for 27% [3]. Despite a UK reduction in total energy use between 2008 and 2009, claimed to be a result of the economic recession, the International Energy Agency (IEA) forecast a global increase of primary energy demand to the year 2035. This will inevitably continue the increase in carbon emissions and pose risks in terms of energy security [5, 6].

2.1.2 Energy security

The main source of primary energy is fossil fuels, which are a finite resource that will eventually peak. The IEA present two scenarios in the World Energy Outlook 2010, the first is the 'New Policies Scenario', where existing policy commitments to reduce greenhouse gas emissions are taken into account. The other is the '450 Scenario', where energy use is reduced to coincide with the capping of greenhouse gas emissions at 450 parts per million of CO_2 equivalent (ppm CO_2 -eq), which is the recommended goal for keeping global temperature increases to 2°C. In the New Policies Scenario global production will peak by approximately 2035 following a continuous increase in demand, cost and supply disruptions. Conversely, in the 450 Scenario global production will peak in 2020. This will be due to weaker demand rather than diminishing reserves, resulting in lower costs and less risks. However, with increasing demand from developing countries such as India and China this best case scenario is unlikely to happen [6]. In the UK, oil and natural gas has already peaked [5]. Since 2004 the UK has been a net importer of these primary fuels, resulting in increasing reliance on less stable countries for supplies, which could have an impact on both energy security and costs [5, 7].

2.1.3 Fuel poverty

Increasing energy use and costs, along with inadequate efficiency performance of dwelling and low household income are all contributory factors to rising levels of fuel poverty [8]. The definition of fuel poverty is where more than 10% of household income is spent on energy use in the home. Where energy costs increase to more than 20%, then the household are classified as being in severe fuel poverty [9]. Between 2005 and 2006, the number of fuel poor households increased by one million across the UK, to approximately 3.5 million out of approximately 26 million homes [10, 11]. In 2008, the number of fuel poor households in Wales was estimated to be 332,000, which is just over 25% of all households in Wales and just under double that of the UK average, demonstrating the magnitude and additional urgency of the situation in Wales [12].

The UK Government has set a target for eradicating fuel poverty in England by 2016, whilst the WAG has set a target of 2018 for Wales. As with carbon emission reduction targets, meeting these targets to eradicate fuel poverty will require a reduction in domestic energy use [9]. Domestic energy use accounts for 30% of all energy consumed in the UK, with over 75% of this energy used for space and water heating [5, 13]. Space heating requirements are linked to the amount of heat loss through the building fabric. Higher levels of heat loss and inadequate environmental performance result in greater energy use, costs and likelihood of occupants being in fuel poverty [14]. In particular, older and detached dwellings have a higher number of households who are fuel poor due to their pronounced inefficient environmental performance [12, 14].

2.2 Environmental performance of existing dwellings

In the UK, the environmental performance of dwellings is audited by calculating energy use and costs for space and water heating, ventilation and lighting, minus savings made from technologies which generate energy. Auditing energy use in buildings is a European requirement stipulated in the Energy Performance in Buildings Directive (201/31/EU) (EPBD). The EPBD requires member states to set out a methodology for calculating energy use and to produce Energy Performance Certificates (EPCs) for buildings [15]. In the UK, the methodology used for calculating the energy performance of new dwellings is the Standard Assessment Procedure (SAP), which provides a rating ranging from one to 100 [16]. The best performance is where a rating of 100 is achieved, representing the highest levels of heating system and building fabric efficiency. In addition, the calculation includes other factors such as type of construction, the building shape, size and orientation and window size and distribution [11]. SAP calculations are used for assessing compliance with Schedule 1, Part L of the Building Regulations and for producing EPCs [17,18].

For existing dwellings EPCs are produced using a reduced data version of SAP (rdSAP). EPCs are required for all dwellings at the point of sale or let to provide potential occupants with an energy efficiency rating to indicate energy use and costs and a list of improvements which could be made to reduce these [11]. The energy efficiency rating has a scale from A to G, with A being the most efficient and G being the least, similar to that used for appliances to allow for ease of understanding [19]. However, the accuracy of the information they contain is questionable. Unlike SAP, rdSAP does not take into consideration details such as building orientation and thickness of insulation in inaccessible areas. The surveyor, who collects the data, is not allowed to disturb or damage the building fabric and therefore cannot accurately measure items such as cavity wall insulation. In this situation, the option of ‘no access’ is selected when inputting the data into the software and as a result, the minimum standard for the age of construction is then assumed [20]. In terms of energy use in a building, the orientation can make a significant difference. This is demonstrated with the principles behind Passive Solar Design, which are a tried and tested method of designing low-energy buildings by utilising solar energy as the main form of heating [21].

The majority of UK dwellings have a SAP rating between 41 and 70 [14], which correlate to E and D ratings on an EPC [19]. However, there are around 3,000,000 existing dwellings which have a rating of F or G, representing the poorest performance in the UK [22]. Many of these are pre-1920 solid wall dwellings, along with other classified hard-to-treat dwellings, which includes those: not on the mains gas network; without a loft space; part of a high-rise block; or where standard efficiency measures cannot be implemented for technical reasons [14]. These dwellings, having a SAP rating of 30 or below, qualify as a Category 1 Hazard for Excess Cold under the Housing, Health and Safety Rating System (HHSRS) [22]. The purpose of the HHSRS is to ensure the health and safety of occupants and visitors of a dwelling by providing a hazard severity rating for identified risks [23]. In Wales, 11% of dwellings qualify as a Category 1 Hazard for Excess cold (and just fewer than two per cent for Damp and mould growth) [24]. Category 1 Hazards are the most severe with increased risks to the health of occupants and chances of being in fuel poverty [22]. There is a great urgency for addressing these hazards and to improve the environmental and physical performance of existing dwellings. However, there is the additional issue of how dwellings are used by occupants, as this also influences energy use and resulting carbon emissions [25].

2.3 Occupant behaviour

EPCs and more technical solutions alone are not enough to make the necessary reductions in energy use and resulting carbon emissions from dwellings. Changes in occupant lifestyles and behaviour have an important role to play in reaching the required targets to mitigate climate change, maintain energy security and reduce fuel poverty. Energy consumption can vary by up 300% as a result of differences in occupant behaviour [26]. In turn this means that changing occupant behaviour can have immediate and positive results for reducing energy use and subsequent costs [27]. However, knowing what these changes should be is not always obvious. As a means of addressing this issue, the UK Government created the Energy Saving Trust and Energy Advice Centres to provide free advice to households on how to increase energy efficiency through practical measures, which include occupant behaviour changes [28].

Energy efficiency advice is provided on the basis of theoretical assumptions made about how homes are used by individuals; these are primarily based on a deficit of information which could have a positive influence on energy use. Other assumptions include social and cultural influences; however these are complex issues which cannot easily be taken into account. The focus for overcoming the deficit of information is raising awareness through education and providing feedback on energy use, either directly or indirectly. Direct feedback, for example in the form of real-time monitors, has the greatest influence, evidenced with savings of between five and 15%. This is compared to indirect feedback, for example in the form of a periodic bill, which only provides savings up to a maximum of 10% [26]. Where households are planning refurbishment works, a real-time energy monitor installed beforehand would provide instant feedback on the effects the improvements have made, hopefully further incentivising efficient use of energy within the dwelling.

3. Drivers and incentives for adaptation of existing dwellings

To ensure the carbon emission reduction targets are achieved, the existing housing stock will have to make its contribution with equal reductions, which is a formidable challenge. *“Setting targets is the easy part; how to roll out an effective upgrading programme to this standard across the nation will require government intervention at a level normally confined to war time”* [29]. In the UK, the main legislative driver for improving existing dwellings is the Building Regulations. Existing dwellings are covered by Schedule 1, Part L1(b) of the Building Regulations (Conservation of fuel and power in existing dwellings). These make requirements for improvements to be made where there is work carried out that will affect the efficiency of either energy related services or thermal elements (floors, walls, roofs, etc.). Guidance for complying with these Building Regulations is covered by Approved Document L1B (ADL1B). Within ADL1B minimum standards of heat loss (measured as U-Values) from thermal elements are recommended where there is work carried out that involves more than 50% of the external element or more than 25% of the entire external envelope [18]. Compliance with the Building Regulations is a legal requirement. Local Authority Building Control Officer’s duties are to ensure compliance with Building Regulations. However, enforcement and even prosecutions for non-compliance are few and far between; this is mainly due to Part L not being considered a priority by Building Control Officers [30].

Whilst the provision of EPCs is mandatory as a driver for behaviour change, following the recommendations for the improvements is not. It has been argued by Brenda Boardman of the Environmental Change Institute at Oxford Brookes University (UK) that EPCs could have a further role to play in implementing strategies to improve existing dwellings [22]. Boardman sets out a strategy which could utilise EPCs to drive up standards and improve the efficiency of the housing stock. Firstly, the accuracy of EPCs should be increased. Secondly, occupants need to be educated about the meaning of the ratings on an EPC, i.e. that F and G ratings mean that much higher costs are being incurred for energy. Thirdly, the ratings should be on full display in estate agents and there should be an internet database providing details about each property’s rating. Fourthly, there should be an online calculator to allow occupants to obtain provisional ratings without having to pay out for a full survey. Finally and foremost, from 2010 no dwelling, starting at a G rating, can be sold twice. It has to be improved by at least two bands (an E rating) before it can be sold again. The rating for dwellings to be sold then moves up to an F rating from 2013 and an E rating from 2016. The costs of the works should be clearly set out on the EPC at the point of sale and the price should be reduced to reflect this, allowing a margin for increased value for the new owner. The results would go a long way towards meeting the targets of reducing emissions by 80% from the existing housing stock by 2050 [ibid].

Other drivers for improving existing dwellings have been implemented by the UK Government through energy supplier obligations under the Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP). CERT requires energy suppliers to invest in energy efficiency measures across the housing sector to achieve overall reductions of 185 $MtCO_2$ (Million tonnes of Carbon Dioxide) [31]. At least 40% of funding has to be directed at low income and elderly households, classified as priority groups. The types of measures include loft, cavity and solid wall insulation, low-energy lighting and appliances, heating system upgrades and micro-generation technologies, such as solar thermal and photovoltaic panels [32]. CESP requires energy suppliers to provide similar measures to households; however, it is only designed for certain areas of low income, which are determined using the Income Domain of the Indices of Multiple Deprivation. The programme supports a ‘whole-house’ approach to encourage multiple measures to be implemented in a single dwelling [33]. Although each of these schemes have the potential to make a substantial contribution to reducing energy use from existing dwellings, the choice of measures to be implemented are decided by the energy suppliers, unless other organisations are involved, such as Housing Associations. The results have been primarily the provision of the easiest and cheapest options, such as loft and cavity wall insulation and low-energy light bulbs [34].

There are limited financial incentives to encourage home-owners and private landlords to improve existing dwellings. The main method is a reduced rate of Value Added Tax at five per cent on certain professionally installed materials aimed at saving energy. These include insulation and draught-proofing, hot water and space heating systems and controls and micro-generation technologies [35]. A further incentive for installing micro-generation technologies, which generate electricity, is the Feed-in-Tariff. Implemented through powers made under the Energy Act 2008, energy suppliers have to pay a fixed tariff for small scale (under 5 kilowatt) generation of electricity. There are two elements to the tariff; a generation tariff, paid for each unit generated, regardless of whether it is used or not, and an export tariff, paid for each unit exported to the National Grid. To further encourage installations in existing buildings, the generation tariff for these is slightly higher than for new build installations [36].

Collectively these drivers and incentives have the potential for going some way to making a contribution to reducing energy use, carbon emissions and fuel poverty in the context of existing dwellings. However, without any monitoring and evaluation of the results, the outcomes of these are effectively just estimates. Related to this is the need for research on how effective the improvement measures are in relation to the techniques used and how occupant behaviour affects the results in terms of the expected savings made [37]. Moving in this direction, the WAG, with support from European Structural Funds, have implemented the Arbed scheme, which has the aim of delivering mass adaptation to existing dwellings in deprived areas of Wales. The scheme is to be run over two phases, with the first to be completed by 31st March 2011. Arbed is primarily being delivered by Housing Associations and has the following characteristics [9]:

- Driving economies of scale and economic benefits through focusing improvements on whole streets or communities;
- Focusing on communities with high levels of fuel poverty;
- Taking a whole-house approach to the assessment for improvements required;
- Using local suppliers and installers wherever possible; and
- Maximising utilisation of other funding opportunities, such as CESP.

Part of the Arbed scheme is to monitor and evaluate how effective the scheme and measures have been in terms of reducing levels of energy use, carbon emissions and fuel poverty [9]. However, there is no methodology or funding within the first phase of Arbed for this assessment.

4. Adaptation of existing dwellings in deprived areas of Wales

This section of the paper introduces the aim, objectives and research methodology of the three year research project being undertaken by the first author of this paper, within the Ecological Built Environment Research and Enterprise (EBERE) group at the University of Wales Institute Cardiff. Commencing in August 2010, the project is investigating and developing an approach for technical and social improvements to deprived dwellings in Wales, taking an ecological focus to reduce energy use, carbon emissions and fuel poverty and increase occupant quality of life. The research involves monitoring and evaluating a mixed tenure of existing dwellings, which are receiving improvement measures in Swansea, UK, through the Arbed scheme. The monitoring is being undertaken at critical stages to allow for an accurate evaluation of the improvements and dissemination of the results, which can be referenced for future adaptation programmes. The improvements are being managed by Coastal Housing Group, the industrial partner to the research project, and Family Housing Association, both Housing Associations are based in Swansea. The types of measures being undertaken, as part of the Arbed scheme, include installation of external wall insulation, replacement heating systems, real-time energy displays and micro-technologies, such as solar hot water and photovoltaic panels.

4.1 Research methodology

In order to establish how effective the measures are at improving the environmental performance of the deprived dwellings and occupant comfort levels, a monitoring programme is to be undertaken. In addition, the technical solutions being implemented are to be recorded to illustrate and evaluate the methods undertaken. The purpose of the monitoring and evaluation is to determine how effective the adaptation measures are, in terms of: thermal performance; occupant comfort; sustainability (from an ecological perspective); buildability and maintainability; and lifecycle costs. As part of the process the most appropriate methods for assessing the effectiveness of the improvements is being explored.

The literature review for this research project has identified gaps in existing literature in terms of: knowledge about occupant perceptions, behaviour and lifestyles in relation to domestic energy use; decisive strategies for mass adaptation and improvements for existing dwellings in the UK; methods of monitoring and evaluating how effective improvement measures are at reducing energy use, carbon emissions and fuel poverty in existing dwellings; and results of monitoring and evaluating improvement measures to existing dwellings, particularly in deprived areas of Wales. To address some of the gaps identified, a methodology is being developed; partly in collaboration with John Littlewood and Tim Taylor [38, 39, 40, 41], fellow researchers within the EBERE group. Littlewood and Taylor [38 to 41] are working on research projects investigating and testing monitoring strategies for low carbon dwellings, also in collaboration with Coastal Housing Group. In developing a strategy for undertaking the monitoring programme for this research project, the research questions, described in Table 1 below, are to be addressed.

The monitoring programme includes the following methods of data collection and analysis from across a sample group of dwellings receiving improvement measures through the Arbed scheme:

- Occupant interview surveys using questionnaires developed to establish:
    - Occupant profiles;
    - Energy use;
    - Types of appliances, lighting and space and water heating systems and controls and ease of use by occupants; and
    - Perceived occupant comfort levels.
- Thermography surveys: using infra-red camera technology to observe heat loss/gains through the fabric.
- Studies of internal and external environmental conditions: using sensors installed in dwellings to record internal environmental conditions (for example temperature and humidity) over a period of at least one year and data on climatic conditions for Swansea will be obtained from a local weather station, installed as part the projects discussed in [38 to 40].
- Recording of methods undertaken to evaluate technical solutions, lifecycle costs, ease and duration of installations and ecological ratings of materials.

The methods of data collection and analysis will be conducted for each phase of the Arbed scheme. Occupant interview surveys and thermography surveys are being undertaken before and after installation of improvement measures for each phase. In the first phase of the Arbed scheme, typical approaches to the fabric upgrades, which use materials with high embodied energy, are being utilised. It is anticipated that the first author will be able to advise on more ecological materials to be used in the second phase to allow a comparison to be made between the two approaches.

Table 1: Project work plan

Work Packages	Description	Research Questions
WP 1	Identify methods of refurbishment and monitoring through extensive literature review	• What are the typical approaches to adaptation of existing dwellings according to location, dwelling and construction type, orientation and occupancy? • What are the methods of monitoring and evaluating the effectiveness of adaptations to existing dwellings?
WP 2	Phase 1 – recording and monitoring	• How effective are the improvement measures being undertaken as part of Arbed phase 1?

WP 3	Phase 1 – Analysis	• What methods were used to improve the existing dwellings as part of Arbed phase 1? • What alternative methods could be used, which take an ecological approach, to improve the existing dwellings as part of Arbed phase 2?
WP 4	Phase 2 – recording and monitoring	• How effective are the improvement measures being undertaken as part of Arbed phase 2?
WP 5	Phase 2 – Analysis	• What methods were used to improve the existing dwellings as part of Arbed phase 2?
WP 6	Overall findings	• How do the two approaches compare, in terms of overall effectiveness?

The expected outcomes of the research include guidance for Housing Association staff to deliver ecological adaptation and the process for evaluating, planning and implementing a monitoring strategy to record environmental performance and occupant attitude and behaviour data for existing deprived dwellings. To accompany this, there will be empirical information illustrating technical details utilising ecological materials for building fabric upgrades, and data illustrating environmental performance and occupant behaviour data for adapted deprived dwellings as part of an ecological and 'whole-street', 'whole-community' approach.

5. Discussion

The major findings of the research thus far has identified that adapting the worst performing existing dwellings in terms of energy use and carbon emissions is a priority. This is evidenced by the strategies which have been implemented at both a European and UK national level. However, it can be argued that if overall targets are to be met then the scale of adaptation needs to extend far beyond what current measures address.

It can be argued that unless adapted existing deprived dwellings are monitored, methods evaluated and results published, the lessons learnt cannot be implemented in further projects and any mistakes may be repeated. Such knowledge is necessary for achieving the overall aims of reducing energy use, carbon emissions and fuel poverty and meet imperative targets to mitigate climate change and maintain energy security. Further still, knowledge is required to avoid adverse implications for the health and wellbeing of occupants from instances of induced deterioration of physical performance within dwellings, as a result of inappropriate methods of adaptation. Coupled with this is the need for greater knowledge about occupant attitudes and behaviour in terms of energy use in existing deprived dwellings and perceptions on comfort and control of internal environments.

The study thus far has reviewed existing literature as a means of assessing the requirements, drivers and incentives for mass adaptation of existing dwellings. In addition, it has provided grounds for monitoring and evaluation to determine if the improvements have the desired results and how these are affected by occupant behaviour patterns. To date (April 2011) the research has included the commencement of data collection in the form occupant interviews and thermography surveys prior to installation of improvement measures as part of the first phase of the Arbed scheme. The next stage of the research is to record the technical solutions undertaken, make recommendations for an ecological approach to the second phase of Arbed and conduct follow up surveys to obtain results for analysis. The survey process will then be repeated for the second phase of Arbed. Following analysis of the results, guidance for future adaptation projects can be produced, based on the findings. This can be disseminated in the form of technical solutions and a monitoring strategy which can be implemented by Housing Associations across Wales and the UK.

6. Conclusions

This paper has set out the background and context to a three-year research project entitled ‘A study to investigate and test traditional and ecological strategies to mitigate and adapt existing deprived dwellings for climate change in the UK’. The context includes the rationale for improving the thermal performance of some of the most deprived existing dwellings in Wales (UK), which correlates with the requirement to meet legally binding targets for reducing carbon emissions, overcome challenges to ensure energy security and eradicate fuel poverty. In relation to these are the inadequate environmental performance of existing dwellings and the impact of occupant behaviour patterns in respect of energy use in households. The research project literature review discusses the limited UK drivers and incentives for the adaptation of existing dwellings, which revealed a requirement for the monitoring and evaluation of the improvements to determine their effectiveness.

The paper has also introduced the reader to the Welsh Assembly Government funded Arbed phase one scheme, which has set out to improve the thermal performance of some of the worst 15% deprived private and publically owned dwellings in Wales by the end of March 2011; managed through Housing Associations. The authors have identified a key weakness in the Arbed phase one scheme and that is the lack of funding for a detailed monitoring protocol, to assess the effectiveness of each Arbed funded project in Wales. The paper has set out the aim and objectives for the research project, which includes the development of a monitoring protocol to assess any reductions in energy use and carbon emissions and changes in occupant attitudes and behaviour following the improvement measures. The improvements are being managed by Coastal Housing Group and Family Housing Association. The outcomes of the research are expected to address gaps in existing knowledge through dissemination of practical guidance for Housing Associations on ecological solutions to adapt dwellings for increased environmental performance and occupant satisfaction.

7. Acknowledgments

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Appendix II: International Post-Graduate Research Conference Paper

Improving existing deprived dwellings in Wales: Monitoring and evaluating thermal performance

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Abstract:
Improving the thermal performance of deprived existing dwellings is a prerequisite to achieving aspirations of reducing energy use, carbon emissions, fuel poverty and increasing occupant quality of life. This paper sets the scene for a 38 month research project, which is investigating and evaluating the improvements being undertaken to some of the deprived existing dwellings, as part of the Welsh Government's Arbed scheme in Swansea, UK. The project aims to determine how effective the improvement measures are at increasing thermal performance. The research methodology includes: classifying dwelling types and construction specification from a number of case study dwellings; occupant interviews and thermography surveys; studies of internal and external environmental conditions; and recording of technical solutions implemented. The findings thus far reveal that to reduce fuel poverty in Wales' existing deprived dwellings requires improvement to the physical performance and changing occupant behaviour. The case study dwellings are characterised by their low energy ratings and the risks they pose to the health of occupants. These dwellings have solid exterior walls and require appropriate technical solutions for upgrade. Determining how effective the improvement measures are at increasing the thermal performance, requires a process of monitoring and evaluation prior, during and post retrofit of improvement works. One of the expected outputs from the research is the production of benchmarks for energy use in dwellings, based on occupancy. This paper will be of interest to people involved in improving the thermal performance of existing deprived dwellings in the UK.

Keywords:
Deprived existing dwellings, Occupant behaviour, Post-Occupancy Evaluation, Thermal performance, Wales.

Introduction

The rationale for improving and adapting existing deprived dwellings is driven by requirements to reduce energy use, carbon emissions, fuel poverty and enhance occupant quality of life. Domestic energy use accounts for 27% of UK carbon emissions, with consumption at its highest in dwellings with the lowest energy efficiency ratings (Defra, 2007). Over 40% of pre-1919 dwellings in the UK have a standard assessment procedure rating of 40 or below (Department of Energy and Climate Change, 2010; Department for Communities and Local Government, 2006). Existing dwellings with the worst thermal performance represent a significant risk to the health of occupants and increased chances of being in fuel poverty (Boardman, 2007). Many of the dwellings have solid exterior walls (EWs) and this necessitates careful consideration when planning improvements (English Heritage, 2010). Coupled with the requirement to improve the physical performance of existing dwellings is the issue of occupant attitude and behaviour towards energy use. The differences in occupant behaviour can have a significant influence on energy consumption (Janda, 2009).

In recognition of the requirement to make mass improvements and adaptation to existing dwellings in Wales, the Welsh Government implemented the “Arbed” scheme. Arbed is the welsh word for ‘save’. This is a Strategic Energy Performance Funding Programme aimed at improving the worst 15% of deprived dwellings across both public and private ownership. The dwellings are categorised by their residence within lower super output areas, which is the method used in Wales to rank deprivation (Welsh Assembly Government, 2008). Arbed is being implemented by Housing Associations (HAs) to provide localised economic, social and environmental benefits. One requirement of the Arbed scheme is to monitor and evaluate how effective the scheme is, in terms of reducing energy use, carbon emissions and fuel poverty (WAG, 2010). However, there is no methodology and limited funding to monitor several thousand dwellings, part of Arbed stage one; thus, the research project was instigated.

The research is being undertaken within the Ecological Built Environment Research and Enterprise (EBERE) group at the University of Wales Institute, Cardiff (UWIC). The project is being undertaken with and is co-funded by Coastal Housing Group (CHG), a HA based in Swansea. The research project is entitled ‘A study to investigate and test traditional and ecological strategies to mitigate and adapt existing deprived dwellings for climate change in the UK’. Commencing in August 2010, the aim is to investigate, develop and test a best practice ecological retrofit methodology for technical and social improvements to existing deprived dwellings in Wales, to reduce energy use, carbon emissions, fuel poverty and thereby increase quality of life. The research involves monitoring and evaluating a sample of dwellings, receiving retrofitted improvements from Arbed funding allocated to CHG and Family HA (a second HA based in Swansea).

The research methodology includes both social and physical methods, which involves undertaking a monitoring programme to establish how effective the measures are at improving the thermal performance of the existing deprived dwellings and occupant comfort levels. The methods of data collection and analysis include occupant interviews, thermography surveys, studies of internal and external environmental conditions, and recording of retrofitted methods. Except for the latter, all methods of data collection and analysis require participation and co-operation of occupants living in the dwellings. As part of the ethics approval granted by UWIC, the first author collecting data is to be accompanied for safety reasons. This has the potential to pose a limitation on the data collection, as it can sometimes be difficult to arrange diaries between the dwelling occupant, the first author and the accompanying staff member.

The findings presented include a requirement to reduce fuel poverty in Wales through improving the thermal performance of existing deprived dwellings and changing occupant behaviour. The worst performing dwellings present a challenge in terms of appropriate methods for upgrading solid EWs. In order to determine how effective the retrofitted improvements are, they are to be monitored and evaluated. The monitoring being undertaken, as part of the research project, offers an opportunity to establish a benchmark for energy use, based on occupancy, which does not currently exist for dwellings in Wales (Leaman *et al.,* 2010). The outcomes of the research are expected to be of benefit to HAs through the provision of practical guidance on ecological solutions to improve and adapt dwellings and for undertaking suitable monitoring and evaluation.

In summary, the main focus of this paper is the introduction of the first stage of a 38 month research project at UWIC; which is attempting to establish a benchmark for energy use according to dwelling typology and the number of occupants in existing deprived dwellings in Swansea. The paper discusses a literature review documenting methodologies for the research project.

Monitoring and evaluating the thermal performance of improvements to deprived existing dwellings

Introduction to Post-Occupancy Evaluation

The most common term for assessing and evaluating the thermal performance of buildings is Post-occupancy Evaluation (POE) (Zimring, 2010; Leaman *et al.,* 2010). Originating in the 1960s and 1970s, POE has evolved from individual case studies to evaluate the environmental performance of public and student dwellings, to a widespread use for public and commercial buildings by the mid 1980s (Zimring, 2010; Stevenson and Leaman, 2010). The main purpose of POE is to obtain knowledge on: how a particular building is performing; how to make further improvements on future buildings; and occupant comfort levels and behaviour (Leaman *et al.,* 2010; Preiser, 2002). As with product research, POE offers designers the opportunity to obtain feedback about changes in requirements, which can then be implemented in the development of future buildings and components (Preiser, 2002).

Early POE studies utilised questionnaires, interviews, site visits and field observations to gather information about buildings and their occupants (Zimring, 2010). Methods of data collection have evolved into established techniques which, in addition to those used initially; include recording of technical solutions and performance of the building fabric, services and systems, and assessing environmental performance. The most challenging aspect of POE is obtaining cooperation of occupants in order to gain access. As a result, the choice of methods undertaken should be limited, as far as possible, in terms of intrusiveness, duration and costs (Leaman *et al.,* 2010). In terms of obtaining occupant perceptions, questionnaires and interviews should investigate comfort, health and control of the internal environment, in relation to heating, cooling, lighting, noise and safety. Publishing results is an important aspect of POE; if results are not shared then it is more difficult for others to learn from the experience, which is one of the main objectives of POE (Leaman *et al.,* 2010). To keep within the boundaries of the data protection Act (1998), all data must be anonymously documented and published.

One of the standard requirements for POE is obtaining a benchmark in terms of energy use based on occupancy, which do not currently exist for dwellings. One reason for this absence is due to the constraints posed by gaining access to collect data (Stevenson and

Leaman, 2010; Leaman *et al.,* 2010). Furthermore, benchmarks must be derived from empirical data, rather than theoretical or modelled data; comprising at least 30 studies in a given geographical area (ibid). This data can then be used to develop benchmarks for different dwelling typologies (detached, terraced, flat, etc.) and occupancies (Leaman *et al.,* 2010). However, for this data to be meaningful, it is not necessary to have 30 samples for each category, four is sufficient (Leaman *et al.,* 2010; Energy Saving Trust, 2008). Following collection and data analysis, a comparison can be made to establish an appropriate norm for different household types, within the wider community (Stevenson and Leaman, 2010). This is of particular relevance in the emerging field of POE for improvements made to existing dwellings (Leaman *et al.,* 2010).

Assessing improved and adapted existing dwellings

The National Audit Office (2008) states that, in order to determine how effective any thermal improvement measures are, they need to be evaluated. Evaluating the thermal performance of improved existing dwellings is thought not to be well documented or researched. However, the strategy entitled “Evaluating energy and carbon performance in the ‘Retrofit for the Future’ demonstrator projects” has been developed by the Energy Saving Trust (EST) for the Technology Strategy Board’s (TSB’s) Retrofit for the Future (RFTF) programme, which commenced in 2009 (TSB and EST, 2009). The main objectives of this EST and TSB strategy include: measuring energy consumption and carbon emissions; to provide a comparison between baseline (designed) performance, actual performance and the targets set for the project; and determining what contribution key design features, such as air-tightness, insulation and renewable energy sources, have made to overall improvements to energy performance (TSB and EST, 2009). The targets include 17 kilograms per square meter (m^2) per annum (p.a.) for carbon dioxide (CO_2) emissions and 115 kilowatt hours/m^2/p.a. for energy use (TSB *et al.,* 2009).

To meet the aims of the EST and TSB strategy (2009) above, data collection and analysis techniques are drawn from those used for assessing new dwellings and include: air-leakage pressurisation tests; thermal imaging; co-heating tests; walk-through inspections; dwelling performance monitoring (temperature, relative humidity and CO_2 levels); outputs from renewable energy sources; occupant interview surveys; and trade and building owner satisfaction surveys (TSB and EST, 2009). Air-leakage pressurisation tests, thermal imaging and walk-through inspections are required to be carried out before and after retrofitted improvement measures. Whilst, co-heating tests are not mandatory, they pose a significant inconvenience to occupants, as the dwelling will need to unoccupied for a period of at least two weeks in order to conduct the test. In addition, the costs of the equipment required for carrying out all the tests can be very expensive per dwelling (ibid). There are 86 individual properties being refurbished across the UK as part of the TSB’s RFTF programme and the intention is to provide data and knowledge for future improvement and adaptation of existing dwellings (TSB, no date). Whilst, this information is important for moving forward in terms of taking a ‘whole-house’ approach to improving and adapting existing dwellings, it may not provide information about taking a ‘whole-street’ approach.

Focusing on existing deprived dwellings

The instigation of the research project was as a result of the lack of funding in the Arbed stage one scheme, to assess and monitor the effectiveness of the retrofitted improvement measures in Wales. In order to establish methods of improving the thermal performance of existing deprived dwellings and determining how effective retrofit measures have been, by using some of the research methodologies used as part of POE studies, it is necessary to examine these key issues: what fuel poverty means; how these dwellings are categorised; the challenges they pose; and the possible solutions for overcoming these challenges.

Fuel poverty in Wales

The definition of fuel poverty is where more than 10% of household income is spent on energy use in the home. Where energy costs increase to more than 20%, then the household are classified as being in severe fuel poverty (WAG, 2010). Between 2005 and 2006, the number of fuel poor households increased by one million across the UK, to approximately 3.5 million of 26 million dwellings (Defra, 2008; DCLG, 2008). In 2008, the number of fuel poor households in Wales was estimated to be 332,000, just over 25% of all households; and just under double that of the UK average. These incidences of fuel poverty are linked to the age and energy efficiency rating of the dwelling (Howarth, 2010).

Characteristics of deprived existing dwellings

The majority of UK dwellings have a D or E energy efficiency rating, based on Energy Performance Certificate calculations (DCLG, 2006; EST, 2010). However, Boardman (2007) highlights that there are a significant number of dwellings in the UK with the lowest ratings of F and G. All G rated and most F rated dwellings qualify as a Category 1 Hazard for Excess cold under the Housing, Health and Safety Rating System (HHSRS) (ibid). The purpose of the HHSRS is to ensure the health and safety of occupants and visitors to a dwelling by providing a hazard severity rating for identified risks (Decent and Safe Homes, 2007). Category 1 Hazards are the most severe with increased risks to the health of occupant and chances of being in fuel poverty (Boardman, 2007). In Wales, 11% of dwellings qualify as a Category 1 Hazard for Excess cold (Howarth, 2010).

Within the UK, 40% of F and G rated dwellings are in Wales (Burrell, 2011). As of the 31st March 2010 there were approximately 1,340,000 dwellings in Wales and of these 30% are pre-1919 dwellings and 90% of these dwellings, have solid EWs (Burrell, 2011; and Howarth 2011). Dwellings with solid EWs lose approximately 45% of their heat through this construction element alone and can pose particularly challenging in terms of upgrading to reduce heat loss (EST, 2011; English Heritage, 2010). Traditionally designed pre-1919 solid EWs are often described as being ‘breathable’ (May, 2005; English Heritage, 2010; Ty-Mawr Lime, 2010). This is because these particular types of EWs were constructed with permeable and hygroscopic materials, which allow moisture to be absorbed and released through evaporation, both internally and externally (ibid). In terms of the thermal performance, maintaining the breathability of vapour permeable and hygroscopic materials is critical as this assists with controlling the relative humidity in the internal rooms of a dwelling (May, 2005; May 2006). In turn, this is fundamental for occupant health in terms of indoor air quality, as these physical properties aid control of mould, dust mites and bacteria (ibid).

Overcoming the challenge of upgrading solid EWs

The method recommended by Immendoerfer *et al (*2008a) for improving the thermal performance of solid EWs is by installing insulation, either externally or internally, to the

EWs. However, Immendoerfer *et al* (2008a) argues that external wall insulation (EWI) is a better intervention than internal wall insulation. This is because EWI leads to better reductions in air-leakage and the risks posed by thermal bridging at wall and floor junctions. Nevertheless, using EWI can pose a challenge in certain areas of EWs. For example, where windows and doors are not being replaced, there may be restrictions on the thickness of insulation that can be returned at the reveals. This poses a significant risk of thermal bridges, which could lead to condensation, resulting in internal mould and damp patches around windows and doors (English Heritage, 2010; Immendorfer *et al,* 2008a; Immendorfer *et al,* 2008b; EST, 2006). In addition, careful attention is required at roof verges and eaves to minimise thermal bridging in these locations. Where dwellings front directly onto a pavement, this will restrict the thickness of insulation that can be used. This can impact on the choice of insulation materials, particularly where there is a desired thermal performance being targeted (ibid).

When selecting insulation materials, Garbutt (2008) argues that one of the most important selection criteria is the potential reductions in energy use. This argument has resulted in recommendations for upgrading solid EWs and thus manufacturers focusing on supplying insulation products with the lowest thermal conductivity values possible (EST, 2006; Shore, 2008). Thorpe, (2010) and the EST (2006) highlight that the most commonly used insulation materials in the UK are from fossil fuel derived rigid boards (such as phenolic foam) and mineral derived batts (such as Fibreglass wool). Furthermore, Thorpe, (2010) and the EST (2006) state that mineral derived batts have some vapour permeability properties, if installed as part of an EWI system; yet none of the fossil fuel derived insulation products discussed provide the hygroscopic properties required for maintaining breathability within internal rooms of buildings. Consequently, using these materials could have adverse effects by conversely reducing thermal performance and potentially introducing mould and damp into the original structure, leading to potential health risks for occupants (English Heritage, 2010; May, 2005).

In addition, the authors' believe that consideration should be given to the environmental impacts from the extraction and processing, toxicity and overall embodied energy of materials specified in the retrofit of existing deprived dwellings. The most common supplied insulation materials (discussed above), with the lowest thermal conductivity, tend to have higher embodied energy when compared to natural insulation materials (Shore 2008). For example, mineral wool insulation has an approximate thermal conductivity of 0.032 W/mK and primary embodied energy of 230 kWh/m^3. Whereas, sheep's wool insulation which can be used in comparable locations to mineral wool, has an approximate thermal conductivity of 0.039 W/mK and primary embodied energy of 30 kWh/m^3 (Shore, 2008).

The main natural materials suitable for use as EWI, which offer suitable physical properties for upgrading solid EWs, include Lime Hemp plaster and Wood Fibre board's (English Heritage, 2010; Ty-Mawr Lime, 2010). Whilst the EST (2006) list wood fibre as an option for EWI, they have not listed the added benefit and additional requirement documented by May (2005, 2006) of this material, which includes the breathability and the need for a breathable finishing layer, such as lime render, respectively (Ty-Mawr Lime, 2010). In terms of reducing heat loss, these natural materials can achieve respectable results. For a typical pre-1919 solid stone wall of 500mm thick the existing level of heat loss is approximately 1.9 W/m^{2}K (ibid). Ty-Mawr Lime, a producer of specialist lime products, recommend that Hemp Lime plaster is applied at a thickness of

50mm, which can reduce the heat loss to approximately 1.2 W/m^2K. The greatest reduction of heat loss can be achieved using wood fibre boards. Heat loss can be reduced to the recommended level of (approximately) 0.30 W/m^2K using 100 mm thick wood fibre boards (ibid).

Whilst physical upgrades are imperative for improving the thermal performance and occupant quality of life within existing deprived dwellings, they will only achieve limited reductions in energy use, carbon emissions and fuel poverty. In order to achieve maximum reductions, physical upgrades need to be coupled with changes in occupant behaviour and attitudes towards energy use and efficiency in dwellings.

Integrating POE with strategies to change occupant behaviour

Energy consumption within dwellings can vary by up to 300% as a result of differences in occupant behaviour (Janda, 2009). In turn, this means changing occupant behaviour could have immediate and positive results for reducing energy use and their subsequent costs. However, knowing what changes are required to occupant behaviour is not always obvious due to individual lifestyles. The main focus of energy efficiency advice has been to raise awareness of impacts of energy use, with the anticipation that this will result in the appropriate actions being taken (NAO, 2008). Despite the distribution of energy efficiency advice there remains a gap between awareness and action to reduce energy use (ibid). It has been argued by the National Endowment for Science, Technology and the Arts (Nesta) (2008) that enabling lasting behaviour change amongst occupants requires advancing beyond awareness. It is claimed that this could be achieved by utilising a community-based social marketing (CBSM) strategy (ibid). As an alternative to merely providing information to occupants, CBSM provides an effective and pragmatic strategy to changing occupant behaviour (McKenzie-Mohr, 2010).

The CBSM strategy supports claims that integrated and interactive education is crucial to the occupant’s role in taking more responsibility for energy use and efficiency in the built environment (Janda, 2009). The strategy is implemented in stages and involves: identifying barriers that prevent occupants making changes to their behaviour; identifying appropriate ‘tools’ for implementing an effective approach; piloting different approaches on a small sample of the community prior to full implementation; and evaluating the effectiveness of different approaches, following full implementation (McKenzie-Mohr, 2010). In support of this technique, Brook Lyndhurst (2010) has undertaken a scoping study for the Welsh Government on how CBSM could be utilised to reduce carbon emissions as a result of occupant behaviour by Welsh residents. The study involved a detailed review of the tools available. These include: regular surveys, checks and audits; visits from local expert advisors and champions demonstrating their own positive behaviour; highlighting cost reductions that can be achieved; developing community and social norms through group work; gaining individual commitments to meet goals within a given period of time; energy monitoring and feedback; and demonstration homes to exemplify positive behaviour. The study concluded with recommendations that included utilising a selection of the tools in combination in order to achieve maximum benefits. Many of the tools correlate with established methods of undertaking POE (as discussed in section 2.1). This offers an opportunity for making the transition from awareness to action at the same time as gathering valuable data.

Research Methodology

The literature review in Section two above has identified the requirement for: establishing a benchmark for conducting POE for dwellings, in terms of energy use and occupancy; assessing improvements made to existing dwellings, in terms of building performance and occupant satisfaction; the use of ecological materials for EWI when upgrading solid walled existing dwellings; and proactive engagement with occupants to encourage positive actions to be taken for reducing energy use and subsequent carbon emissions. In an attempt to address some of these requirements, the research project, being undertaken by the first author of this paper, involves conducting a social and physical monitoring programme on a number of the existing deprived dwellings, which have received retrofit improvement measures in Swansea, as part of stage one of the Arbed scheme.

The social monitoring programme consists of: occupant interview surveys, using a questionnaire to establish pre-retrofit and post-retrofit improvement energy use, carbon emissions and perceived comfort and control of internal environment. The physical monitoring includes thermography surveys to establish pre-retrofit and post-retrofit improvement heat loss through EWs; and subject to funding longitudinal studies of internal and external environmental conditions, to obtain air temperature and relative humidity data over a period of at least one year. Furthermore, recording and evaluation of the construction retrofit details, as installed for EWI compared with the design details, to investigate whether: design specification has translated into construction (through retrofit solutions); any deficiencies or problems; lifecycle costs of measures installed; ease and duration of installation; and ecological ratings of materials used. It is anticipated that the data collection and analysis will be repeated for a second stage of Arbed, which is to be implemented later in 2011.

The choice of techniques for the monitoring programme corresponds with established recommendations for undertaking POE (as described in section 2.1 above). Participation by occupants is completely voluntary and disruption is kept to an absolute minimum. Each occupant is contacted by letter to make mutually convenient arrangements for conducting the monitoring. For the occupant interview surveys, a questionnaire has been developed by the research team (authors of this paper) and has been approved by UWIC's ethics committee. The use of a questionnaire enables a structured interview to take place, which can then be replicated with all participating occupants to ensure consistency of data gathered. Structured interviews, which ask closed questions, also allow quantitative data to be gathered more readily (Haigh, 2008). Where attitudes are to be recorded and to enable these to be quantified, the Likert scale has been employed. The Likert scale uses either a five-point or seven-point scale to gauge attitudes (Hoxley, 2008). The interviews are being conducted face-to-face in occupant's homes.

The questions aim to gather data about: demographic information, such as tenure, age groups and number of occupants; property details, such as type and age of dwelling, construction and windows; energy use, in terms of quantity, expenditure and types of appliances; space heating and hot water systems, such as type, age and controls; lighting (artificial and natural); ventilation, in terms of use of mechanical extraction and opening of windows; and perceived comfort levels and control of internal environment. In addition, an opportunity is provided to comment on anything else not covered by a particular question. The interview process commences by providing occupants with an information sheet, stating: further details about the research project; that any personal data they provide is protected by the Data Protection Act (1998); that their participation is voluntary; and they are free to withdraw at any time. Occupants are asked to sign a consent form and the questions are then asked. The whole process takes between 20 and 40 minutes.

To date (July 2011), pre-improvement occupant survey interviews and thermography surveys have commenced for the first stage of the Arbed scheme. Despite attempts to undertake these in advance of the works commencing, engaging with occupants proved virtually impossible until this time. Following advice from CHG staff, the first author was advised not to commence any data collection until confirmation was given to occupants that works were to proceed. As a result, some interviews have taken place during the initial stages of works. However, it is being emphasised to the occupants that the purpose at this stage of data collection, is to capture a representation of their views and attitudes on the comfort and control of internal conditions and recording energy consumption from utility bills, prior to commencement of retrofitting works.

Findings and Discussion

Burrell (2011) has revealed that the magnitude of the fuel poverty in Wales is exacerbated by the scale of hard-to-treat, pre-1919 solid wall dwellings. Whilst it is necessary to upgrade the fabric of these pre-1919 solid wall dwellings, the literature (English Heritage, 2010) has demonstrated that using the appropriate materials is of equal importance. Despite the evidence from literature (May, 2005; and 2006) that maintaining the breathability in solid walls is imperative for maintaining the integrity of the structure and the health of occupants, the majority of literature, for example from the EST, promotes the use of materials that do not pose the necessary physical properties. In addition, Ty-Mawr Lime (2010) has revealed that appropriate fabric upgrades can be achieved using materials that have less of an impact on global resource depletion, coupled with fewer emissions as a result of the manufacturing process. Utilising POE methodologies offers the opportunity to establish evidence for the most appropriate methods of upgrading solid walls to improve the environmental performance and occupant quality of life within existing deprived dwellings in the UK. In terms of conducting POE, there is a contradiction between the recommendations for the best approach. Leaman *et al* (2010) argue that methods should be minimal in terms of disruption, duration and expense. Whereas the EST (TSB and EST, 2009) has put forward methods, which are contradictory for the TSB's RFTF programme and in addition, whilst the programme will provide valuable data on the improvements that can be made to existing dwellings, it will not provide a benchmark of energy use based upon occupancy of dwellings. This is because properties being refurbished are not in one geographical area (ibid).

As a result of the monitoring and evaluation being undertaken as part of the research project documented in this paper, it is anticipated that it will be possible to establish a dwelling POE benchmark for energy use based on occupancy, in dwellings with solid EWs, in Swansea. It should also be possible to obtain a benchmark for both pre-retrofit and post-retrofit upgrades and for both a typical non-ecological and an ecological approach to fabric upgrades using EWI on solid EWs. In addition, obtaining a benchmark and developing a community norm for different dwelling and occupancy categories could be utilised as part of a CBSM tool for encouraging changes in occupant behaviour.

Conclusion and Further Research

This paper has set out the background and context to a 38 month research project entitled ‘A study to investigate and test traditional and ecological strategies to mitigate and adapt existing deprived dwellings for climate change in the UK’, which commenced in August 2010. The context includes the rationale for improving the thermal performance of some of the most deprived existing dwellings in Wales, which correlates with the requirement to reduce energy use, carbon emissions and fuel poverty. In relation to these requirements are the: methods of determining the effectiveness of improvement measures; challenges posed by upgrading solid EWs; and strategies for encouraging behavioural change amongst occupants. The paper has also revealed the opportunity to establish a dwelling POE benchmark for energy use based on occupancy within deprived existing dwellings in Swansea.

The next stage of the research is to record the technical solutions undertaken, make recommendations for an ecological approach to the second Arbed phase and conduct follow up interview and thermography surveys to obtain results for analysis. The surveys will then be repeated for the second phase of Arbed. Following analysis of the results, guidance for future improvement projects can be produced, based on the findings. This can be disseminated in the form of technical solutions and a monitoring strategy, which can be implemented by HAs across Wales and the UK.

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Appendix III: Retrofit 2012 Conference Paper

Assessing the execution of retrofitted external wall insulation for pre-1919 dwellings in Swansea (UK)

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Abstract:
The purpose of this paper is to evaluate the execution of retrofitted external wall insulation as a method of improving the thermal performance of pre-1919 dwellings with solid exterior walls. Public and private case study dwellings in Swansea, UK, have been monitored before, during and after installation of external wall insulation, which have been funded by the Welsh Government's Arbed I scheme. The installations have been procured by a principal contractor through a 'Design and Build' contract with Coastal Housing Group and Family Housing Association, based in Swansea. The methodology for the research includes field observations, to record technical solutions implemented on site, and pre-retrofit and post-retrofit thermographic surveys, to assess heat loss through the dwelling fabric. The findings include photographic, technical and thermographic evidence of potential thermal bridges, resulting from an incomplete covering of insulation. Whilst some thermal bridging is unavoidable, some could have been avoided with systematic preliminary surveys and technical detailing at the design stage and improved execution of quality on site. Furthermore, external wall insulation manufacturers are recommended to explore the development of additional products and methods to enable thermal bridging to be avoided at critical junctions encountered at pre-1919 dwellings. This paper will be of interest to stakeholders involved in improving the thermal performance of existing dwellings in the UK.

Keywords:
External wall insulation, Evaluation, Pre-1919 dwellings, Thermal bridging, Wales

Introduction

Within the UK, Wales has some of the oldest and poorest quality housing stock. Approximately 30% of dwellings in Wales were built prior to 1919 and of these 90% have solid exterior walls, which mean they lose around 45% of their heat through this one thermal element (Energy Saving Trust (EST), 2011a; EST, 2011b). In 2009, the Welsh Government implemented the Arbed scheme in recognition of the requirement to make mass thermal improvements to the poorest quality dwellings in Wales (Welsh Assembly Government (WAG), 2010a). Arbed is the Welsh word for 'Save'. The scheme is a Strategic Energy Performance Funding Programme, which is being run over two phases. The aim is to improve the most deprived 15% of publically and privately owned dwellings in Wales. The first phase of Arbed (Arbed I hereafter) has been delivered by housing associations and local authorities across Wales (ibid). One of the funding requirements was that monitoring and evaluation should be undertaken to assess the effectiveness of the improvement measures (WAG, 2010b). However, the methodology had very limited funding allocated for these assessments across Wales.

A three year doctoral research project was instigated in response to the requirement for these assessments to be undertaken, which commenced in August 2010. The research is being undertaken within the Ecological Built Environment Research and Enterprise group at the University of Wales Institute Cardiff (UWIC). Working in collaboration with Coastal Housing Group (CHG), based in Swansea, one of the objectives of the research includes collecting and analysing data before, during and after retrofitted thermal improvements through the Arbed I scheme in Swansea. The main improvement measure undertaken and thus the main focus of the research is that of retrofitted external wall insulation to pre-1919 dwellings with solid exterior walls.

The aim of this paper is to appraise the execution of retrofitted external wall insulation applied to pre-1919 dwellings through the Arbed I scheme in Swansea. Retrofitting insulation to improve the thermal performance of pre-1919 dwellings is relatively uncommon in the UK. As a result, there is limited experience and guidance available, particularly to older existing dwellings where typical construction details cannot be applied. The potential outcome is for the possibility of avoidable thermal bridging and consequent condensation. It is proposed that evaluating the installation of retrofitted insulation through the Arbed I scheme in Wales offers an opportunity to analyse the issues encountered at pre-1919 dwellings. To explore this proposal, field observations to record technical solutions on site and pre-retrofit (pre-R:T) and post-retrofit (post-R:T) thermographic surveys have been undertaken at a sample of pre-1919 dwellings in Swansea. These methods are to be followed by trade, building owner and occupant satisfaction surveys. The retrofitted insulation was initiated by CHG and Family Housing Association (FHA), who are both housing associations based in Swansea. The installations were implemented using a design and build contract with a principal contractor, who employed sub-contractors to undertake the work. The site operatives also had access to technical assistance from the manufacturers of the insulation systems.

The research is limited to the case studies in Swansea and thus not a reflection of installations generally across the UK. Nevertheless, the findings could be applied to other locations in the UK where there are pre-1919 dwellings. The key findings are that: the occurrence of thermal bridging is either avoidable and unavoidable at different junctions within the exterior walls; greater attention is required before and during the design stage and during installation to ensure avoidable thermal bridges do not occur; and the suppliers of the systems are recommended to explore the possibilities for additional products and methods to minimise instances of avoidable thermal bridging further. The findings are expected to be of benefit to stakeholders involved in implementing thermal improvements to pre-1919 dwellings. This paper commences by reviewing literature to discuss the advantages and challenges for using external wall insulation and methods of evaluating installations. This is followed by the research methodology, findings and discussion and conclusions drawn from the research.

Retrofitting external wall insulation to solid exterior walls

External wall insulation

Whilst external wall insulation is not suitable for all dwellings with solid exterior walls, for example where the external facade has a particular aesthetic value, it has many advantages over the alternative of using internal wall insulation to improve thermal performance (Immendorfer *et al,* 2008a; Immendorfer *et al,* 2008b). The main advantages include: increased opportunities to achieve a complete covering and thus remove risks posed by unavoidable thermal bridging, for example at partition wall and floor junctions; improved air-tightness; thermal mass exposed to the internal space to control overheating risk is retained; less disruption to occupants; no loss of internal floor area; and internal fixtures and fittings do not have to be relocated or restricted to predetermined locations (English Heritage, 2010; King and Weeks, 2010; Immendorfer *et al,* 2008a; Immendorfer *et al,* 2008b; Construction Products Association, 2010).

Where a complete covering of insulation is not achieved, the cold un-insulated areas (thermal bridges) will entice a concentration of condensation to these locations as the load will no longer be shared by the other warmer surfaces (English Heritage, 2010). Thermal bridging between thermal elements and around openings can be responsible for approximately 30% of heat loss from a building (King and Weeks, 2010). Heat loss is also reduced as a result of improving air-tightness. External wall insulation systems seal gaps and cracks in the building fabric, which cause draughts as a result of warm air being replaced by cold air. This cold air then requires heating, thus using more energy (EST, 2010). The use of external wall insulation can further reduce energy use as it allows the thermal mass of solid walls to be retained for use within the dwelling, which aids the maintenance of indoor comfort levels (Immendorfer *et al*, 2008b).

Nevertheless, retrofitting external wall insulation can pose significant technical challenges. Whilst challenges can be experienced in terms of repositioning rainwater downpipes, external lights and satellite dishes for example, the main challenge is that of avoidable thermal bridging. As with all domestic renovations involving existing thermal elements, Approved Document L1B of the UK Building Regulations recommends that thermal bridging is avoided wherever possible (H.M. Government, 2010). Minimising instances of thermal bridging is critical to avoid internal and interstitial condensation and reduce heat loss (King and Weeks, 2010). Whilst internal wall insulation poses a risk of thermal bridging at partition wall and floor junctions, which are unavoidable, external wall insulation presents challenges in other locations. To avert avoidable thermal bridging, the design of retrofitted external wall insulation requires particular attention when detailing: around window and door openings; wall to roof junctions; window sills; and at any projections, such as porches or conservatories (CPA, 2010; English Heritage, 2010; EST, 2006; Immendorfer *et al,* 2008a). Appropriate preliminary surveys are required to achieve design details to prevent avoidable thermal bridging (Energy Solutions, n.d). These surveys are also a technical requirement stipulated under the installation guidance for external wall insulation systems accredited by the British Board of Agrément (BBA), for example certificate number: 03/4058, issued for one of Wetherby Building Systems Limited’s external wall insulation systems (BBA, 2011).

In some circumstances it may not be possible to achieve the necessary level of detailing required to avoid thermal bridging (English Heritage, 2010). Subsequently, English Heritage (2010) argues that, if the consequences of the thermal bridges are likely to be severe, it may be better not to insulate at all. When other building work is being undertaken, this could offer the ideal opportunity to install external wall insulation without creating any thermal bridges. For example, where a new roof covering is being applied to a dwelling with flush eaves, the roof could be extended to provide an overhang to cover the top of the external wall insulation (CPA, 2010). The alternative is that the top of the insulation is protected by a capping. Nonetheless, it is inevitable that with this approach there will be a thermal bridge created at the eaves (ibid). The next issue to overcome is one of execution. Once appropriate detailing at the design stage has been achieved, this then needs to be coupled with delivery on site. Poor workmanship can undermine design intentions, resulting in the occurrence of avoidable thermal bridging and thus a reduced thermal performance (Immendorfer *et al,* 2008a). In order to develop knowledge of the issues surrounding thermal bridging, related to retrofitting external wall insulation, undertaking an evaluation of installations could provide valuable feedback, based on empirical evidence.

Evaluating retrofitted external wall insulation

The assessment of thermal performance of buildings is often referred to as Post-occupancy Evaluation (POE) (Zimring, 2010; Leaman *et al,* 2010). Established methods of data collection include: questionnaires; interviews; site visits/field observations; and recording of technical solutions and performance of the building fabric, services and systems (ibid). In order to gain maximum cooperation from occupants and building owners, where they differ, the choice of methods should be determined to limit intrusiveness, duration and costs, as much as possible (Leaman *et al,* 2010). Traditionally, POE is undertaken for new buildings. However, there is an emerging field of POE for existing dwellings that have received thermal improvements (ibid).

The most documented strategy in the UK is that which has been developed by the EST and Technology Strategy Board (TSB) for the TSB's 'Retrofit for the Future' programme (TSB and EST, 2009). Drawing on methods used to assess new dwellings, data collection and analysis techniques include: air-leakage pressurisation tests; thermal imaging; co-heating tests; walk-through inspections; dwelling performance monitoring of temperature, relative humidity and carbon dioxide (CO_2); outputs from renewable energy sources; occupant interview surveys; and trade and building owner satisfaction surveys (ibid). Thomsen and Rose (2009) advocate the use of infrared thermography to identify thermal bridging, relating to execution on site. This claim is also supported by Pearson and Seaman (2003), who argue that thermal imaging provides an efficient way of determining the effectiveness of insulation applied to the fabric of buildings.

Research Methodology

The focus of this research is to evaluate the execution of retrofitted external wall insulation installed to pre-1919 dwellings in Swansea, UK, through the Arbed I scheme. The literature review in Section 2.1 above, highlighted that the main challenge when retrofitting external wall insulation is that of avoidable thermal bridging, resulting from either inadequate preliminary surveys or design details, poor execution or a combination of all three. In terms of evaluating retrofitted external wall insulation, Section 2.2 above listed a number of data collection methods and analysis techniques that could be used. In deciding upon a methodology for this research, the following factors were considered: appropriateness; intrusiveness; duration; and costs. Co-heating tests, dwelling performance monitoring and outputs from renewable energy sources are not considered appropriate for evaluating the execution of external wall insulation systems. Air-leakage pressurisation tests, in combination with thermal imaging, were considered inappropriate because they are intrusive and disruptive from an occupant's perspective.

Therefore, the methodological approach decided upon are: field observations to record technical solutions on site, using photography and production of technical details; pre-retrofit (pre-R:T) and post-retrofit (post-R:T) thermography surveys; and trade, building owner and occupant satisfaction surveys. The lead and second authors of this paper are Level One certified thermographers and have access to a thermal camera for use on the project. The lead author is a qualified Architectural Technologist and therefore trained to analyse technical details. In addition, approval has been granted by the appropriate UWIC ethical committee for the questionnaires, developed to undertake the trade, building owner and occupant satisfaction surveys. Collectively these methods of data collection could provide sufficient information to effectively evaluate the execution of retrofitted external wall insulation at pre-1919 dwellings. To date (October 2011), field observations and pre-R:T and post-R:T surveys have been undertaken; these results are summarised in Section 4 below. Trade, building owner and occupant satisfaction surveys are ongoing; these results will be documented in a future publication.

Field observations

Field observations were undertaken before, during and after retrofitted external wall insulation at the pre-1919 dwellings, which were part of the Arbed I scheme in Swansea. In addition to the lead author taking photographs, CHG provided photographs from their records for their Arbed I dwellings. Technical details were produced using a combination of the photographs and observations made during site visits. Annotations have been added to the details using information obtained from the manufacturer's specifications. In addition, the details produced from the field observations have been compared to the external wall insulation manufacturer's generic details.

Thermography surveys

The pre-R:T and post-R:T surveys were used to qualitatively assess retrofitted external wall insulation at four pre-1919 dwellings. The thermal images produced from qualitative surveys provide thermal patterns that indicate possible locations of increased heat loss. The process for implementing the thermography surveys involved contacting each occupant to: explain the purpose of the survey; advise them of the date, time and names of the thermographers; and to request that they activate their heating prior to the survey, to ensure there was a sufficient temperature difference between the outside and inside of the dwelling. The environmental criteria for undertaking a thermographic survey includes a minimum temperature difference of 10°, along with no solar radiation and precipitation for the preceding hour and 24 hours, respectively and a maximum wind speed of 10 meters per second. In addition to the thermal images, photographs were taken to aid visual interpretation when analysing the results.

Findings and Discussion

This section of the paper provides an overview of findings from field observations and the pre-R:T and post-R:T surveys undertaken at a sample of Arbed I pre-1919 dwellings in Swansea (A to D). The results from field observations include photographs taken before, during and after installations of retrofitted external wall insulation and technical details produced using a combination of photographs, observations and manufacturer's specifications. The thermal images were taken before and after retrofitted insulation.

Field observations

The photograph in Figure 1 was taken during the installation of the insulation at sample dwelling A. The grey area in the centre of the image has not been insulated for the reason that if it had been then the occupant would not be able to open the window. The result is a potentially large thermal bridge. This issue could have been identified in a preliminary survey and a more acceptable solution to the problem determined. Figure 1 also shows a potential thermal bridge at the eaves of the extension, which can be seen in the top left of the image, due to a capping having been installed, below the fascia board, to cover the top of the insulation. However, without extending the roof overhang, this approach to protecting the top of the insulation appears to be the only solution offered by the manufacturer.

The photograph in Figure 2 was taken during the installation of the insulation at the plinth of the external wall, which joins the pavement in front of dwelling sample B. There are gaps between the insulation boards and between the insulation and the rail supporting the insulation that is covering the remainder of the wall above. These gaps appear to be due to poor workmanship on site and could lead to condensation as a result of thermal bridging. In addition, it would appear that there is sufficient door frame depth to accommodate a reduced thickness of insulation at the door reveal. However, no insulation was installed on the door reveal.

The photograph in Figure 3 was taken after the installation of insulation at dwelling sample C and shows the eaves and gable wall junction of an end-terrace dwelling. The new fascia board stops short of the end of the external wall. As a result, a small area of insulation, which had not been covered by the fascia board, had to be rendered and a dash finish applied. In addition, the overhang of the capping had to be cut away to allow the new rainwater downpipe to be fitted and thus poses a risk of insufficient protection to the top of the insulation. Had an adequate preliminary survey been undertaken, there could have been appropriate detailing at the design stage and then this could have been executed on site.

Figure 4 shows the generic detail for one of the external wall insulation systems used in Swansea, produced by one of the Arbed I approved suppliers, as published in BBA certificate number: 03/4058 (BBA, 2011). Figure 5 shows the reproduction of a construction detail, as observed on site by the lead author, at dwelling samples A, C and D, which is different to the manufacturer's recommendations. It would appear from the observed detail that an attempt has been made to retain the feature of the window sill for aesthetic purposes and to also reduce heat loss further than that recommended by the manufacturer. Whilst aesthetically this approach appears to be more acceptable, without completely covering the sill (above and below) with insulation, the attempt to reduce heat loss is likely to be in vain as there are still paths for potential thermal bridging (as shown in Figure 5). A possible solution would be to use a reduced thickness of insulation on top of the window sill and to return the insulation underneath.

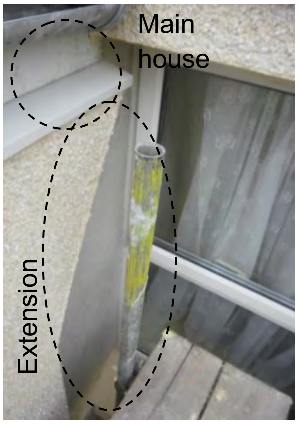

Figure 1: Example of thermal bridging resulting from an inadequate preliminary survey

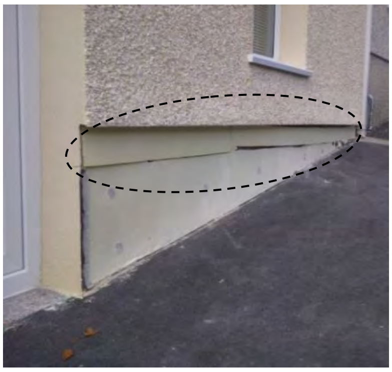

Figure 2: Example of poor execution, which could lead to thermal bridging

Figure 3: Example of poor detailing and execution resulting from an inadequate preliminary survey

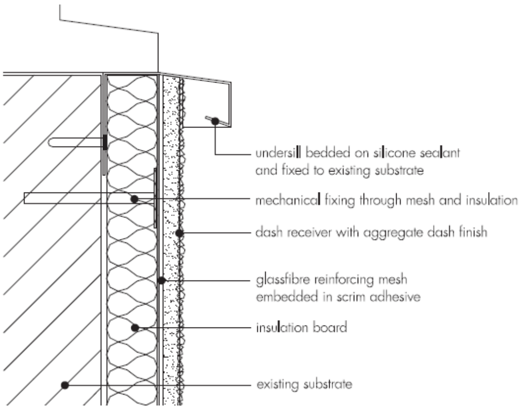

Figure 4: Window sill detail by one of the approved Arbed I suppliers (BBA, 2011)

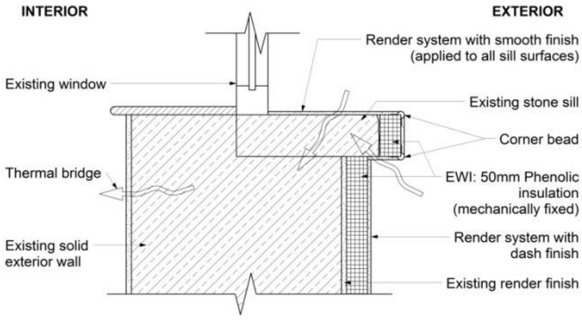

Figure 5: Window sill detail as observed on site

Thermographic surveys

Within the thermal images, the lighter shades represent the greatest amount of heat loss and the darker shades, the least. *Please note: the temperature scale on the thermal images is not representative of actual temperature readings as these are qualitative survey images.* Figures 6 and 7 show dwelling sample D before the external wall insulation system was installed.

Figure 6: Photograph of dwelling before installation of insulation

Figure 7: Pre-R:T survey image of dwelling, as shown in Figure 6

The apparent increased heat loss from the ground floor external wall to that for the first floor could be a result of the first floor rooms being cooler due to the window being open. Figures 8 to 10 show the same dwelling sample D, after the insulation was installed. Figure 10 does not illustrate the whole dwelling; it is just a focus on the bottom of the external wall. There appears to be evidence of thermal bridging: at the step below the external door; at window and door reveals; under the window sill; and where the insulation used at the base of the wall joins that used for the remainder of the wall above. Overcoming the potential thermal bridge at the step and below the exterior door is a junction where a solution does not appear to have been explored; this is evidenced by the lack of information available within the manufacturer's documentation, for example BBA certificate number: 03/4058 (BBA, 2011).

Insulation was not installed at the window and door reveals due to the frame thickness not being of an adequate size, despite a new door having been fitted as part of the works. However, without adjustments to the width of the opening, which could have been considered as part of a preliminary survey, a thicker door frame may have resulted in the access being below the recommended minimum width. As demonstrated in Figure 5; insulation was not installed above and below window sills. Whilst the thermal image does not show the top of the window sill, due to the angle that it was taken, there is evidence of heat escaping below the sill as a result of insulation having not been installed in this location. The heat loss between the insulation at the base of wall to that above is likely to be due to gaps created by poor execution, as demonstrated in Figure 2 above. However, it should be noted that Figures 2 and 9 are different dwellings. Whilst overall heat loss appears to have been reduced, there is evidence of thermal bridging due to an incomplete covering of insulation and poor execution on site. Together, Figures 2, 3 and 10 could be used as part of training material for external wall insulation installers to provide a visual method of illustrating the consequences of poor execution on site.

Figure 8: Photograph of dwelling shown in Figure 6, after installation of insulation

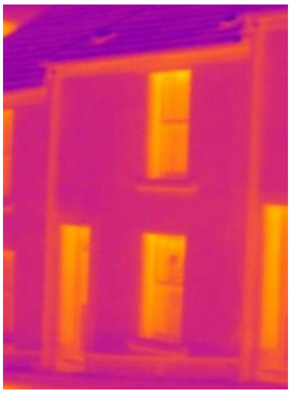

Figure 9: Post-R:T survey image of dwellings, as shown in Figure 8

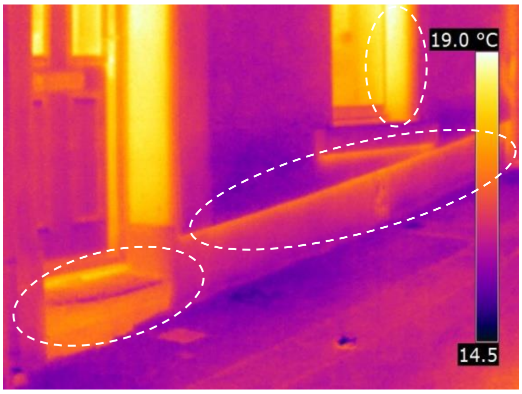

Figure 10: Post-R:T survey image showing focus of lower section of facade for dwelling shown in Figure 8

Conclusion and Further Research

This paper has presented the methodology and key findings from part of an evaluation for the execution of retrofitted external wall insulation at pre-1919 dwellings with solid exterior walls, through the Arbed I scheme in Swansea, UK. The paper began by reviewing literature, which discussed the advantages and challenges posed by retrofitting external wall insulation to existing dwellings and established methods of evaluating building work. The main advantages of installing external wall insulation, over the alternative of internal wall insulation, were identified as: reduced instances of unavoidable thermal bridging, for example at partition wall and floor junctions; increased air-tightness; and retained use of thermal mass. However, the main challenge for retrofitting external wall insulation is that of eliminating avoidable thermal bridging in locations such as: window and door openings; wall to roof junctions; and window sills. To overcome these challenges, it is desirable to undertake thorough preliminary surveys, which should be followed by suitable technical details at the design stage and then quality execution on site.

Based on established techniques of data collection, the methodological approach taken for this research involves: field observations to record technical solutions implemented on site, using photography and technical detailing; pre-retrofit (pre-R:T) and post-retrofit (post-R:T) thermography surveys; and trade, building owner and occupant satisfaction surveys. The findings presented in this paper are from data collected to date (December 2011) and include an overview from field observations and pre-R:T and post-R:T surveys. The data confirms that pre-1919 dwellings present many technical challenges for retrofitting external wall insulation, particularly when adequate preliminary surveys and technical details are not undertaken. As a result there is photographic, technical and thermographic evidence of thermal bridging due to an incomplete covering of insulation and poor execution. Furthermore, manufacturers of these systems appear to offer a limited range of products and methods for overcoming critical junctions within pre-1919 solid exterior walls. It is therefore recommended that further technical solutions are explored by all stakeholders involved in retrofitting external wall insulation to pre-1919 dwellings. As a method of improving standards of installation for retrofitting external wall insulation, it is recommended that photographs and thermal images from this type of research, for example Figures 2, 3 and 10, are used for training purposes to illustrate the consequences of poor execution.

The next stage of the research is to complete the trade, building owner and occupant satisfaction surveys. These surveys will provide valuable feedback from all stakeholders involved in the Arbed I scheme in Swansea and further extend the knowledge gained from the experience. Further research is recommended to assess the implications of the potential thermal bridges identified in this paper by monitoring and measuring condensation risks to both the dwellings and occupants. The aim of these assessments should be to determine if it is acceptable to insulate as much as possible, knowing that some thermal bridging will occur, or if it is absolutely critical to achieve a complete covering. In addition, technical details for retrofitting external wall insulation should be developed and disseminated to overcome some of the non-standard junctions encountered at pre-1919 dwellings, preferably using ecological materials.

Acknowledgement

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Appendix IV: Structural Survey Journal Paper

Assessing retrofitted external wall insulation using infrared thermography

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Abstract

Purpose – This paper discusses the methodology and results of using thermography for pre-retrofit (pre-R:T) and post-retrofit (post-R:T) surveys undertaken to qualitatively assess retrofitted external wall insulation (EWI) on pre-1919 existing dwellings with solid exterior walls.

Design/methodology/approach –This study involved undertaking qualitative thermography surveys before and after installation of EWI at two mid-terrace dwellings in Swansea (UK). One dwelling was part of a whole-street approach and the other was an isolated installation.

Findings – The two case studies have provided evidence of potential thermal bridges created as a result of an incomplete covering of EWI. Whilst overall heat loss appears to have been reduced, further evidence is required to establish the extent to which these thermal bridges reduce overall thermal performance.

Research limitations/implications – Only two schemes undertaken in Swansea (UK) are represented in this study and are therefore not a reflection of EWI installations generally. Nevertheless, the study suggests more general concerns with the installation of EWI where a continuous covering of insulation cannot be achieved. Further research is required to assess the long-term implications of thermal bridges on the condition of the dwelling and the health of occupants.

Originality/value – This paper has introduced and tested a pre-R:T and post-R:T methodology for assessing the thermal performance of deprived dwellings, which have had EWI retrofitted to solid exterior walls. By using the pre-R:T and post-R:T methodology the paper has demonstrated a visual method for illustrating problems in retrofitting EWI and highlighted improvements in thermal performance, which can be used by stakeholders involved in the maintenance and improvement of existing dwellings.

Keywords Existing dwellings, External wall insulation, Infrared thermography, Thermal performance, Retrofit

Paper type Research paper

1. Introduction

The aim of this paper is to discuss the use of infrared thermography, as a qualitative test method, for assessing the installation of retrofitted external wall insulation (EWI) to pre-1919 dwellings with solid exterior walls (SEWs). *(Note: this is not about quantifying heat loss).* Installation of EWI to dwellings on a mass scale is uncommon in the UK and therefore there is limited experience on: the effectiveness of these measures; the implications of not providing a continuous covering; and how to overcome many of the non-standard junction details present in older existing dwellings. It is proposed that using thermography qualitatively is one method that can be used to overcome these issues by demonstrating to those responsible for implementation and installation of EWI systems, what the consequences are of poor execution and where to focus attention during future installations to prevent potential problems occurring.

To explore this proposal, qualitative thermography surveys have been undertaken at the same sample of pre-1919 deprived dwellings with SEWs in Swansea (UK), both before and after installation of retrofitted EWI. The two samples presented in this paper are terraced dwellings, with one being part of a whole-street approach and the other being an isolated installation. The EWI has been installed as part of a Welsh Government funded thermal improvement scheme, entitled Arbed I, aimed at the most deprived dwellings in Wales. This study forms part of a three year doctorate research project being undertaken by the lead author within the Ecological Built Environment Research and Enterprise (EBERE) group at Cardiff Metropolitan University, which commenced in August 2010. Primarily working in collaboration with Coastal Housing Group, the aim of the research is to investigate, develop and test a best practice ecological retrofit methodology for technical and social improvements to deprived existing dwellings in Wales, to reduce energy use, carbon emissions and fuel poverty and thereby increase occupant quality of life.

The paper commences by reviewing literature to: set out the rationale for improving the thermal performance of deprived existing dwellings in the UK and Wales; provide a brief overview of the issues surrounding the use of EWI; introduce the Welsh Government's Arbed I scheme; and present infrared thermography as a method of monitoring and evaluating the effectiveness of EWI. This is then followed by a description of the study in Swansea and the methodology used to undertake the infrared thermography surveys, along with the results, discussion and conclusions drawn from the study.

2. Background and context

2.1 Rationale for improving existing deprived dwellings

The UK Climate Change Act 2008 sets out a legally binding target for an 80% reduction in greenhouse gas emissions by 2050, based on the 1990 baseline (H.M. Government, 2008). The main greenhouse gas contributing to climate change is carbon dioxide (Department for Environment, Food and Rural Affairs, 2007). Housing accounts for over 25% of UK carbon emissions resulting from domestic energy use, with over 75% of this energy used for space and water heating purposes (Department of Energy and Climate Change, 2010; Department for Trade and Industry, 2008). In addition, over two thirds of the UK existing housing stock is predicted to still be in use in 2050 (Department for Communities and Local Government, 2008).

It is anticipated that reducing domestic energy use and subsequent costs will also contribute to a decrease in the number of households in fuel poverty. The factors associated with fuel poverty are: high energy costs; low income; and poor quality dwellings (Kemp and Wexler, 2010). Dwellings that are classified as being of poor quality are more likely to be older (typically pre-1919) and have a low energy efficiency rating (Howarth, 2010). Those dwellings with the lowest energy efficiency ratings (Standard Assessment Procedure (SAP) rating of 30 or below), qualify as a Category one Hazard for Excess cold under the Housing, Health and Safety Rating System and pose a significant risk to the health of occupants (Boardman, 2007).

Within the UK, 40% of all dwellings with a SAP rating of 40 or below are in Wales (Energy Saving Trust (EST), 2011a). Wales has some of the oldest dwellings in the UK, with over 30% having been built before 1919 and of these 90% have SEWs, making it more challenging to improve their thermal performance (EST, 2011a; Howarth, 2011). Dwellings with SEWs lose approximately 45% of their heat through this element alone (EST, 2011b). Therefore, improving the thermal performance of SEWs offers the greatest opportunity for reducing energy consumption for the purposes of heating these types of dwellings.

2.2 Upgrading solid exterior walls

As documented in Hopper *et al* (2011), EWI, rather than internal wall insulation, is considered the preferred method of insulating existing SEWs. The main reasons are: there are reduced instances of thermal bridging, for example at floor and wall junctions; thermal mass is maintained, which aids regulation of internal environmental conditions; it improves air-tightness; and there is a reduced risk of interstitial condensation (ibid). EWI offers the greatest potential to achieve a complete covering of SEWs, to allow these benefits to be realised (Immendorfer *et al,* 2008a). Nevertheless, retrofitting EWI is not without its challenges, for example adaptation is likely to be required at roof verges and eaves, services inlets and outlets, and window and door reveals (English Heritage, 2010; EST, 2010). The most significant risk posed by these challenges, is that of thermal bridging (ibid).

According to English Heritage (2010), Immendorfer *et al* (2008a and 2008b) and the EST (2006), thermal bridging can lead to condensation, which in turn could result in damp and mould growth internally in these locations and subsequently pose a health risk to occupants. In addition, English Heritage (2010) argues that if thermal bridges cannot be avoided and the consequences are likely to be severe, then it could be better not to insulate at all. However, the authors are unable to find any literature that documents the results of any long-term monitoring of post-retrofit dwellings and therefore the effects of remaining thermal bridging on the health of the occupants.

2.3 Arbed: Improving Wales' most deprived existing dwellings

In recognition of the requirement to make mass improvements to deprived existing dwellings in Wales, the Welsh Government instigated the 'Arbed' scheme in 2009 (WAG, 2010a). Arbed is the Welsh word for 'save'. The scheme is a Strategic Energy Performance Funding Programme aimed at improving the most deprived 15% of dwellings in Wales, across both public and private ownership. Arbed I is being implemented by Housing Associations and Local Authorities across Wales to deliver localised economic, social and environmental benefits (ibid). The types of measures being installed as part of the Arbed I scheme are: EWI; connection to the mains gas network; solar thermal panels; solar Photovoltaic panels; and heat pumps (WAG, 2010b).

One of the requirements of the Arbed I scheme is for monitoring and evaluation to be undertaken to determine how effective the improvement measures are at reducing energy use, carbon emissions and fuel poverty (WAG, 2010c). However, there was no methodology and very limited funding provided for these assessments. In Swansea, the main improvement measure being implemented is EWI to dwellings with SEWs that were built prior to 1919. According to Pearson and Seaman (2003), an efficient way of determining the effectiveness of insulation applied to the fabric of buildings is through the use of infrared thermography. This claim is also supported by Thomsen and Rose (2009), who have undertaken a study across Europe to analyse the occurrences of thermal bridges relating to execution quality on site, for both new build and retrofit building work.

3. Infrared Thermography

All objects with a temperature above -273ºC (absolute zero) emit radiant heat (Pearson, 2002). Thermography is a technique for producing a visible image of this invisible heat energy (infrared radiation) emitted from the surface of an object, through a non-contact thermal imaging device (Hart, 1991; Pearson, 2002; Snell and Spring, 2002; Infrared Training Center, 2010). A thermogram is the visible image produced through the use of an infrared camera (Hart, 1991; Infrared Training Center, 2010). The thermogram is a map of the temperature difference across the surface of objects being viewed, which are displayed as different colours or shades of grey (Snell and Spring, 2002; Pearson and Seaman, 2003; Lo and Choi, 2004). When interpreting thermograms, it is necessary to understand the surface characteristics of the materials being viewed, in terms of their emissivity and reflectivity. Materials with high emissivity values have a low reflectivity and vice versa (Lo and Choi, 2004). Only materials with a high emissivity provide a reliable reading as materials with a low emissivity will tend to reflect the temperature of surrounding objects and thus could produce misleading results, particularly where they are being interpreted by someone who has not undertaken appropriate thermography training (Snell and Spring, 2002; Lo and Choi, 2004; Infrared Training Center, 2010).

Whilst infrared thermography can be employed for undertaking both qualitative and quantitative surveys of buildings, Pearson (2002) argues that other methods should be adopted to quantify heat loss from a building. This is due to the precise thermal and environmental conditions required to obtain accurate results, which rarely occur. In most instances qualitative thermographic building surveys provide sufficient information, for example to identify: continuity of insulation; occurrences of thermal bridges; sources of air-leakage, particularly at critical junctions; moisture and damp within an element; hidden components, such as pipes and wall ties; and electrical faults (Hart, 1991; Pearson, 2002; Thomsen and Rose, 2009; Littlewood *et al,* 2011; Taylor *et al*, 2011).

When undertaking thermographic surveys of buildings, there are a number of criteria for the environmental conditions required to maximise the accuracy of the data being collected (Hart, 1991; Pearson, 2002; APT, no date). However, there are discrepancies between some of the recommendations made. Hart (1991) recommends that the facade of the building should not be exposed to sufficient solar radiation that would affect the results, during and for at least 12 hours prior to the survey. Hart (1991) continues by stating that cold and overcast days are the most suitable environmental conditions for undertaking thermography surveys. Whereas, Pearson (2002) suggests at least one hour should elapse following exposure to direct solar radiation, before a survey is undertaken. Pearson (2002) also recommends that surveys are undertaken in darkness to minimise effects from solar radiation. Both Hart (1991) and Pearson (2002) recommend a temperature difference of at least 10ºC between the inside and outside of the building for the preceding 24 hours and during the survey being undertaken. However, APT (no date) recommend a 5ºC temperature difference during and for the four hours prior to the survey.

Pearson (2002) recommends that the building should not be exposed to precipitation for the preceding 24 hours of a survey. All recommendations are for surfaces to be dry at the time of the survey (Hart, 1991; Pearson, 2002; APT, no date). The final criterion is for wind speeds not exceeding six meters per second (m/s), according to APT (no date) and 10 m/s, according to Pearson (2002).

4. Methodology for assessing retrofitted EWI in Swansea (UK)

This study is limited to qualitative thermographic surveys to assess the continuity of retrofitted EWI and thus potential thermal bridging. Qualitative surveys are considered the most appropriate method for these assessments, as discussed in Section 3 above. Therefore, attempts have not been made to quantify heat loss as this did not form part of the study. Furthermore, data is not available for the precise construction of the existing exterior walls. As a result, assumptions have been made, which are presented in the results (Section 5) below, to allow the reader greater understanding of the methods implemented. Data is also not available for the costs associated for an individual dwelling that had EWI as the work formed part of a large scheme involving multiple interventions and these varied across dwellings.

The study presented in this paper involved using qualitative techniques to undertake thermographic surveys at two pre-1919 dwellings with SEWs that received EWI through the Arbed scheme in Swansea. The surveys were undertaken before and after installation of the EWI to allow an overall comparison to be made. Both dwellings are mid-terrace. One is part of a whole-street approach to the EWI (Case study A hereafter) and the other is an example of an isolated installation, where the neighbours either side were not insulated (Case study B hereafter). The infrared camera used for all thermographic surveys was a FLIR B365. The tasks undertaken in preparation for each of the surveys are set out in Table 1 below:

Table 2: Tasks undertaken in preparation for the thermographic surveys.

1	Weather forecast was checked and a suitable day was chosen to undertake survey.
2	Each occupant was contacted, either by telephone or in person, to: • Provide an explanation of: o The purpose of the survey; o Why it had to undertaken during the hours of darkness; and o Possible reasons for a likely change in arrangements (for example, precipitation in the preceding 24 hours); • Advise them of the: o Date; o Time; and o Names of the thermographers; • Request that they activate their heating at least four hours before the time of the survey (to ensure there was an adequate temperature difference between the inside and outside of the dwelling). *All preparations for the pre-retrofit (pre-R:T) surveys were repeated for the post-retrofit (post-R:T) surveys for each dwelling; this was due to the length of time between the pre-R:T and post-R:T surveys.*
3	Batteries for the camera were checked prior to each survey and charged if necessary.
4	Digital photographs were taken during the day prior to each survey. These aid visual interpretation of the thermograms.

Undertaking the thermographic surveys required precautions to be taken. Firstly, due to the surveys being undertaken in the dark and the requirement to enter dwellings where occupants were unknown by the thermographers, it was not considered safe for any lone working. At least two thermographers were present on all surveys; this meant that one person could focus on capturing the images, whilst the other person recorded the environmental data and details about each thermogram. Secondly, due to the location of the dwellings adjacent to highways, caution had to be taken by the thermographers when choosing the ideal location for capturing images, as these were often in the middle of a road. This limited the possibilities for capturing some images.

4.1 Pre-retrofit thermography (pre-R:T) surveys

The pre-R:T survey for Case study A was undertaken on the 27th January 2011 and Case study B was on the 7th April 2011. Meteorological data, recorded by the nearest weather station, for during and the preceding 24 hours to each survey, obtained from City and County of Swansea (2011), is as shown in Table 2 below. To verify the recommended environmental conditions had been achieved for the pre-R:T surveys, details were recorded at the time of each survey; these are presented in Table 3, along with: the time for each survey; time of sunset; and orientation of the dwellings. Temperature, relative humidity and wind speed readings were obtained using a Kestrel 3000 handheld weather meter. In discussion with the occupants, as part of the preparations, it was requested that the thermographers enter the dwelling to take the internal temperature and relative humidity readings. Due to changes in the weather forecast the survey undertaken to Case study A had to be rearranged once and for Case study B, the date had to be changed twice.

Table 3: Meteorological data recorded for pre-R:T surveys at Cwm Level Park 30m mast (City and County of Swansea, 2011)

	Case study	
	A	B
Average external air temperature during survey	3.1ºC	15.1ºC
Average external relative humidity during survey	58.6%	73.8%
Maximum (hourly average) temperature in 24h preceding survey	6.2ºC	17.6ºC
Minimum (hourly average) temperature in 24h preceding survey	1.5ºC	8.4ºC
Precipitation in 24h preceding survey	0.0 mm	0.0 mm
Average wind speed during survey (m/s)	3.6 m/s	0.8 m/s

Table 3: Details and environmental data for pre-R:T surveys

	Case Study	
	A	B
Time of sunset (Time and Date AS, 2011)	16:53	19:55
Time of survey	19:00	21:50
Orientation (font/back)	N/S	NW/SE
Internal temperature (ºC)	21.5	25.5
Internal relative humidity (%)	44.8	50.2
External temperature (ºC)	4	15.2
External relative humidity (%)	54.5	68.3
Wind speed (m/s)	1.8	0.4

4.2 Post-retrofit thermography (post-R:T) surveys

Both post-R:T surveys were undertaken on the 27th June 2011. Meteorological data, from the same nearest weather station, for during and the preceding 24 hours to the survey, obtained from City and County of Swansea (2011), is as shown in Table 4 below. The sun set at 21:34 on the 26th June 2011 and the sun rose at 04:57 on the 27th June 2011 (Time and Date AS, 2011). Due to the time of year, the post-R:T surveys commenced two hours before sunrise. Unfortunately, the 26th June 2011 was the warmest day of the year to date and was not ideal for undertaking thermographic surveys. However, the occupants were very cooperative and agreed to activate their heating at 21:00 on the 26th June 2011 and leave it on overnight. They also agreed to keep their windows shut.

The timing of the surveys were planned so as to allow any solar radiation, absorbed by building elements during the day, to be dispersed as much as possible. As with the pre-R:T surveys, to verify that recommended environmental conditions had been achieved, these details were recorded at the time of the post-R:T surveys and are presented in Table 5. Whilst external temperature, relative humidity and wind speed readings were obtainable at the time of the survey using the Kestrel 3000, internal readings were not. The solution decided upon, to overcome the issue of not being able to enter the dwellings at the time of the surveys, was to install 'Signatrol' data loggers to record internal temperature and relative humidity readings at 10 minute intervals. Each dwelling had two data loggers installed (one in the ground floor and one in the first floor) within rooms located at the front of the dwelling, prior to the survey. The data loggers were then collected following the surveys. Data was retrieved from the loggers by connecting them to a computer and downloaded using the accompanying 'TempIT-Pro' software.

Table 4: Meteorological data recorded for p:RT surveys at Cwm Level Park 30m mast (City and County of Swansea, 2011)

Average external air temperature during survey	16.6ºC
Average external relative humidity during survey	94.0%
Maximum (hourly average) temperature in 24h preceding survey	27.4ºC
Minimum (hourly average) temperature in 24h preceding survey	14.5ºC
Precipitation in 24h preceding survey	0.0 mm
Average wind speed during survey (m/s)	0.6 m/s

Table 5: Details and environmental data for post-R:T thermography surveys

	Case Study	
	A	**B**
Time of survey	02:00	03:10
Internal temperature (ºC)	26.5	25.8
Internal relative humidity (%)	54.5	62.5
External temperature (ºC)	19.5	19.5
External relative humidity (%)	77.5	73.9
Wind speed (m/s)	0.4	2.6

5. Results

To aid understanding of the thermographic results, this section of the paper commences with simple technical details (produced by the lead author) illustrating how the EWI was installed at the following critical junctions: pavement to external wall (Figure 1); window reveals (Figure 2); window sills (Figures 3 and 4); and eaves (Figure 5). Despite client expectations, observation at different stages on some of the properties showed that the specified detail was not fully applied. Further investigation would be needed to establish whether this was because adaptation was required on site to address an unanticipated obstacle i.e. non-standard junction details or lack of supervision, inadequate training, or other reason.

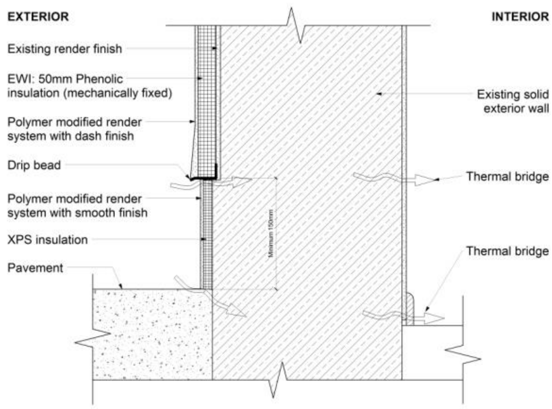

Figure 1: Section detail – Pavement to external wall junction

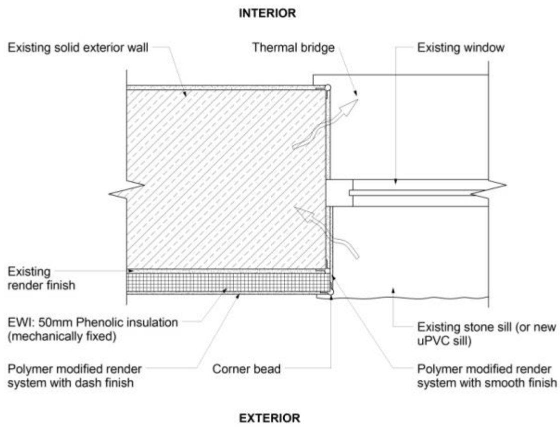

Figure 2: Plan detail - Window reveal

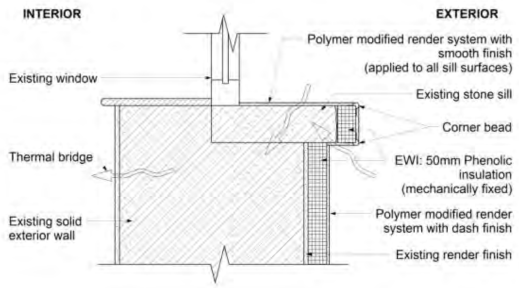

Figure 3: Section detail - Stone window sill (Method used for Case study A)

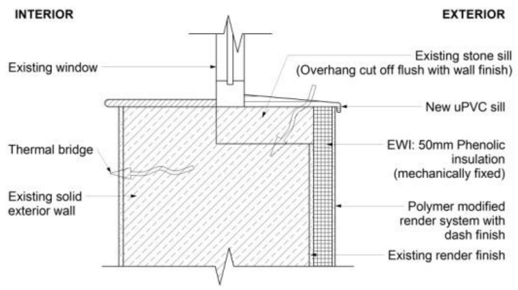

Figure 4: Section detail – Stone window sill (Method used for Case Study B)

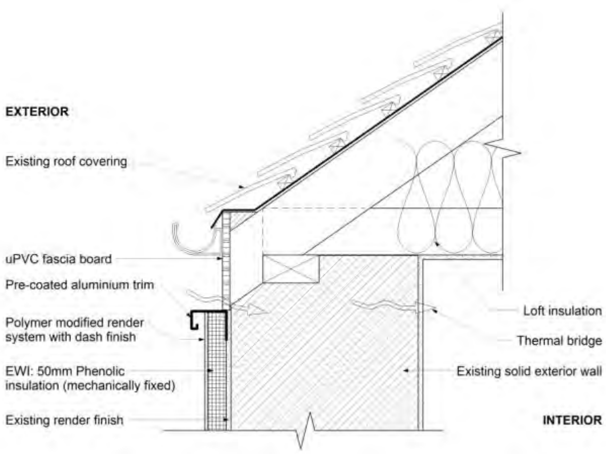

Figure 5: Section detail - Eaves

The results for each case study are presented as thermograms with corresponding photographs. Each of the thermograms have been 'thermally tuned' in the accompanying software for the thermal camera, to enhance the clarity of the images. *Please note: the temperature scale on the thermograms is not representative of actual temperature readings as these are qualitative survey images.* Lighter shading towards orange and yellow shows greater heat loss and darker shading towards blue shows lower heat loss. Figures 7, 9, 10, 11, 13, 15, 16 and 17 illustrate the qualitative thermographic results.

5.1 Case study A

Pre-retrofitted EWI

At the time of the survey the temperature difference between the inside and outside of the dwelling was between 17.5 and 18.4ºC (Kestrel 3000 reading and Meteorological data, respectively). The main observations from the thermogram include:

- Apparent overall increased heat loss through the exterior wall when compared to the dwelling next door (to the left).
- Apparent increased heat loss through the exterior wall surrounding the ground floor window, particularly where the wall meets the pavement and just below the eaves. However, it is likely that the internal space on the first floor is somewhat cooler than the ground floor due to the first floor window being open. This also explains the extended area of heat escaping from the upper portion of the first floor window.
- All window and door frames appear to be losing a significant amount of heat.
- Visibility of the brickwork that frames the windows, which has since been covered in render; this is due to the higher thermal resistance of bricks compared to the rest of the wall, which is thought to be constructed of different material, for example stone.

Figure 6: Photograph of Case study A before installation of EWI

Figure 7: Thermogram of Case study A before installation of EWI

Post-retrofitted EWI

There was a 7 – 10.3ºC (Kestrel 3000 reading and Meteorological data, respectively) temperature difference between the inside and outside of the dwelling at the time of the survey. The main observations from the thermograms are:

- The EWI appears to have made an overall improvement on the heat loss through the exterior wall as the pattern variations and brickwork framing the windows observed in the pre-R:T survey is no longer visible.
- Apparent thermal bridges: at the window and door reveals; under the window sills; at the eaves; and at the junction between the different insulation materials used at the plinth of the wall and that for the remainder of the wall above. However, particular caution should be taken in respect of the window and door reveals and the eaves due to the higher thermal resistance of the brickwork that surrounds the openings and the highly reflective material of the fascia boards, respectively. Nevertheless, there is the possibility that there is a thermal bridge at both of these locations due to the reveals having not been insulated and the EWI ceasing just below the fascia (as shown in Figures 2 and 5 above).

Figure 8: Photograph of Case study A after installation of EWI

Figure 9: Thermogram of Case study A after installation of EWI

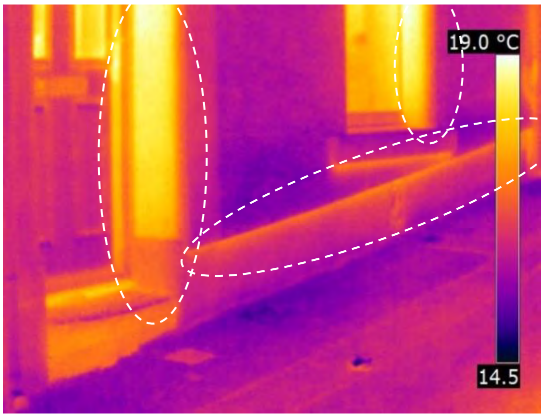

Figure 10: Thermogram of bottom of door and ground floor window and wall to pavement junction for Case study A after installation of EWI

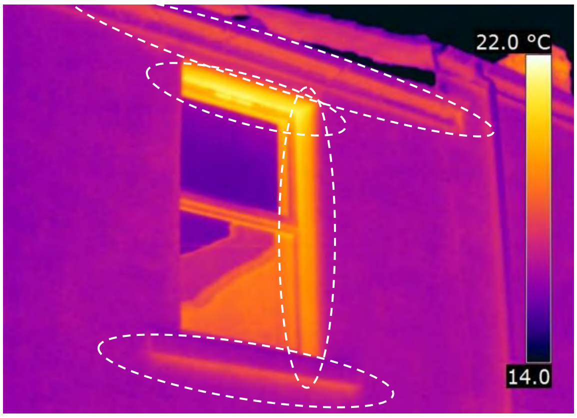

Figure 11: Thermogram of first floor window and eaves for Case study A after installation of EWI

5.2 Case study B

Pre-retrofitted EWI

There was a temperature difference of 10.3 – 10.4ºC (Kestrel 3000 reading and Meteorological data, respectively) between the inside and outside of the dwelling at the time of the survey. The main observations from the thermogram include:

- Apparent uneven distribution of heat loss across the exterior wall.
- Apparent increased heat loss around windows and door.

- As with Case study A, the brickwork that frames the windows is visible despite it previously having been covered with render.
- The cooler area over the door is likely to be where the metal flashing is reflecting the cold sky.

Figure 12: Photograph of Case study B before installation of EWI

Figure 13: Thermogram of Case study B before installation of EWI

Post-retrofitted EWI

There was a 6.3 – 9.5ºC (Kestrel 3000 reading and Meteorological data, respectively) temperature difference between the inside and outside of the dwelling at the time of the survey. The main observations from the thermograms are:

- Apparent overall improvement on heat loss demonstrated by the stark difference between the dwelling that received the EWI to those either side, which have not.
- As with case study A, the pattern variations and brickwork framing the windows is no longer visible.
- Apparent thermal bridges: at the window and door reveals; under the window sills (despite original stone sills having been cut off flush with the existing wall, as shown in Figure 4); at the eaves (where the insulation ceases below the fascia board); where the insulation has been cut around the service pipes entering the dwelling; and around the vent cover. Note: as with Case study A, caution needs to be taken in respect of the window and door reveals and eaves due to the higher thermal resistance of the brickwork and highly reflective fascia material, respectively.

Figure 14: Photograph of Case study B after installation of EWI

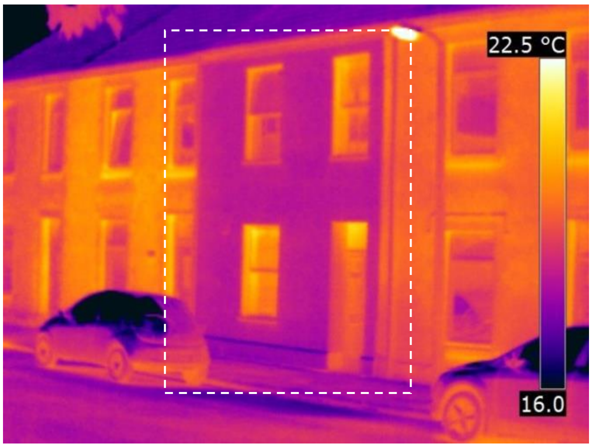

Figure 15: Thermogram of Case study B after installation of EWI

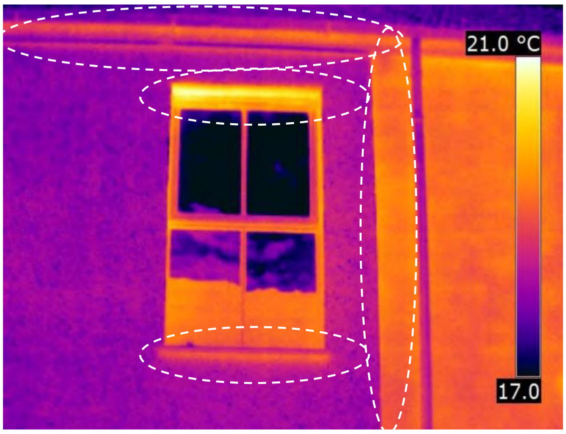

Figure 16: Thermogram of first floor window and at party wall junction

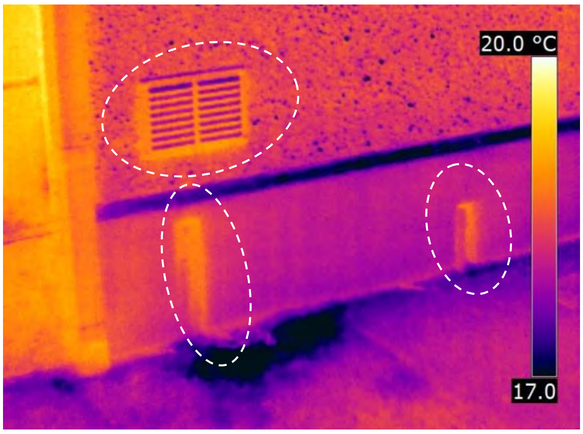

Figure 17: Thermogram of exterior wall to pavement junction indicating EWI at plinth level that has been cut around service pipes entering the dwelling and external vent

6. Discussion

First and foremost the main observation from the results presented in this paper, which corresponds with literature by Pearson and Seaman (2003) and Thomsen and Rose (2009), is that qualitative thermography is an effective tool for project managers and maintenance managers, as a pre-retrofit and post-retrofit survey method, to assess the before and after affects on thermal performance of retrofitting EWI to existing dwellings. Furthermore, pre-R:T surveys can be utilised to identify where to focus thermal improvements and post-R:T surveys to illustrate where there are problems in quality control of the EWI retrofit, at site level. Using pre-R:T and post-R:T survey methods, the thermal patterns that have been identified could indicate potential thermal bridges, and thus an increased rate of heat loss: at the reveals for windows and doors; under the window sills; and at the eaves, as a result of the EWI not being installed in these locations. According to authors such as English Heritage (2010) and the EST (2006), potentially, these thermal bridges could lead to condensation and thus incidences of internal damp and mould growth at the locations not insulated. There is also the possibility of thermal bridging occurring in neighbouring dwellings, which have not had EWI installed, as the party wall provides an avenue for heat loss. Taking a whole-street approach to the installation of EWI removes the likelihood of these thermal bridges occurring at party walls. Where there are thermal bridges between the junctions of two insulation materials (at the top of the plinth of the wall; as shown in Figure 10), this is an execution issue that could be addressed in future installations. However, to establish the extent to which there is a risk factor resulting from the potential thermal bridges identified, due to the level of uncertainty surrounding the effects on the health of occupants, as documented by English Heritage (2010), it is desirable that further monitoring, along with measurements or modelling be undertaken and results documented to fill this gap in knowledge. An additional means of measurement may be to conduct internal post-R:T surveys focused on areas of the SEWs identified as posing potential thermal bridges, benchmarked against neighbouring or similar dwellings that did not receive EWI.

In terms of undertaking thermographic surveys at occupied existing dwellings, there are four main issues that have been identified in this paper, as shown in Table 6, which should be given forethought in future surveys.

Table 6: Issues identified from undertaking thermography surveys at occupied dwellings

1	Arranging thermographic surveys at occupied dwellings requires striking a balance between giving occupants plenty of notice and obtaining weather forecasts with a greater degree of accuracy.
2	When undertaking thermographic surveys to dwellings that front onto a highway, there is a possibility that there will be parked cars causing an obstruction to the visibility.
3	When a survey is to be undertaken at a dwelling that is located on a busy highway; it is not always possible to take images at the required distance to achieve maximum quality. Should a thermographer wish to increase the quality of the image by moving closer to the dwelling, this then poses a significant risk from moving vehicles.
4	Even when specific instructions are given to occupants in preparation for a survey, these may not necessarily be followed. It is therefore difficult to rely on occupants to undertake some of the preparation tasks required. For example, requesting that heating is turned up to its maximum and windows to be kept shut.

Following identification of the issues in Table 6 above, it is recommended that a pre-R:T and post-R:T protocol is developed within the EBERE group at Cardiff Metropolitan University to ensure that all factors are taken into consideration for future surveys at existing dwellings. The protocol should be published on the EBERE website to allow others, who are proposing to undertake thermographic surveys at existing dwellings, to consider the experiences gained from this and future studies. Further to issue three in Table 6, it is recommended that thermographers take personal protective equipment, such as a high visibility jacket, to all surveys where they are located near highways.

7. Conclusions

The literature review has presented evidence by Boardman (2007), the Energy Saving Trust (2011a) and Howarth (2011) for the importance of improving deprived dwellings in the UK and, in particular, in Wales. Improving the thermal performance of pre-1919 dwellings with solid exterior walls can be achieved with the application of external wall insulation (EWI). A complete covering is desirable to fully avoid thermal bridging and the subsequent potential risk of damp and mould growth, which, according to English Heritage (2010) could have health implications for occupants. However, further investigation and evidence is required to establish the extent of these risks. Improving existing dwellings was recognised as necessary by the Welsh Government in 2009 (WAG, 2010a), who instigated the Arbed I scheme to fund measures that would increase the thermal performance of the most deprived 15% of dwellings in Wales. The Arbed I scheme has been delivered by housing associations and local authorities across Wales. The dominant method of improvement undertaken in Swansea, was the installation of EWI.

One of the criteria, set out by the then Welsh Assembly Government (2010c), for the Arbed I funding was that monitoring and evaluation had to be undertaken to assess the effectiveness of the improvements made. However, there was no methodology and very limited funding provided for these assessments. This paper has presented the methodology and results for undertaking qualitative infrared pre-retrofit thermography (pre-R:T) and post-retrofit thermography (post-R:T) surveys, before and after the installation of EWI, at two dwellings in Swansea, UK; funded as part of the Arbed I scheme. One of the dwellings is part of a whole-street approach and one is where the neighbouring dwellings have not received EWI. The thermal images have identified temperature differences that could indicate potential thermal bridges present: at the reveals for windows and doors; under window sills; where two insulation materials have been joined; at the eaves; and at party walls, in the case study where a whole-street approach has not been taken. This study should be followed by further investigation to determine how best to measure the implications of such potential thermal bridges. One approach is long term monitoring of the dwellings for possible mould growth at such junctions. In addition, it should be determined whether the EWI has improved overall comfort levels for occupants and reduced their energy use and costs and minimised carbon emissions.

The results of the qualitative thermographic surveys presented in this paper, particularly for the post-retrofit of Case study B, provide an opportunity to promote the installation of EWI. The thermal images appear to substantially endorse the benefits of EWI with the contrast between the dwelling that received EWI and those which have not being clearly visible. However, given the extent of the potential thermal bridges that have been identified, it is recommended that when the application of EWI is at the design stage, particular attention is given to ensuring that a complete covering is achieved by focussing on how to overcome non-standard and critical junctions. Furthermore, this attention to detail should then be ensured when execution is undertaken on site. In addition, where EWI is to be installed, thermograms from this study, particularly for the post-retrofit of Case study A, could be used as part of the skills training undertaken by installers to demonstrate the effects of poor execution on site. Furthermore, the use of pre-R:T surveys could inform the types of retrofit works that could be deployed by stakeholders responsible for improving existing dwellings.

7.1 Further research

The authors suggest that further research is needed to assess the long-term implications of the potential thermal bridges identified in this study, as some issues may take time to appear. This research will commence as part of the lead authors doctorate project and includes: further thermography surveys; longitudinal studies of internal environmental conditions, such as temperature, relative humidity and particulates to discover the potential for mould growth; and occupant interviews. In addition, assessing improvements in air-tightness would complement thermography surveys to provide a comprehensive appraisal of the benefits of EWI. However, whilst it is known that air-leakage is a source of heat loss, there could also be implications in terms of condensation, air-quality and humidity levels resulting from making pre-1919 dwellings with SEWs significantly more air-tight. The dwellings would need to be monitored to determine the effects; these should be studied as part of the assessments stated above. The results of this work are to be published in future papers.

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Andrew Michael Thomas ICIOB BSc (Hons) Project & Construction Management has been employed as Maintenance Manager of Coastal Housing Group, Swansea with responsibility for overseeing all aspect of property maintenance for circa 5,000 properties since 2003. Previously Planned Maintenance Co-ordinator with Swansea Housing Association for 5 years. Prior to these positions, he worked in various roles within housing development and building surveying.

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Appendix V: CMU's Academic Research Review

Is running your home costing the earth?

By Jo Hopper & Tim Taylor

Homeowners and tenants could start looking at their homes in a whole new way, thanks to an innovative method of seeing if their properties are keeping the heat in or costing more than they should.

If houses are not designed correctly in the first place, or the construction is faulty, then energy costs can rocket – but it is impossible to tell from just looking at buildings which are heat-loss nightmares and which are cosy, energy-conservation dreams. The UK Government expects standards to improve for newly built homes and existing homes undergoing improvements, but the construction industry are struggling to keep pace.

What if hidden problems could be fixed before the builders leave the site? Or what if there was a way of providing evidence of poor workmanship that is hidden after builders have left, that could be used to support a claim for getting the situation resolved?

A way of doing this is by using a thermal camera to take pictures of houses before, during and after building work to reveal where heat is escaping. Thermal cameras can 'see heat' and identify how well the insulation is working; their quality has improved dramatically and they are coming down in price making their routine use more practicable.

The energy we use in our homes really is costing the earth since it makes the biggest contribution of any sector to UK carbon dioxide emissions, which is the main greenhouse gas causing climate change. This research considers two situations where a thermal camera has been used to assess heat loss from homes in Swansea; Tim Taylor is studying new houses during construction, and Jo Hopper investigates existing homes before and after insulation is installed. In both projects, the PhD students have teamed up with Coastal Housing Group; a housing association based in Swansea.

New homes

Tim Taylor

Once people have moved in, problems with the insulation in the building can be expensive and disruptive to rectify. A typical house may be built from several thousand parts, so it is not surprising that mistakes can be made on construction sites (Figures 1 and 2). It therefore helps to identify problems at an earlier stage before they are "built-in".

The project is investigating how testing with a thermal camera can be implemented at different stages during the construction of new homes with a view to identifying defects in the construction. This approach could help provide assurance that new homes are as energy efficient as they claim to be.

A key objective of the research is to develop test procedures that can work on a building site. The preparation of the building is important because reliable results can only be obtained under the right test conditions. Additionally, the results should be interpreted and assessed by persons with special training in the use of a thermal camera.

The quality of feedback obtained from the tests is an equally important consideration. Firstly, the results need to be passed on so that defects can be located and recommendations made for further investigation or repair. Secondly, the lessons learned should be taken forward for future projects so that the feedback supports the improvement of practices in design and construction.

Does testing with a thermal camera have the potential to become a routine inspection procedure for the industry? This research project hopes to find the answer.

Getting under the skin of new homes

Figure 1

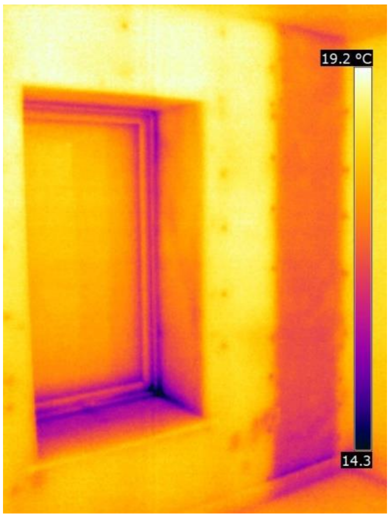

Figure 2

A thermal camera can reveal problems that lie beneath the surface. This new energy-efficient flat is almost ready for someone to move in. However, the darker red parts of the picture show more heat escaping, for example around the window-frame and in the corner where it appears the insulation has stopped short. Visual inspection would miss both of these problems.

Existing homes

Jo Hopper

Potential problem areas in older homes can also be discovered by using thermal imaging to reveal which parts could be helped by an eco-makeover.

This research is evaluating the effectiveness of improvement measures to homes delivered through the 'Arbed' scheme. Funded by the Welsh Government, Arbed (the Welsh word for 'save') aims to improve the energy efficiency of the most deprived homes across Wales.

Thermal images were taken at a selection of homes before and after external wall insulation was fixed to the outside of the houses. The photograph in Figure 3 and thermal image in Figure 4 is an example of a single installation. The lighter shades of orange and yellow represent the greatest amount of heat escaping, whilst the darker shades of purple and blue represent the least. There is a stark difference in the amount of apparent heat loss from the house that received the insulation in comparison to its neighbours.

This simple comparison illustrates the benefits of installing insulation to the outside of external walls. Ultimately, this should also mean less energy is used to heat the upgraded house.

However, the improvement may have been compromised by the quality of the installation. A closer inspection appeared to show gaps in the insulation where heat can still escape. Consequently, the results of the survey could be used to make a case with the builder that the workmanship on site was of poor quality and to help manufacturers improve their products. For example, manufacturers could use the thermal images to assist with the design of better solutions to seal common difficult junctions around openings in the wall for pipes and ducts. The images could also be used as part of the training for installers to demonstrate the consequences of leaving gaps between the insulation and around openings.

Figure 3

Figure 4

Acknowledgements

Both Tim and Jo are undertaking doctoral projects funded by Knowledge Economy Skills Scholarships under the Low Carbon Stream. The projects are funded by Cardiff Metropolitan University, Coastal Housing Group, and the European Social Fund through the European Union's Convergence programme administered by the Welsh Government.

Biographies

Tim Taylor

Tim Taylor graduated from the University of Cambridge with a Master's degree in Civil, Structural and Environmental Engineering (MEng) in 2006. His research interests include sustainable building design, building performance evaluation, sustainable development and ethical procurement issues in the construction products sector.

Jo Hopper

Jo Hopper graduated from University of Wales Institute, Cardiff with a first class honours degree in Architectural Technology and won the CIAT National Student Award for Technical Excellence in 2010. Her research interests include ecological retrofit solutions, community energy systems, occupant behaviour towards energy use, and sustainable living.

Dr John R Littlewood

John designed the industry collaboration and won the funding for the KESS doctoral projects. His research interests include: ecological design and improvement to existing dwellings, and the monitoring of environmental performance and occupant attitudes and behaviour.

Mr John Counsell

John Counsell is a Principal Lecturer at Cardiff Met. His research interests include Architectural Design, 3D Geographic Information Systems, Building Information Modelling, Architectural Heritage and Conservation and Ecological design of buildings.

Appendix VI: CIAT Student Award 2012 Technical Report

Evaluating the installation of retrofitted external wall insulation

Abstract

This paper presents an overview of an evaluation of the installation of retrofitted external wall insulation (EWI) at existing dwellings in Swansea. The EWI was funded and installed through the Welsh Government's Arbed scheme. The main focus of the evaluation was identifying the occurrence of potential thermal bridges as these can undermine the overall effectiveness of the EWI. Furthermore, thermal bridging can lead to internal condensation on the walls and ceilings and thus damp and mould growth, which poses a health risk to occupants. Working in collaboration with two housing associations who implemented the retrofitted EWI, the data collection involved field observations to record the technical solutions that were implemented on site and pre-retrofit and post-retrofit thermographic surveys to assess heat loss through the external walls of the dwellings. The key findings from the evaluation are the occurrence of potential thermal bridges due to a lack of preliminary surveys and appropriate technical details at the design stage of the retrofit process and poor execution quality on site. This paper will be of interest to stakeholders involved in retrofitting EWI, in particular Architectural Technologists who are responsible for the detailing of critical junctions at the design stage of a retrofit project.

Keywords: Dwellings, Evaluation, External wall insulation, Retrofit, Thermal bridge

Introduction

This paper is based on part of a final report, which has been prepared to complete the MPhil stage of an academic research project at Cardiff Metropolitan University (CMU). The research project was developed as a result of a lack of methodology and limited funding to assess the effectiveness of retrofitted energy efficiency improvement measures at dwellings in Swansea. The improvement measures were funded by the first phase of the Welsh Government's 'Arbed' scheme (Arbed I hereafter) and implemented by Coastal Housing Group (CHG) and Family Housing Association (FHA), who are both housing associations based in Swansea. The requirement for monitoring and evaluation of the improvement measures formed part of the funding criteria. However, without a methodology and the limited funding, the housing associations and CMU saw an opportunity to develop and undertake valuable research in the increasingly important field of retrofit in the domestic sector.

The purpose of this paper is to illustrate some of the key findings from the evaluation of the installation of retrofitted external wall insulation (EWI), as this was the main intervention employed by both CHG and FHA. The EWI was installed at some of the most deprived dwellings with the lowest energy efficiency ratings in Wales. The dwellings are all classified as hard-to-treat due to their solid exterior wall construction and were built before 1919. In addition, the households were classified as being in fuel poverty. To undertake the evaluation, data was collected through: dialogue with the housing associations; field observations to record the technical solutions implemented on site; and pre-retrofit and post-retrofit thermographic surveys. This paper commences by discussing the rationale and context for retrofitting EWI at domestic buildings; this is then followed by the methodology, findings and discussion, and conclusions from the evaluation.

Rationale for retrofitting external wall insulation

In the UK, the domestic sector is responsible for approximately 27% of carbon emissions, which is the main greenhouse gas contributing to climate change. Over 75% of these carbon emissions are from energy used to provide space heating in homes (Department for Energy and Climate Change, 2010; Department for Trade and Industry, 2008). This space heating demand is relative to the amount of heat loss through the external fabric and thus the least energy efficient dwellings contribute the most carbon emissions. One of the least energy efficient external fabrics for dwellings is solid walls. Solid walls allow approximately 45% of heat generated within the dwelling to be lost (Energy Saving Trust, 2011a). In addition, solid walls are classified as hard-to-treat' as they cannot receive easy to install and low-cost fabric upgrades, such as cavity wall insulation (Energy Solutions, 2011).

Around 15% of the approximately 26 million existing dwellings in the UK were built before 1919 with solid exterior walls. Furthermore, 19% of UK households are in fuel poverty, which means more than 10% of income is spent on energy use in the home (Department for Communities and Local Government, 2006; DECC, 2012). In Wales, the figures are opposite in that there are more pre-1919 dwellings than there are households in fuel poverty. Approximately 30% of existing dwellings in Wales were built before 1919 with solid walls and around 26% of households are in fuel poverty (EST, 2011b). Thus, improving the thermal performance of pre-1919 dwellings with solid walls should make a significant contribution to reducing domestic carbon emissions and fuel poverty, particularly in Wales. Whilst solid walls can be insulated externally or internally to improve thermal performance; this paper is focussed upon externally applied insulation.

Implementing retrofitted external wall insulation

Retrofitting EWI has many advantages over the alternative of internal wall insulation for improving the thermal performance of solid walls. The main advantage is the reduction of risks posed by unavoidable thermal bridging, for example at partition wall and floor junctions (Immendoerfer *et al,* 2008; Building Research Establishment, 2002). However, achieving a complete covering of EWI at particular critical junctions to prevent *all* thermal bridging during installation can be challenging. These junctions include: window and door openings; wall to roof junctions; window sills; and any projections, such as porches and conservatories (Construction Products Association, 2010; English Heritage, 2010; EST, 2006; Immendoerfer *et al,* 2008).

Thermal bridging can lead to increased heat loss and thus a reduction in the overall thermal performance of the EWI, along with internal surface condensation due to localised lower surface temperatures (Ward, 2006). The greater the level of insulation in buildings, the more significant thermal bridging becomes in terms of the overall thermal performance (Burberry, 1997). This is supported by claims that heat loss can be increased by as much as 30% as a result of thermal bridging between thermal elements and around openings (King and Weeks, 2010). However, the most serious effect of thermal bridging is potential internal surface condensation as this poses a risk of damp and mould growth occurring, which could have severe consequences for the health of occupants (English Heritage, 2010). Health issues associated with damp and mould growth includes: respiratory diseases; asthma; fungal infections; nausea and diarrhoea; and depression and anxiety (Roys *et al*, 2010).

Where thermal bridging does introduce internal surface condensation, to overcome this, occupants can either: increase the internal air temperature to raise the internal surface temperature above the dew point temperature of the air; or increase the rate of ventilation to reduce the dew point temperature of the air to below the dew point temperature of the internal surface. However, with either, or a combination of these approaches, energy use will be increased (Burberry, 1997), which will undermine the overall effectiveness and thus purpose of the EWI. Furthermore, households in fuel poverty are unlikely to be able to afford to increase their energy use sufficiently to prevent the internal surface condensation and thus potential damp and mould growth occurring.

It can therefore be concluded that thermal bridging needs to be avoided wherever possible, in particular at dwellings where households are in fuel poverty. To prevent thermal bridging occurring, the method of implementing retrofitted EWI should involve individual preliminary surveys, which can then inform the production of appropriate technical detailing at the design stage of the retrofitting process, in particular for the critical junctions identified above (Energy Solutions, 2011). These design intentions then need to be executed on site, to ensure they are not undermined by poor workmanship (Immendoerfer *et al*, 2008; Thomsen and Rose, 2009).

Methodology

In addition to the overall thermal performance, the literature review above has identified that the main issue to assess with retrofitted EWI is thermal bridging. For assessing the overall effectiveness of insulation and the location of thermal bridges, thermographic surveys are claimed to be the most efficient and informative technique available (Pearson and Seaman, 2003; Thomsen and Rose, 2009). Thus, thermographic surveys have been undertaken before and after the EWI installations. However, to gather further data to aid the evaluation process, dialogue with the housing associations and field observations have also been undertaken. These methods of data collection are based on established techniques used to undertake building performance evaluations (Zimring, 2010; Leaman *et al,* 2010; Technology Strategy Board and EST, 2009).

Dialogue with the housing associations

Through meetings, discussions and correspondence with the housing associations it has been possible to determine: the process employed to implement the retrofitted EWI; when the installations were taking place and therefore when to undertake the thermographic surveys and field observations; and the locations of the Arbed I dwellings that were receiving the retrofitted EWI. Collectively, this dialogue with the housing associations has proved invaluable in enabling the retrofitted EWI installations to be evaluated.

Field observations

Using a combination of photography and the reproduction of construction details, field observations allow a comprehensive understanding of the technical solutions that were implemented on site. Photographs were taken before, during and after the installations of the EWI at a sample of the Arbed I dwellings. CHG have also provided photographs from their records for the evaluation. The observed construction details have been produced to record the methods of installation on site. The details were then drawn up in CAD software using a combination of observations, photographs and technical information from the manufacturers.

Thermographic surveys

To assess improvements in overall heat loss and identify potential thermal bridging within the external walls that have received EWI, pre-retrofit and post-retrofit qualitative thermographic surveys were undertaken at a small sample of the Arbed I dwellings. Qualitative thermography produces thermal patterns, which can be used to identify locations of increased heat loss from the external fabric. However, it should be noted that this method does not allow for the measurement of heat loss. To aid interpretation of the thermal images, photographic images are also captured. There are strict environmental criteria for implementing thermographic surveys to maximise accuracy; these are summarised in Table 1. The process for implementing the thermographic surveys is set out in Table 2.

Table 1: Environmental criteria for undertaking thermographic surveys

Minimum temperature difference of 10°C between the inside and outside of the dwelling, with the inside being the warmer side.
No solar radiation exposed to surfaces for at least an hour before the survey.
No precipitation on surfaces for at least 24 hours before the survey.
Maximum wind speed of 10 metres per second during the survey.

Table 2: Process for implementing the thermographic surveys

1.	Check weather forecast to identify suitable day to undertake survey.
2.	Contact each occupant, either by telephone or in person, to: • Provide an explanation of: ○ The purpose of the survey; ○ Reason survey has to be undertaken during the hours of darkness; ○ Possible reasons for a likely change in arrangements (for example, precipitation in the preceding 24 hours); • Advise them of the: ○ Date; ○ Time; and ○ Names of the thermographers; • Request that they activate their heating at least four hours before the time of the survey (to ensure there is an adequate temperature difference between inside and outside the dwelling).
3.	Check batteries for the thermal camera and charge if necessary.
4.	Take digital photographs during the day prior to each survey.

Findings and discussion

This section of the paper illustrates and discusses a small sample of the findings from the evaluation and is focussed on the technical solutions at the roof eaves and verge junctions.

Commencing with the findings from dialogue with the housing associations, this is then followed by the field observations and concludes with the thermographic surveys.

Dialogue with housing associations

Through meetings, discussions and correspondence with the housing associations, it has been identified that an external project manager and a principle contractor were employed to oversee and undertake the Arbed I works, respectively. The principle contractor then used sub-contractors to install the EWI. A design and build contract was procured with the principle contractor, which meant they were responsible for all preliminary surveys, resultant technical design details and installation of the works. However, there is little evidence that preliminary surveys were undertaken to inform the production of specific technical details for the Arbed I dwellings. This is demonstrated by the housing associations having only received copies of generic details, produced by the manufacturer, and by some of the methods used to install the EWI, which are confirmed in the small sample of field observations below.

Field observations

The photograph in Figure 1 is the external corner junction between the eaves and verge at the gable wall and was taken after the retrofitted EWI was installed at one of the case study dwellings. This photograph represents an example of lack of planning before implementation and poor execution on site. The following issues are illustrated: the new fascia board, which was installed as part of the works, does not extend to the new outside edge of the gable wall, resulting in an unsatisfactory finish; there is a gap between the edge of the fascia board and insulation board that has been fixed to the gable wall, which could allow rainwater to enter and penetrate the insulation, as well as exacerbating the potential thermal bridge at the eaves; the capping that is covering the top of the insulation on the gable wall has been cut too short and therefore does not provide complete protection from rainwater penetration; and the gutter does not extend to the external edge of the roof tiles and therefore rainwater can run down into the top of the unprotected insulation board fixed to the gable wall. Where rainwater can penetrate the insulation, the likely consequence is that the overall thermal performance will be impaired.

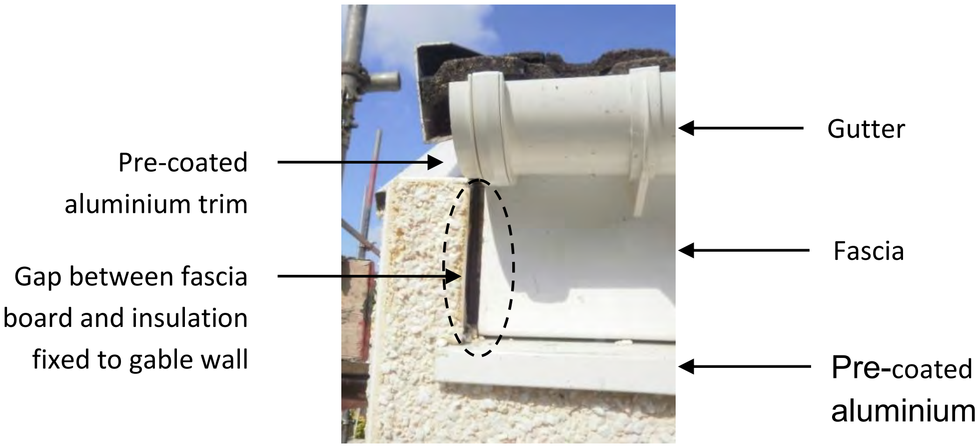

Figure 12: Photograph of a poorly planned and executed eaves junction detail (Hopper, 2012)

Figure 2 is the observed technical solution for the eaves. The detail illustrates the use of a 'pre-coated aluminium trim' to cap the top of the insulation below the fascia board, as shown in

Figure 1. The observed detail identifies the potential path of a thermal bridge at the eaves, resulting from the insulation stopping below the fascia board. This method is the manufacturer's recommended technical solution for protecting the top of the insulation at buildings that do not have a roof overhang. However, it would appear that a more satisfactory solution should be explored to reduce the potential risks by this method of installation. If there is a thermal bridge in the location identified, there is a risk of internal condensation occurring. The condensation could lead to damp and mould growth on the internal surface of the walls and ceiling, which could affect the health of occupants.

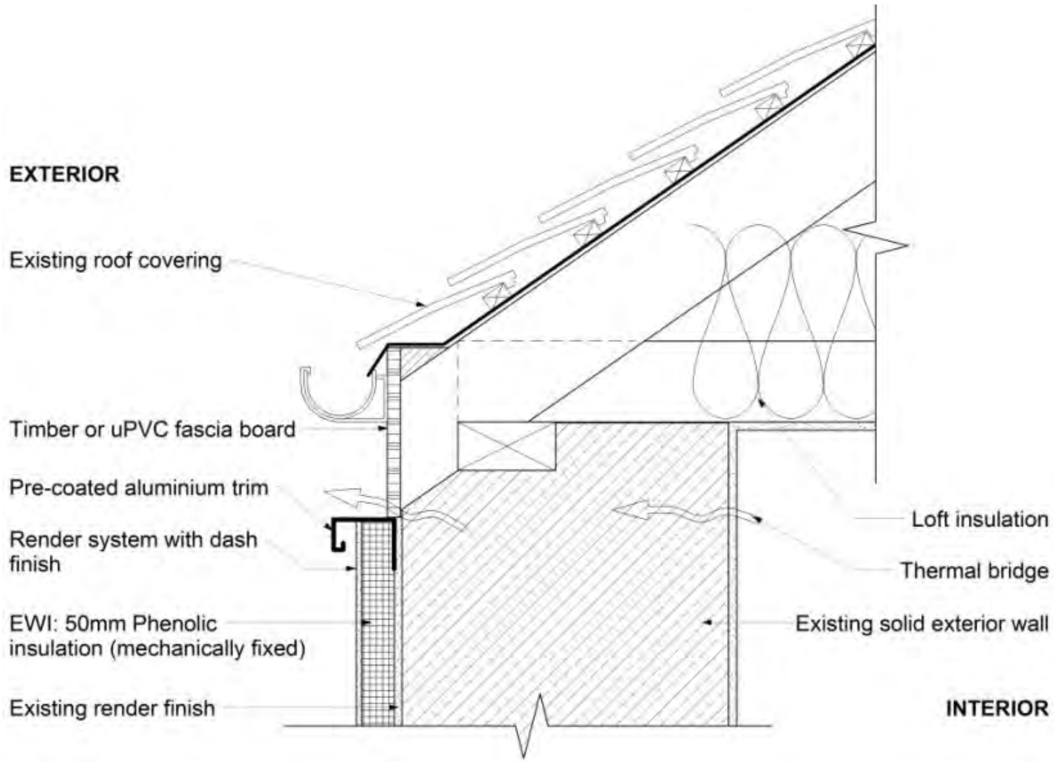

Figure 13: Eaves section detail as observed on site (Hopper, 2012)

Thermographic surveys

Figures 3 and 4 are a photograph and thermal image of an Arbed I dwelling before retrofitted EWI was installed, respectively. Figure 5 is a photograph of the same case study dwelling after the EWI was installed and Figures 6 and 7 are the corresponding thermal images. The comparison between Figures 4 and 6 appear to demonstrate an overall reduction in heat loss through the external walls, which could be used to promote the retrofitting of EWI. However, Figures 6 and 7 appear to illustrate that thermal bridging has potentially occurred: at the eaves; at the verge (of the porch); under the window sills; at the reveals for window and door openings; and at the junction between the porch roof and wall, and the main external wall. Whilst field observations suggest that these thermal bridges could occur, the thermal images appear to provide evidence to this effect.

Figure 14: Photograph of a case study dwelling before EWI was installed (Hopper, 2012)

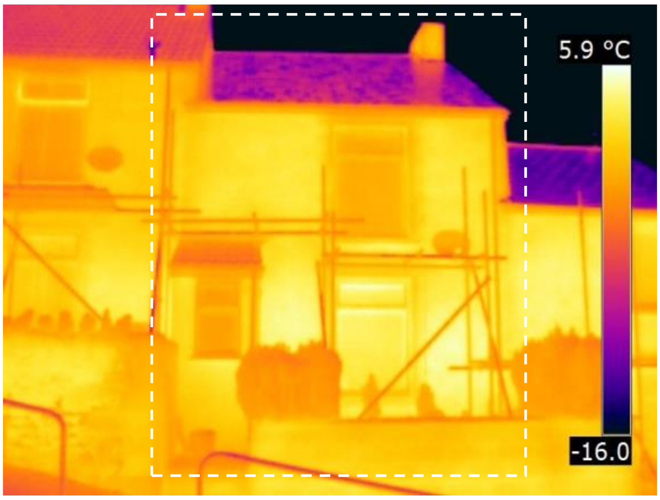

Figure 15: Thermal image of a case study dwelling before EWI was installed (Hopper, 2012)

Figure 16: Photograph of a case study dwelling after EWI was installed (Hopper, 2012)

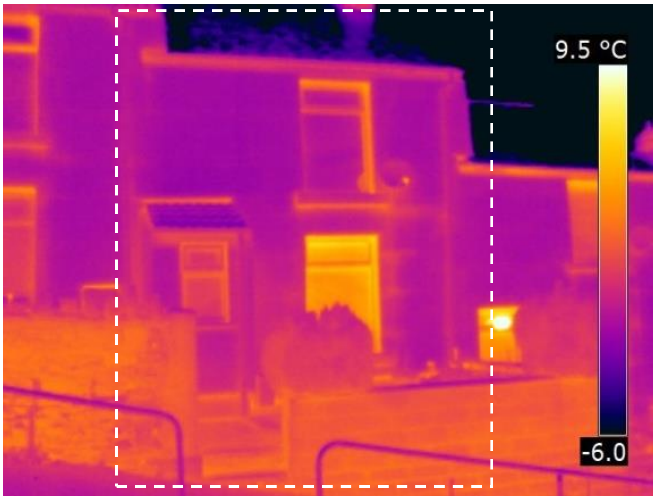

Figure 17: Thermal image of a case study dwelling after EWI was installed (Hopper, 2012)

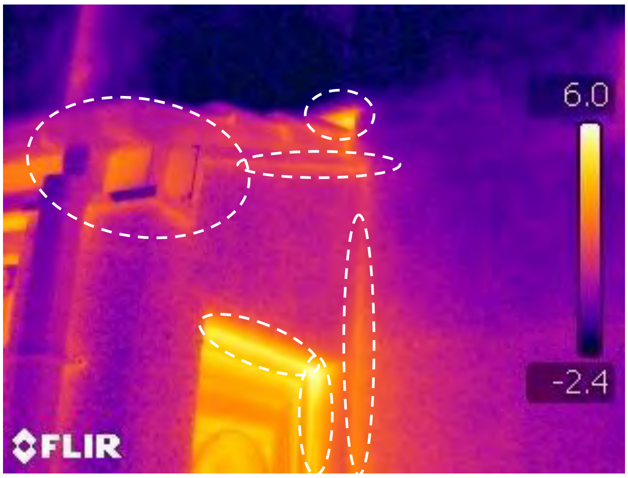

Figure 18: Thermal image showing eaves detail at front porch of case study dwelling (Hopper, 2012)

Conclusions

The purpose of this paper was to illustrate some of the key findings from an evaluation of the installation of retrofitted external wall insulation (EWI). The retrofitted EWI was installed at some of the most deprived existing dwellings in Swansea. Coastal Housing Group (CHG) and Family Housing Association (FHA), who are both housing associations based in Swansea, implemented the EWI installations following allocation of funding through the first phase of the Welsh Government's Arbed scheme (Arbed I). The evaluation was undertaken as a result of a lack of methodology and limited funding to assess the effectiveness of the EWI, which was a funding criterion of Arbed I.

The evaluation commenced with a literature review, which identified the importance of upgrading the thermal performance of solid exterior walls in terms of reducing UK carbon emissions. Furthermore, it has been identified that when retrofitting EWI the occurrence of thermal bridging can undermine the overall thermal performance and this could potentially introduce internal condensation, which can lead to damp and mould growth and subsequently pose a health risk to occupants. Thus, the focus of this evaluation is thermal bridging through the EWI. In order to assess the occurrence of thermal bridging, the methodology for data collection involves: dialogue with the housing associations to gain a better understanding of how the EWI was implemented; field observations using photography and the reproduction of technical details to record the technical solutions that were implemented on site; and pre-retrofit and post-retrofit thermographic surveys to assess overall reductions in heat loss and identify the locations of potential thermal bridging.

The key findings from the data indicate that potential thermal bridging has occurred due to a lack of preliminary surveys and appropriate technical details at the design stage of the retrofit process, and poor execution on site. From these findings, it can be concluded that the production of observed technical details has provided a valuable link between photographic and thermographic data for assessing some of the potential issues surrounding the methods and quality of installation of the retrofitted EWI. To identify if the thermal bridging does introduce internal condensation, it is recommended that further research is undertaken, which includes longitudinal monitoring of moisture levels on the internal surfaces within the dwellings.

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Appendix VII: CIAT Research & Practice Book Chapter

Case study D

Assessing retrofitted external wall insulation

Jo Hopper

Assessing the performance of retrofitted external wall insulation to existing properties is the theme of this case study chapter. The work draws on applied research conducted on existing houses in South Wales. The background and context to the research is described, followed by an exploration of the issues relevant to the insulation of solid external walls of existing dwelling houses. This is followed by the methodology, findings and discussion, and conclusion, which includes recommendations and implications for research by architectural technologists.

INTRODUCTION

Within this chapter the author demonstrates the significance of the architectural technologist's knowledge and skills for undertaking applied research. The author is an architectural technologist and winner of the CIAT Student Award for Technical Excellence in 2010 (CIAT, 2011). The award winning submission was based on the final year design project from the author's first degree, which was from the Cardiff School of Art and Design within Cardiff Metropolitan University (formerly the University of Wales Institute Cardiff). Following graduation the author successfully applied to study for a PhD through applied research within the same school. The aim of the research is to evaluate the implementation of retrofitted external wall insulation (EWI) and the resultant impact on energy use, carbon emissions and fuel poverty. EWI was installed through the first phase of the Welsh Government's Arbed funding scheme at a selection of Swansea's hard-to-treat dwellings. One of the funding criteria was that monitoring and evaluation should be undertaken to demonstrate the effectiveness of the energy efficiency improvements. However, there was no methodology in place and very limited funding for these assessments, therefore the doctoral research project was designed by a housing association based in Swansea in conjunction with Cardiff Metropolitan University with the aim of meeting the requirements.

One of the objectives of the research is to examine the technical solutions used to retrofit the EWI and determine the effects on the quality of installations. The methodology adopted includes site visits to discuss the retrofit process with the housing association and to undertake field observations (during and after installations), along with pre-retrofit and post-retrofit thermographic surveys. The key findings comprise evidence of potential thermal bridging as a result of an incomplete covering of insulation, which was due to either: inadequate preliminary surveys; the omission of appropriate technical details at the design stage; poor execution and insufficient quality control on-site during installations; or a combination of these issues. These findings could have implications for stakeholders involved in EWI retrofit projects, in particular for phase two of the Welsh Government's Arbed scheme and the UK Government's forthcoming Green Deal initiative.

BACKGROUND AND CONTEXT

The UK Government has set a legally binding target to reduce greenhouse gas (GHG) emissions by 80% by 2050. However, if this target is to be realised then the reduction in

GHG emissions resulting from energy use in existing dwellings needs to be prevalent. With over 66% of the current housing stock expected to still be in use in 2050 (Department for Communities and Local Government (DCLG), 2008), thermally improving existing dwellings is becoming a priority. The challenge of undertaking these improvements is equally important, as the UK have a substantial number of older and poor quality dwellings. Around 15% of approximately 26 million existing dwellings in the UK were built before 1919 and 40% have a Standard Assessment Procedure (SAP) rating of 41 or below, which correlates to an F or G rating on an Energy Performance Certificate (DCLG, 2006).

All G rated and many F rated dwellings have a SAP rating of 30 or below, which indicates they have very poor thermal and fuel efficiency (Boardman, 2007; DCLG, 2006). These dwellings also qualify as a Category One Hazard for Excess Cold under the Housing, Health and Safety Rating System, which means they pose a risk to the health of occupants (Boardman, 2007). The majority of these dwellings are also classified as 'hard-to-treat', which denotes that they are either: of solid wall construction; of non-traditional construction; not on the mains gas network; do not have a loft space; are part of high rise block; or are not suitable for standard efficiency measures for technical reasons (National Energy Action, 2008; Housing Energy Advisor, 2011). According to National Energy Action (2008), over 50% of hard-to-treat dwellings are of solid wall construction.

In Wales approximately 21% of existing dwellings have solid walls (King, 2012a). In recognition of the requirement to thermally improve these and other poor quality existing dwellings the Welsh Government implemented the Arbed funding scheme in 2009. The purpose of the scheme is to take a community-based and whole-street approach to the reduction of energy use, carbon emissions and fuel poverty. For phase one of Arbed, local authorities and social housing providers were able to bid for a share in the funding to upgrade both public and privately owned dwellings in the most deprived areas across Wales. Approximately 30% of the £60 million funding was invested in insulating solid walls at nearly 3000 hard-to-treat dwellings across Wales (Welsh Government, 2011). These figures suggest an average cost of £6000 per dwelling, which is around 50% less than for an isolated installation. These reduced costs were achieved due to the application of economies of scale (Welsh Government, 2011). EWI costs at this level are comparable to levels of funding that are expected to be available through the Green Deal, which is estimated to be up to £10,000 (AECB, 2011).

INSULATING SOLID WALLS

Solid walls can either be insulated internally or externally. As documented in Hopper *et al* (2012a), the advantages of retrofitting EWI over internal wall insulation include: reduced risks from unavoidable thermal bridging caused by an incomplete covering of insulation, for example at partition wall and floor junctions; air-tightness is improved; thermal mass is retained on the inside of the building, thus aiding control of the internal environment; minimal disruption to occupants; internal floor area is retained; and internal fittings and fixtures do not have to be relocated or restricted to predetermined locations. The main advantage of EWI is that it provides a thermal and waterproof layer for the entire envelope of the building (King, 2012b). However, retrofitting EWI can present technical challenges to ensure a complete covering is achieved.

Where EWI is not continuous, avoidable thermal bridging can occur. This poses a risk of internal and interstitial condensation, which can lead to damp and mould growth, and compromise reductions in heat loss (Hopper *et al,* 2011 and 2012a; English Heritage, 2010; EST, 2006; Immendorfer *et al,* 2008). According to King and Weeks (2010), approximately 30% of heat loss from a building can be attributed to thermal bridging between thermal elements and around openings. Furthermore, Burberry (1997) states that the greater the level of insulation in buildings, the more significant thermal bridging becomes in terms of the overall thermal performance. To minimise thermal bridging when retrofitting EWI, and thus increase overall thermal performance, preliminary surveys should be undertaken to inform the production of appropriate technical details at the design stage (Energy Solutions, n.d.). Particular attention is required when designing details for: window and door openings; wall to roof junctions; window sills; and any projections, such as porches and conservatories (Construction Products Association, 2010; English Heritage, 2010; EST, 2006; Immendorfer *et al,* 2008; Hopper *et al,* 2012a). These design intentions then need to be executed accurately on site, to ensure overall thermal performance is not undermined by poor workmanship (Immendorfer *et al,* 2008; Hopper *et al,* 2012a).

METHODOLOGY

The focus of this study is to assess EWI installations at some of the Arbed phase one case study dwellings in Swansea. The purpose of these assessments is to examine the technical solutions implemented on site and determine the effects on the quality of the EWI installations. Based on the literature review the most significant issue that could affect the overall quality of the EWI's physical performance is that of thermal bridging, and the subsequent consequences related to possible condensation. Using established building performance evaluation techniques for data collection, the methodological approach decided upon includes: site visits, which involved meeting with the housing association and undertaking field observations at the dwellings to record methods of installation; and pre-retrofit and post-retrofit thermographic surveys to assess before and after heat loss. Collectively, these methods should allow for the identification and causes of potential thermal bridging.

Site visits

During the site visits regular meetings were undertaken with the housing association and information was collected to inform the process used to implement retrofitting the EWI at their allocated Arbed dwellings. Site visits also involved field observations, where the main method of data collection was photography. Photographs were taken before, during and after EWI installations, which allowed a record to be kept for the different stages of the retrofit process. Through field observations, the technical details that were implemented on site were also recorded. These technical details were then drawn in CAD software, using a combination of the photographs, observations made by the author, and generic details and specifications obtained from the manufacturers of the EWI systems.

Thermographic surveys

Pre-retrofit and post-retrofit thermographic surveys were undertaken to qualitatively assess external wall insulation that has been installed at a small sample of the Arbed case study dwellings in Swansea. The qualitative thermographic survey images display thermal patterns that indicate the possible locations of increased heat loss and thus potential thermal bridging. Due to the environmental conditions recommended to undertake a thermographic survey, the initial challenge was to determine a day with a suitable weather forecast, both before and during the planned survey. The recommendations include: no solar radiation for at least the preceding hour before the survey; no precipitation during the survey and for the preceding 24 hours to ensure the fabric is completely dry; and maximum wind speeds of 10 meters per second. Furthermore, a 10℃ temperature difference between the inside and the outside of the building during the survey is recommended.

Once a suitable date and time for each survey was determined, occupants were contacted, either by telephone or in person, to explain the purpose of the survey and to establish their availability. If the occupant was available, they were: advised of the names of the thermographers; requested to activate their heating at least four hours prior to the survey; requested that all windows and doors are kept shut before and during the survey; asked for permission to take photographs of their home, as well as take the thermal images; and permission was requested to enter their home at the time of the survey to record internal temperature and relative humidity readings. Photographs were taken the day preceding the surveys for the purposes of aiding interpretation of the thermal images.

Results from one Arbed dwelling in Swansea are described for the pre-retrofit and post-retrofit thermographic surveys. These results represent common findings displayed at many of the Arbed dwellings in Swansea.

FINDINGS AND DISCUSSION

The housing association worked with an external project manager and engaged a design and build contract with a principal contractor to oversee and undertake the retrofitting works. The contractor employed sub-contractors to install the EWI. Although the principal contractor was responsible for the preliminary surveys and the resultant technical details for the various types of junctions, there is little evidence that these were undertaken. Lack of evidence is demonstrated by some of the methods used to install the EWI, confirmed in the field observations. Furthermore, the housing association only received copies of generic technical details and specifications, which were produced by manufacturers.

Time constraints imposed by one of the Arbed funding criteria may have restricted the level of preliminary work that could reasonably be undertaken. This criterion was that works had to be completed by the end of March 2011, which was less than 12 months after confirmation that the funds were to be awarded. Much of this time was spent engaging with occupants of dwellings and undertaking procurement for the works. Installations of the EWI commenced in late December 2010. This meant that much of the work had to be undertaken in poor weather conditions, despite the manufacturers' recommendations that the EWI is not to be installed in such circumstances.

Field observations

Figure 1 is an example of a completely sealed external junction at the eaves, which demonstrates that despite the challenges of retrofitting EWI, relatively good detailing can be achieved in practice. Nevertheless, there is likely to be a thermal bridge created at the eaves due to the insulation stopping below the fascia board, as demonstrated in Figure 4. This is the technical solution recommended by the manufacturer for buildings with no roof overhang at the eaves and verge junctions, which is the form of roof construction at the case study dwellings.

Figure 2 is an example of poor execution on site, a direct contrast to Figure 1, in that it appears that not enough thought and consideration has gone into how to achieve a satisfactory technical solution. The new fascia board, which was installed as part of the works, does not extend to the new outside edge of the gable wall, resulting in an unsatisfactory finish. There is a gap between the edge of fascia board and the insulation board that has been fixed to the gable wall, which could allow rainwater to enter and penetrate the insulation, as well as exacerbating the potential thermal bridge at the eaves. The capping that is covering the top of the insulation on the gable wall has been cut too short and therefore does not provide complete protection from rainwater penetration. Furthermore, the gutter does not extend to the external edge of the roof tiles and therefore rainwater can run down into the top of the unprotected insulation board fixed to the gable wall. Where rainwater can penetrate the insulation, the likely consequence is that the overall thermal performance will be impaired.

Figure 3 demonstrates a lack of a preliminary survey that should have identified the obstruction the insulation will cause for opening the window. As a result, an area of the wall has been left un-insulated and has created a thermal bridge. Had a preliminary survey been undertaken, a more appropriate technical solution for the junction may have been ascertained. This particular issue was relatively common in the Arbed case study dwellings in Swansea and in each situation where this was encountered, an area of the wall had to be left without any insulation.

Figure 1: Example of a well planned and executed junction detail

Figure 2: Example of a poorly planned and executed junction detail

Figure 3: Example of lack of a preliminary survey and appropriate technical detail

Figures 4 to 6 (which are not to scale) illustrate the technical solutions implemented on site at eaves, window sills and pavement to external wall junctions. These details have been produced based on observations from sites and have provided a valuable link between photographic and thermographic data for assessing some of the potential issues. Figure 4 demonstrates the use of the pre-coated aluminium trim to cap the top of the insulation, which can be seen in Figures 1 and 2. This detail identifies the potential path of a thermal bridge at the eaves, resulting from the insulation stopping below the fascia board. As discussed above, this is the manufacturer's recommended technical solution for protecting the top of the insulation at buildings that do not have a roof overhang.

However, it would appear that a more satisfactory solution should be explored to reduce the potential risks posed by this method of installation. If there is a thermal bridge in the location indicated, there is a risk of interstitial and internal condensation. This could lead to the rotting of timber and thus jeopardise the structural integrity of the roof construction, and also lead to damp and mould growth on the internal surface of the walls and ceiling, which could affect the health of the occupants.

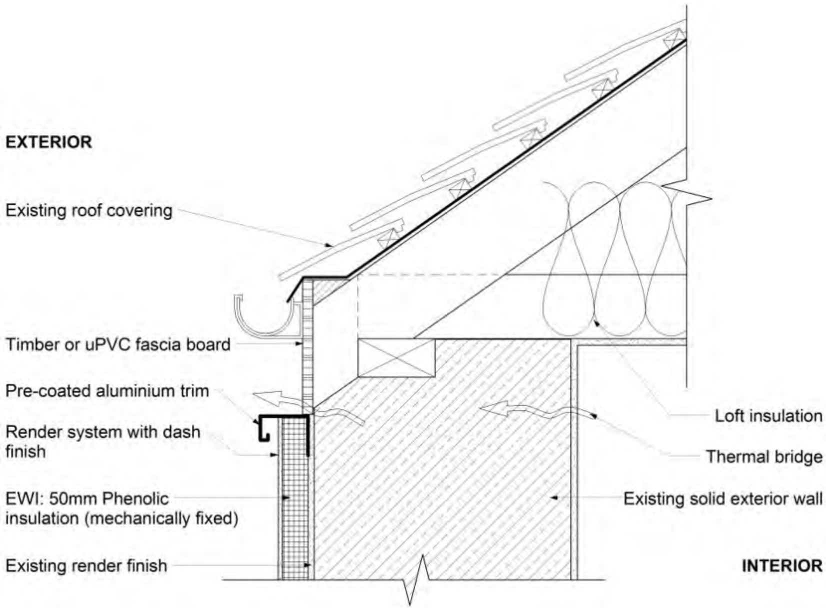

Figure 4: Eaves detail as observed on site (Source: Hopper *et al* 2012b)

Figure 5 illustrates the method of installing the EWI system at the window sill junctions. To maintain the window projection, insulation was fixed to the front of the existing stone sills. The rationale for this method does not appear to be for the purpose of minimising heat loss at this junction because there is the potential for thermal bridging through and below the existing stone sill. This could result in damp and mould growth occurring below the window sill on the internal surface of the wall. A more satisfactory solution could have been to insulate above and below the window sill and thus provide a continuous covering. This could be improved further by ensuring that future window replacements incorporate frames with a thermal break.

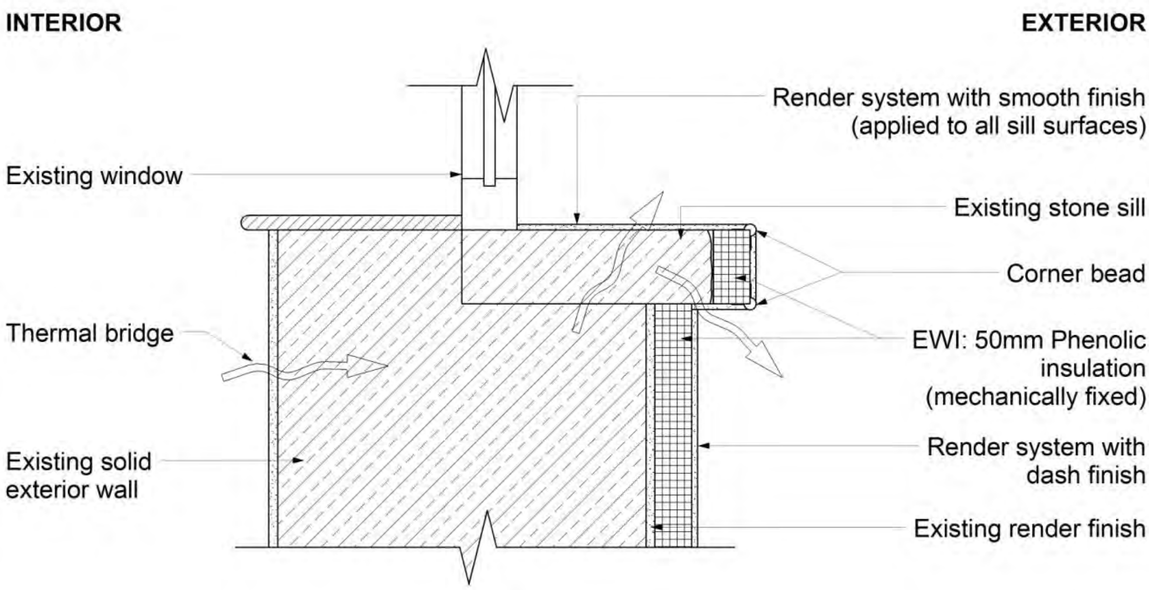

Figure 5: Window sill detail as observed on site (Source: Hopper *et al,* 2012b)

Figure 6 shows the method used to insulate the base of the external wall at the junction with the pavement. There are two variations in the methods of installation recommended by the manufacturer in their generic details. One method is that extruded polystyrene (XPS) is installed below the phenolic insulation, which is used above the damp proof course (dpc) level. With this method the manufacturer's recommendations also illustrate that the XPS should be installed below ground level. The other method is for no insulation to be installed below the dpc level. Instead with this method, the plinth area of the external wall can be painted with silicone paint. While an attempt has been made at the Arbed case study dwellings in Swansea to improve the thermal performance by insulating the plinth of the external wall, unless the first method is used there remains the potential for thermal bridging at ground level (as shown in Figure 6). Due to the age of the dwellings it is predicted that most of them have suspended timber ground floor constructions. If condensation occurs due to the thermal bridging, there is a risk that the floor structure could get damp and thus rot. In addition, damp and mould growth could occur at the base of the internal surface of the external wall.

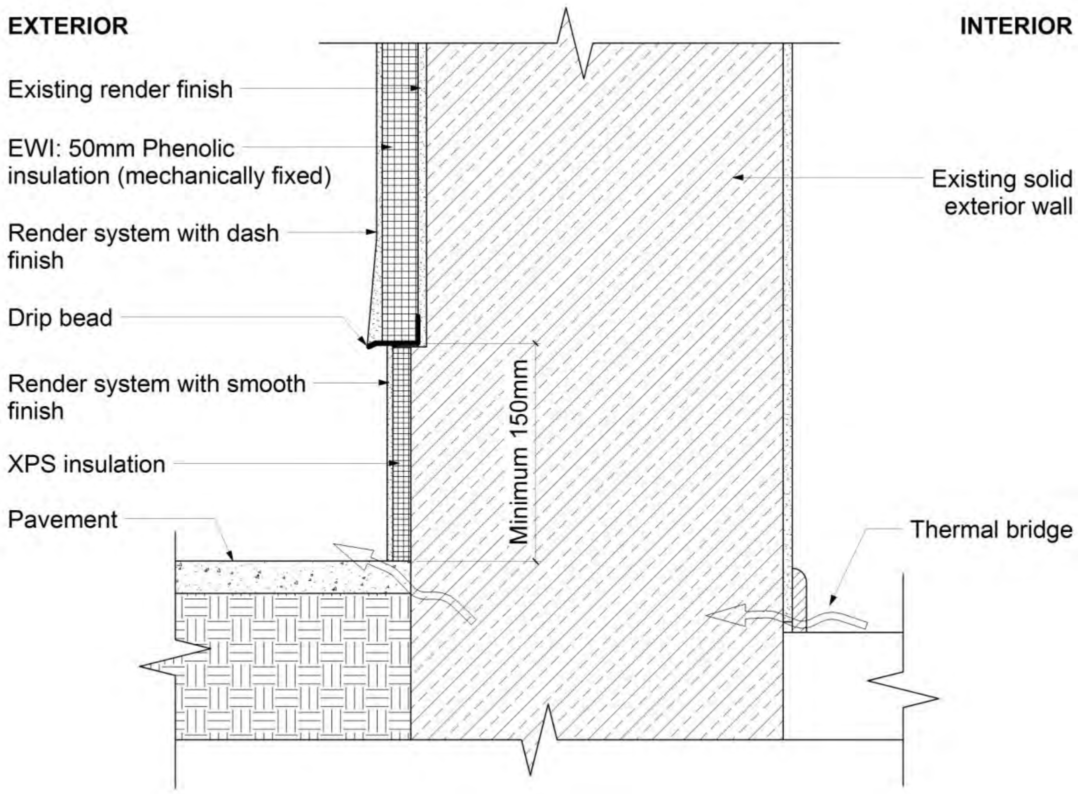

Figure 6: Pavement to external wall junction detail as observed on site (Source: Hopper *et al* 2012b)

Thermographic surveys

Figures 7 to 11 show an Arbed case study dwelling in Swansea before and after the work took place. Figures 7 and 9 aid interpretation of the thermal images (Figures 8, 10 and 11). The comparison between Figures 8 and 10 appears to demonstrate an overall reduction in heat loss through the external walls, which could be used to promote the installation of EWI. However, Figures 10 and 11 appear to illustrate that thermal bridging has occurred: at the eaves; under the window sills; at the reveals for window and door openings; between the XPS covering the plinth of the external wall and the phenolic insulation covering the remainder of the external wall above; at the junction between the pavement and external wall; and where services enter the dwelling, for example the gas pipe. While the field observations suggested that these thermal bridges could occur, the thermal images appear to confirm that they do.

As discussed by King and Weeks (2010), English Heritage (2010) and Hopper *et al* (2012), not only could thermal bridges undermine reductions in heat loss, they also present a potential risk to both the dwelling structure and health of occupants due to interstitial and internal surface condensation. If the illustrated methods for implementing EWI were to be used for the Green Deal, there could be implications for litigation as a result of this induced condensation. In order to reduce the risk to the health of occupants posed by consequential damp and mould growth, the internal air temperature needs to be increased to raise the internal surface temperature above the dew point temperature of the air. The alternative is that the dew point temperature of the air is reduced to below the dew point temperature of the internal surface by increasing the rate of ventilation. With either, or a combination of these approaches, energy use will be increased, which will undermine the overall effectiveness and thus the purpose of the EWI. Furthermore, insufficient reductions in energy use will result in the principles of the Green Deal not working for EWI; and achieving the 2050 target could be jeopardised.

Figure 7: Photograph of an Arbed case study dwelling before retrofitted EWI was installed

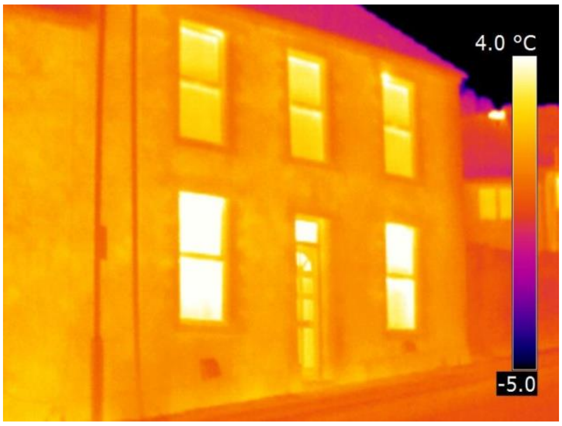

Figure 8: Thermal image of an Arbed case study dwelling before retrofitted EWI was installed

Figure 9: Photograph of an Arbed case study dwelling after retrofitted EWI was installed

Figure 10: Thermal image of an Arbed case study dwelling after retrofitted EWI was installed

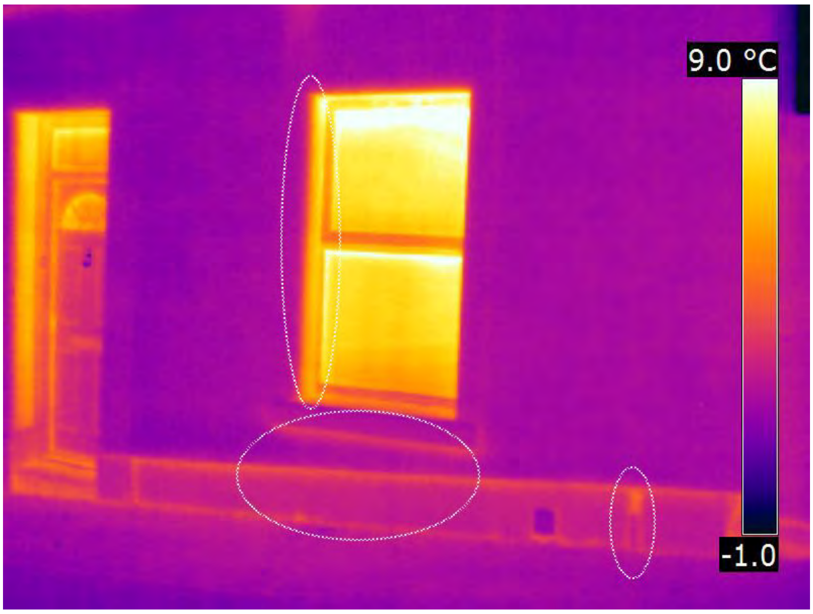

Figure 11: Thermal image showing small area of external wall after retrofitted EWI was installed

CONCLUSION

The findings have demonstrated that thermal bridging can result from a lack of preliminary surveys and appropriate design details for the individual dwellings at the design stage, along with poor execution and a lack of appropriate quality control on site during the installations. These findings could have implications for future EWI installations, in particular proposals through the second phase of Arbed and the forthcoming Green Deal initiative. It is recommended that further research is undertaken to investigate: the occurrence of interstitial and internal condensation in the locations identified, for example at the eaves, under window sills and external wall to ground floor junctions; any resultant affects on the structure of the dwellings and health of occupants; and alternative technical solutions to prevent thermal bridging at a range of critical junctions, which are commonplace at existing dwellings.

This case study has also helped to demonstrate the value of the skills and knowledge of an architectural technologist for undertaking applied research. In the author's opinion architectural technologists are suitably qualified with the technical and scientific knowledge and skills to:

- Assess existing dwellings for suitability for retrofitting EWI through undertaking preliminary surveys;
- Identify and produce appropriate technical details to overcome thermal bridging at some of the problematic and non-standard junctions that are encountered at existing dwellings, particularly those that are older and unique in their original construction;
- Recommend appropriate materials for the wide variety of constructions used to build existing dwellings in the UK;
- Undertake on-site quality control checks (for example, using field observations and thermographic surveys) and make impulsive decisions on how to overcome unidentified issues that are encountered during the retrofit process;

- Monitor and evaluate the implementation and execution of retrofit projects to ensure that lessons learnt are acted upon during decision making of future projects;
- Assist manufacturers with developing new products to overcome non-standard junctions to avoid thermal bridging; and
- Undertake Green Deal Assessments to reduce potential for future litigation that could result from inappropriate advice and recommendations from a lesser qualified assessor.

Acknowledgements

This case study chapter forms part of a three year doctoral research project, which is funded by Cardiff Metropolitan University, the European Social Fund through the European Union's Convergence programme administered by the Welsh Government, and Coastal Housing Group.

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Appendix VIII: Pre-retrofit Occupant Survey Questionnaire and Supporting Documents

The Ecological Built Environment Research & Enterprise group (EBERE)

Cardiff School of Art and Design
Western Avenue
Cardiff, CF5 2YB

9th February 2011

Dear Sir or Madam,

The University of Wales Institute, Cardiff (UWIC) are working with Coastal Housing Group to conduct research about energy use, Occupant behaviour and Occupant comfort in existing homes in Swansea and Neath. We would like to know about your home and how you use and feel about it.

In order to do this we would like to conduct a face-to-face interview survey questionnaire by visiting you in your home at a time which is convenient to you. The interview should take approximately 30 to 45 minutes and would greatly contribute to knowledge about existing homes and their occupants. In addition, we would like to discuss with you the possibility of monitoring the environmental conditions in your home.

<u>This is NOT a commercial or governmental survey</u>

Information about existing homes is very important in order to gain an understanding of whether they currently meet occupant comfort and well-being requirements and how they need to be improved to ensure they are fit for purpose for the immediate and future generations.

If you think you would be interested in taking part in this valuable research please contact us either by telephone, email or post using the enclosed form and pre-paid envelope, stating your name, your preferred contact details and your interest in taking part. We will then contact you to provide you with further information about the research study and if, after receiving this information; you are willing to take part in the interviews we will arrange a mutually convenient time to visit you. You will be given a copy of the information about the research and you will be asked to sign a consent form, to which you will be given a copy, prior to the interviews and monitoring commencing.

Yours faithfully,

Jo Hopper

Ms Jo Hopper
University of Wales Institute, Cardiff
Tel: 02920 201196
Mobile: 07926 537644
Email: johopper@uwic.ac.uk

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.
Director of EBERE: Dr John R Littlewood jlittlewood@uwic.ac.uk

1

The Ecological Built Environment Research & Enterprise group (EBERE)

For postal returns

Please fill in your preferred contact details, your name and signature to confirm your interest in taking part in the research and that you would like further information. **You are NOT agreeing to take part in the interviews and monitoring research at this stage. You are just registering your interest.**

Address:

Postcode:

Telephone number:

Email:

I am interested in taking part in the research and I am happy for you to contact me with further information.

Name……………………………………………………………

Signature……………………………………………………….

Date……………………………………………………………..

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2

The Ecological Built Environment Research & Enterprise group (EBERE)

Cardiff School of Art and Design

Western Avenue

Cardiff, CF5 2YB

15th February 2011

Environmental Performance of Existing Homes Project

Participant Information Sheet

UWIC Ethic Committee Reference number: 18.01.02/11 Hopper

Dear Sir or Madam,

We would like to invite you to take part in a research project that is investigating the environmental performance of existing homes in Swansea and Neath. The study aims to assess the environmental impacts of existing homes in use and how they can be improved for the comfort and well-being of occupants, whilst reducing energy use and carbon emissions. This is a University research project, not a commercial or governmental survey, and the results will be used to contribute to our knowledge and understanding of how the environmental impacts of existing housing can be reduced. The research is being undertaken by the Ecological Built Environment Research & Enterprise group (EBERE) at the University of Wales Institute, Cardiff (UWIC) and is being funded by Coastal Housing Group, UWIC and the European Social Fund through the European Union's Convergence programme administered by the Welsh Assembly Government.

We are asking residents who are receiving improvement measures from Coastal Housing Group's Arbed scheme to their homes to contribute their ideas, experiences and opinions about their homes. In order to do this we would like to conduct a face-to-face interview survey questionnaire by visiting you in your home at a time which is convenient to you. The interview should take approximately 30 to 45 minutes and would greatly contribute to knowledge about existing homes and their occupants. In addition, we would like to discuss with you the possibility of monitoring the environmental conditions in your home. Please fill in your details on the enclosed consent form. This is a very important aspect of our work so that we can measure the environmental impacts of existing homes following the improvement measures which Coastal Housing Group are managing. Participants will neither be named nor identifiable in any publications or other public presentation of the research. All records will be securely kept in accordance with data protection legislation and the individual records will be destroyed after 10 years.

Your involvement

In order to proceed, it is important that you are clear about what your participation will involve so that you are in a position to make an informed decision as to whether you wish to take part. This information sheet accompanies the consent form.

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.

Director of EBERE: Dr John R Littlewood jlittlewood@uwic.ac.uk

Social monitoring (Interviews)

If you consent to taking part in the interviews, one of our researchers may contact you to arrange an appointment (at a time convenient to you) so that you can take part in the survey about your home. In preparation for the interview it would be useful and could save time if you have the previous year's utility bills to hand.

Physical monitoring (Monitoring Environmental Performance)

We would like to monitor the thermal performance and energy use in your home. Monitoring will be carried out by a researcher from UWIC and will not require any action by you. The types of monitoring we would like to undertake involve measuring: the heat loss/ gain through the external fabric of your home using infra-red thermography; temperature; humidity; ventilation (natural and mechanical); electrical circuit flows; and energy use using Smart meters.

Anonymity

We will take all reasonable steps to preserve your anonymity and we will respect your privacy at all times. When producing project reports and other publications based on the research, the data that we collect from your home and from interviews we conduct with you will be presented in an anonymous form. This means that we will not provide any information that would positively identify your home, you or any member of your household.

We are bound by the terms of the data protection act and, unless you give your permission, we will not disclose any information we hold about you or your household to anyone outside the EBERE research team. Your data will be held securely at the University and will be destroyed after 10 years.

When we have finished the study and analysed the information, the consent form and all the forms we use to gather data will be kept for 10 years since this is a requirement of one of the funding bodies for this research project.

Withdrawal

We fully understand that you may change your mind about being involved in the project and would reassure you that you are free to withdraw from the project at any time. If you feel it necessary to withdraw, all personal information will be deleted and if requested all research data relating to your home will be deleted also.

Further Information

If you have any queries about the project, or would like further information before making up your mind, please don't hesitate to contact me or one of the team at UWIC.

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The Ecological Built Environment Research & Enterprise group (EBERE)

Jo Hopper

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The EBERE Team of Researchers

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The Ecological Built Environment Research & Enterprise group (EBERE)

CONSENT FORM

UWIC Ethics Reference Number	18.01.02/11 Hopper
Participant name or Study ID Number	
Title of Project	Environmental Performance of Existing Homes Project
Name of Researcher	Jo Hopper

PLEASE COMPLETE THIS SECTION BEFORE THE INTERVIEW AND MONITORING COMMENCES

Please write your initials in each box and sign and date the declaration below:

1. I confirm that I have read and understand the information sheet dated 16th February 2011 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my relationship with UWIC or Coastal Housing Group, or my legal rights, being affected. ☐
3. I understand that relevant sections of any research notes and data collected during the study may be looked at by those UWIC employees responsible for undertaking and monitoring this research and for data protection. I give permission for these individuals to have access to my records for that purpose. ☐
4. I agree to take part in the above study. ☐
5. I agree to the interview being audio recorded. ☐

____

Name of participant

____________________________ ________________

Signature of participant Date

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.

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The Ecological Built Environment Research & Enterprise group (EBERE)

HOME QUESTIONNAIRE

For use in interviews:

1. HOUSEHOLD DETAILS

1.1. Address:

Postcode:

1.2. Tenure: (Mark one box only)		
Owner occupied ☐	Rented (Social landlord) ☐	Rented (Private landlord) ☐

1.3. How many people normally live in your home within the following age groups?			
Under 5 years old		18 – 65 years	
5 – 17 years		Over 65 years	

1.4. How many people of each gender normally live in your home?	
Male	Female

1.5. What periods of the day is your home occupied: (Mark all that apply)				
a. During weekdays?				
Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐
b. At weekends?				
Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐

1.6. What is the total annual income for your household? (Mark one box only)		
Below £15,000 ☐	£15,000 - £25,000 ☐	£25,000 - £35,000 ☐
£35,000 - £45,000 ☐	Over £45,000 ☐	Do not want to say ☐

Home Questionnaire

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1.7. What is the level of the highest educational qualification in the household? (Mark one box only)		
No qualifications ☐	GCSE / 'O' Level or equivalent ☐	A-Level or equivalent ☐
Vocational qualifications (NVQ/ SVQ) or equivalent ☐	Degree ☐ Higher degree ☐	Do not want to say ☐

2. PROPERTY DETAILS

2.1. What type of home do you live in? (Mark one box only)		
Detached ☐	Semi-detached ☐	Mid-terrace ☐
End-terrace ☐	Flat ☐	Other (Please specify) ☐ …………………………………………

2.2. When was your home built, approximately? (Mark one box only)			
Before 1900 ☐	1901 – 1920 ☐	1921 – 1950 ☐	1951 – 1980 ☐
1981 – 1990 ☐	1991 – 2000 ☐	Since 2001 ☐	Don't know ☐

2.3. How many of the following rooms do you have in your home?					
Bedrooms		Living rooms		Dining rooms	
Kitchens		Kitchen/ Diner		Bathrooms	
Halls		Stairs		Landings	
Other (please specify)					

2.4. What type of external walls does your home have? (Mark all that apply)			
Solid ☐	Cavity ☐	Timber frame ☐	Don't know ☐

2.5. Are the external walls of your home insulated? (Mark one box only)			
Yes, all ☐	Yes, some ☐	No ☐	Don't know ☐
If yes, what type of insulation has been used? (Mark all that apply)			
Internal ☐	Cavity ☐	External ☐	Don't know ☐

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2.6. Does your home have a loft space? (Mark one box only)

Yes ☐	No ☐	Don't know ☐

If yes, is it insulated? (Mark one box only)

Yes ☐	No ☐	Don't know ☐

If yes, is the insulation on the floor of the roof space or directly under the roof covering (i.e. between, above and/ or below the rafters)? (Mark all that apply)

On the floor ☐	Under roof covering ☐	Don't know ☐

2.7. Does your home have any double, secondary or triple glazing? (Mark one box only)

Yes ☐	No ☐	Don't know ☐

If yes, what type, what percentage do they represent and how old are they? (Mark all that apply)

Sealed unit with double glazing ☐ Percentage..........................% Age..............................years	Fixed secondary glazing ☐ Percentage..........................% Age..............................years	Temporary secondary glazing ☐ Percentage..........................% Age..............................years
Triple glazing ☐ Percentage..........................% Age..............................years	Don't know ☐	

3. ENERGY USE

3.1. Which of the following appliances do you use in your home? (Mark all that apply)

	Yes	No		Yes	No		Yes	No
Refrigerator	☐	☐	Washing machine	☐	☐	Electric kettle	☐	☐
Freezer	☐	☐	Tumble dryer	☐	☐	Desktop computer	☐	☐
Microwave	☐	☐	Television	☐	☐	Laptop computer	☐	☐
Dish-washer	☐	☐	Hi-Fi/ Audio system	☐	☐	Mobile phone charger	☐	☐

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3.2. How much and how often do you pay for ELECTRICITY in each season?			
	Weekly	Monthly	Quarterly
Winter	£		£
Spring	£	£	£
Summer	£		£
Autumn	£		£
(Please refer to your electricity bill) What is your annual consumption?..KWh			

3.3. How much and how often do you pay for MAINS GAS in each season?			
	Weekly	Monthly	Quarterly
Winter	£		£
Spring	£	£	£
Summer	£		£
Autumn	£		£
(Please refer to your gas bill) What is your annual consumption?..KWh			

3.4. Do you use any OTHER FUEL(S) on a regular basis? (Mark all that apply)			
Bottled Gas ☐	LPG ☐	Oil ☐	House coal ☐
Wood ☐	Other (please specify)... ☐		
How much and how often do you pay in each season?			
	Weekly	Monthly	Quarterly
Winter	£		£
Spring	£	£	£
Summer	£		£
Autumn	£		£
(Please refer to your bill/s) What is your annual consumption?..			

Home Questionnaire | Ms Jo Hopper, EBERE, UWIC | Page 4 of 12

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The Ecological Built Environment Research & Enterprise group (EBERE)

3.5. Do you spend more than 10% of your household income on electricity and heating for your home? (This can be worked out either weekly, monthly or yearly depending on how often you pay your bills and receive your income)		
Yes ☐	No ☐	Don't know ☐

(Calculation – if required)

3.6. Do you experience any financial difficulties with paying your household utility bills (e.g. for electricity, gas, water)? (Mark one box only)				
Always ☐	Usually ☐	Sometimes ☐	Rarely ☐	Never ☐

3.7. Have you had to make any lifestyle choices because of the cost of your household bills (e.g. putting up with the cold to save money on heating bills)? (Mark one box only)	
No ☐	Yes ☐ (Write comment below)

3.8. Please state how much you agree with the following statements:				
I am worried about how much ENERGY I use for *environmental* reasons:				
Strongly agree ☐	Agree ☐	Neither agree nor disagree ☐	Disagree ☐	Strongly disagree ☐
I am worried about how much ENERGY I use for *financial* reasons:				
Strongly agree ☐	Agree ☐	Neither agree nor disagree ☐	Disagree ☐	Strongly disagree ☐

3.9. Do you understand the following terms?		
Sustainability	Yes ☐	No ☐
If yes, please specify		

Home Questionnaire | Ms Jo Hopper, EBERE, UWIC | Page 5 of 12

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One planet living	Yes ☐	No ☐
If yes, please specify		
Ecological footprint	Yes ☐	No ☐
If yes, please specify		
Low carbon living	Yes ☐	No ☐
If yes, please specify		

3.10. Do you want to find out more about these terms?	Yes ☐	No ☐

4. ROOM HEATING SYSTEM

4.1. What type of room heating system does your home use? (Mark one box only)

Boiler and radiators ☐	Storage heaters ☐	Room heaters ☐
Other (e.g. coal fire) (Please specify).. ☐		Don't know ☐

4.2. How old is your room heating system? (Mark one box only)

Less than 5 years ☐	5 – 10 years ☐	Over 10 years ☐	Don't know ☐

4.3. What temperature do you set your room heating system at?

Winter ....°C	Summer ....°C	Don't know ☐

4.4. What is the main fuel used for your room heating system? (Mark one box only)

Mains Natural Gas ☐	Bottled Gas ☐	LPG (bulk) ☐	Oil ☐
House coal ☐	Nightsaver off peak electricity ☐	Other off peak electricity ☐	On peak electricity ☐
Wood ☐	Other (Please specify).. ☐		Don't know ☐

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4.5. What type of controls do you have for your room heating system? (Mark all that apply)			
No controls ☐	Room thermostat(s) ☐	Timer/ programmer ☐	Thermostatic radiator valves (TVRs) ☐
Automatic charge control on storage heaters ☐	Other ☐ (Please specify)............		Don't know ☐

4.6. If you have a programmer for your room heating system, how many settings does it have? (Mark one box only)			
24 hours ☐	7 days ☐	Other (Please specify)............ ☐	Don't know ☐

4.7. How easy are the room heating system controls to operate? (Mark one box only)				
Easy ☐	Fairly easy ☐	OK ☐	Difficult ☐	Very difficult ☐

5. HOT WATER SYSTEM

5.1. How is your hot water provided? (Mark one box only)			
Central heating system ☐	Dual immersion (On & Off peak) ☐	Single immersion (Off peak Nightsaver) ☐	Single immersion (On peak) ☐
Gas combi boiler (instantaneous) ☐	Instant electric ☐	Gas, Oil or Solid (e.g. coal or wood) fuel range ☐	Don't know ☐

5.2. What temperature do you set your hot water system at?		
Winter .... °C	Summer .... °C	Don't know ☐

5.3. Is your hot water cylinder insulated? (Mark one box only)		
Not applicable ☐	No insulation ☐	Yes, with spray foam ☐ Thickness............mm
Yes, with a jacket ☐ Thickness............mm	Don't know ☐	

5.4. Do you have any pipe insulation on the pipes between your boiler and hot water cylinder? (Mark one box only)			
Not applicable ☐	Yes ☐	No ☐	Don't know ☐

Home Questionnaire | Ms Jo Hopper, EBERE, UWIC Tel: 029 2020 1196 Email: johopper@uwic.ac.uk | Page 7 of 12

Director of EBERE: Dr J. Littlewood; Email: jlittlewood@uwic.ac.uk

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5.5. What hot water system controls do you have? (Mark all that apply)				
None (except on/ off switch) ☐	Programmer ☐	Timer ☐	Main heating controls ☐	Don't know ☐

5.6. If you have a programmer for your hot water system, how many settings does it have? (Mark one box only)				
24 hours ☐	7 days ☐	Main heating controls ☐	Other (Please specify) ☐	Don't know ☐

5.7. How easy are the hot water system controls to operate? (Mark one box only)				
Easy ☐	Fairly easy ☐	OK ☐	Difficult ☐	Very difficult ☐

6. LIGHTING

6.1. Do you have energy saving light bulbs in your light fittings? (Mark one box only)			
Yes, all ☐	Yes, some ☐ What percentage ....%	No ☐	Don't know ☐

6.2. Do all rooms in your home have access to natural light during the day? (i.e. through windows and/ or glazed doors) (Mark one box only)		
Yes ☐	No (Please specify which rooms don't) ☐	Don't know ☐

7. VENTILATION

7.1. How often do you use the cooker hood/ extractor when someone is cooking in the kitchen? (Mark one box for each season only)

	Always	Usually	Sometimes	Rarely	Never
In the WINTER?	☐	☐	☐	☐	☐
In the SUMMER?	☐	☐	☐	☐	☐
Not applicable (do not have a cooker hood/ extractor in the kitchen)				☐	

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7.2. Have you noticed any of the following in each of the rooms listed?
(Mark all that apply)

	Condensation on windows/ walls/ ceiling	Damp patches on walls	Mould on walls/ ceiling	Damp on furniture, floor covering or clothes	Mould on furniture, floor covering or clothes	None of these problems in this room
Living room	☐	☐	☐	☐	☐	☐
Kitchen	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐
Bedroom 1	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐	☐
Bedroom 4	☐	☐	☐	☐	☐	☐

7.3. Do you ever keep your windows closed in WINTER for any of the following reasons?
(Mark one box on each line)

	Always	Usually	Sometimes	Rarely	Never
Cold	☐	☐	☐	☐	☐
Draughts	☐	☐	☐	☐	☐
Noise outside	☐	☐	☐	☐	☐
Security (fear of intruders getting in)	☐	☐	☐	☐	☐
Smells of air pollution outdoors	☐	☐	☐	☐	☐
Saving energy	☐	☐	☐	☐	☐

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7.4. Do you ever keep your windows closed in SUMMER for any of the following reasons?
(Mark one box on each line)

	Always	Usually	Sometimes	Rarely	Never
Cold	☐	☐	☐	☐	☐
Draughts	☐	☐	☐	☐	☐
Noise outside	☐	☐	☐	☐	☐
Security (fear of intruders getting in)	☐	☐	☐	☐	☐
Smells of air pollution outdoors	☐	☐	☐	☐	☐
Saving energy	☐	☐	☐	☐	☐

8. COMFORT

8.1. How would describe the typical living conditions in your home, in terms of the overall comfort?
(Mark one box on each scale, which best expresses judgement)

		1	2	3	4	5	6	7	
In WINTER?	Satisfactory	☐	☐	☐	☐	☐	☐	☐	Unsatisfactory
In SUMMER?	Satisfactory	☐	☐	☐	☐	☐	☐	☐	Unsatisfactory

9. CONTROL OF ENVIRONMENT

9.1. How much control do you feel you have over the following aspects of your home environment? (Mark one box on each scale, which best expresses the interviewee's judgement)

		1	2	3	4	5	6	7	
Temperature	None at all	☐	☐	☐	☐	☐	☐	☐	A lot
Heating	None at all	☐	☐	☐	☐	☐	☐	☐	A lot

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		1	2	3	4	5	6	7	
Cooling	None at all	☐	☐	☐	☐	☐	☐	☐	A lot
Ventilation	None at all	☐	☐	☐	☐	☐	☐	☐	A lot
Natural light	None at all	☐	☐	☐	☐	☐	☐	☐	A lot
Lighting	None at all	☐	☐	☐	☐	☐	☐	☐	A lot
Noise	None at all	☐	☐	☐	☐	☐	☐	☐	A lot

10. IS THERE ANYTHING ELSE YOU WOULD LIKE TO COMMENT ON ABOUT LIVING IN YOUR HOME?

E.g. Comfort, environmental conditions, services provision

Thank you for taking the time to take part in this interview survey questionnaire.

Home Questionnaire

Ms Jo Hopper, EBERE, UWIC
Tel: 029 2020 1196
Email: johopper@uwic.ac.uk

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Director of EBERE: Dr J. Littlewood; Email: jlittlewood@uwic.ac.uk

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Do you have any comments that you would like to feed back to us about the process we have used in conducting the survey interviews, i.e. from the initial letter inviting you to register your interest to carrying out this interview today?

Do you have any suggestions on how we could improve the process?

Would you be happy for us to return to do a follow up survey interview?

Home Questionnaire

Ms Jo Hopper, EBERE, UWIC
Tel: 029 2020 1196
Email: johopper@uwic.ac.uk

Director of EBERE: Dr J. Littlewood; Email: jlittlewood@uwic.ac.uk

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Appendix IX: Pre-retrofit Occupant Survey Ethics Application

UWIC APPLICATION FOR ETHICS APPROVAL

All Principal Investigators (PI) undertaking a research project which involves human participants should complete and sign this application form.

The document *Guidelines for obtaining ethics approval* gives full details of how to complete this form and is available via the research pages of the UWIC website. You should refer to this document in order to avoid unnecessary delays with your application.

As a PI, you are responsible for exercising appropriate professional judgement in this review and for operating within UEC (and any School and professional) guidelines in the conduct of the study.

Participant recruitment or data collection must not commence until ethics clearance has been obtained.

Principal Investigator:	Jo Hopper
Supervisor (if student project):	Dr John Littlewood
School:	Cardiff School of Art & Design
Type of researcher:	Postgraduate Student (no teaching)
Programme enrolled on:	MPhil/PhD
Project Title:	Energy efficiency improvements to existing homes' project

PART ONE – ETHICS REVIEW CHECKLIST

ERC1: Will the study involve NHS patients or staff?	No

If **YES**, you do not need to complete Part Two of this form. Instead, an application for ethics approval must be submitted to the appropriate external NHS Research Ethics Committee. Complete Declaration A overleaf and forward a copy of your NHS application plus Part One of this form to your School Ethics Committee for information.

ERC2: Does your research fall <u>*entirely*</u> within one of the following three categories: • Paper-based, involving only documents in the public domain • Laboratory based, not involving human participants or human tissue samples (eg electronics, chemical analysis) • Practice-based, not involving human participants (eg exhibitions, curatorial, reflective analysis, practice audit)	No

If **YES**, you do not need to complete Part Two of this form. Instead, complete Declaration B overleaf and send the completed form to your School Ethics Committee for information.

If **NO**, you must complete Part Two of this form and submit your application (Part One and Part Two) to your School Ethics Committee for consideration.

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UWIC APPLICATION FOR ETHICS APPROVAL

DECLARATION A	
I confirm that the information contained in this form is correct My research involves human participants and ERC1 indicates I must obtain ethics clearance from the appropriate external health authority ethics committee. Signature of Principal Investigator:	
Date:	Click here to enter a date.

DECLARATION B	
I confirm that the information contained in this form is correct My research falls entirely within the categories described in ERC2 and I do not need to take further action to obtain ethics clearance. Signature of Principal Investigator:	
Date:	Click here to enter a date.
Brief synopsis of project:	
Click here to enter text.	

FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor: Click here to enter text.	Date: Click here to enter a date.
Signature of Supervisor:	

School Research Ethics Committee use only	
☐ Considered and supported	☐ Considered and not supported
Name: Click here to enter text.	Date: Click here to enter a date.

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UWIC APPLICATION FOR ETHICS APPROVAL

PART TWO – APPLICATION FOR ETHICS APPROVAL

Expected Start Date:	26/03/2012
Approximate Duration:	12 months
Funding Body (if applicable):	Knowledge Economy Skills Scholarship (KESS) funded by the European Social Fund through the European Union's Convergence programme administered by the Welsh Government.
Other researcher(s) working on the project	Dr John Littlewood (CSAD), Professor Andrew Geens (CIBSE), Professor George Karani (CSHS), John Counsell (CSAD)
Does your project require ethical approval from an NREC or other body?	No
If yes, please name the NREC or other body	Click here to enter text.
Does your project use Human Tissue?	No

Has CRB clearance been given?	No	If yes, which organisation holds details of the check[1]?	Click here to enter text.

DECLARATION	
I confirm that the information contained in this form is correct Signature of Principal Investigator:	Date: 14/03/2012
FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor: Dr John R Littlewood	Date: 14/03/2012
Signature of Supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☐ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐ Project rejected ☐
Project reference number: Click here to enter text.	
Name: Click here to enter text.	Date: Click here to enter a date.
Signature:	

[1] In cases where a CRB check has been sought by an external organisation, confirmation from that organisation that a satisfactory check has been received is required by UWIC at application stage.

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UWIC APPLICATION FOR ETHICS APPROVAL

A – PROJECT DETAILS	
A1 In order to give members of the ethics committee some idea of the nature of your research, please answer the following questions with regard to this project:	
Will you take blood or tissue samples from participants?	No
Will the study involve prolonged or repetitive testing OTHER THAN repetitive training exercises of a type which form part of the participants normal activities (such as athletics or music training)?	No
Are drugs, placebos or other substances (eg vitamins) to be administered to participants?	No
Could the study induce physiological or psychological stress or anxiety significantly greater than the participants are likely to experience in their daily lives?	No
Does the study involve participants who are unable to give informed consent?	No
Will the study involve children? (NB: Projects in professional practice involving those under the age of 18 in a public place (in school or a statutory setting) with the relevant permission are exempt)	No
Is pain or more than mild discomfort likely to result from the study?	No
Will financial inducements, other than reasonable expenses and compensation for time, be offered to participants?	No
Will deception of participants to necessary during the study?	No

A2 Briefly describe the rationale behind your project
The UK Government has set a legally binding target to reduce UK carbon emissions by 34% by 2020 and by 80% by 2050, using 1990 levels as a baseline. With over 25% of UK carbon emissions resulting from energy use in homes and over two thirds of existing homes expected to still be in use in 2050, there is an urgent requirement to address the energy efficiency of existing dwellings. Wales has some of the oldest and most energy inefficient dwellings in the UK. In recognition of this, the Welsh Government instigated the Arbed funding scheme in 2009. The aim of Arbed is to improve the energy efficiency of the top 15% most deprived homes across Wales. The funding was awarded to local authorities and housing associations across Wales to enable them to improve both publically and privately owned homes. One of the funding requirements was that monitoring and evaluation had to be undertaken to determine how effective the improvement measures were at reducing energy use, carbon emissions and fuel poverty. However, there was limited funding and no methodology set out for these assessments. To aid this issue to be addressed, the doctoral research project was developed in collaboration with Coastal Housing Group (CHG), a housing association based in Swansea, after they had won funding through the Arbed scheme. The main method of improvement implemented by CHG is that of retrofitting external wall insulation (EWI) to pre-1919 dwellings with solid exterior walls.
A3 What are the aims of the research?
The aim of the research project is to investigate the impact of retrofitted EWI on energy use, carbon emissions and fuel poverty in pre-1919 solid wall dwellings. The objectives set out to meet the aim, include: assessing the cost-effectiveness of retrofitting EWI relative to energy and carbon savings

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UWIC APPLICATION FOR ETHICS APPROVAL

and alleviating fuel poverty; examining the effects of occupant behaviour on the energy efficiency of existing dwellings that have received the retrofitted EWI; and evaluating the methods used to implement the retrofitted EWI to establish what worked well and what didn't work so well and determine the effects on costs and quality of installation. The outputs from the research project are expected to include: a methodology for engaging with occupants and stakeholders to evaluate domestic retrofit projects; a methodology for assessing the implementation of retrofitted EWI; empirical data and recommendations related to retrofitting EWI through the Welsh Government's Arbed scheme, which could have implications for the UK Government's forthcoming Green Deal; and pre-retrofit and post-retrofit domestic energy use and carbon emission benchmarks, reported as kWh/sq m/year and CO2/sq m/year, respectively, for a variety of dwelling typologies and occupancies for the geographical region of Swansea, which does not currently exist. The purpose of this application is to extend ethical approval for gathering data from occupants about their home, energy use and behaviour, before the retrofitted EWI is installed. The extension is required due to the original approval being over 12 months old and the requirement to make alterations, based on the experience gained from undertaking the previous surveys (see Section A6 below for more details). The original ethic committee reference number is: 18.01.02/11 Hopper.

A4 Will you be using an approved protocol in your project?	No
A5 If yes, please state the name and code of the approved protocol to be used[1]	
Click here to enter text.	

If your project does involve the use of an approved protocol, please indicate when answering the following questions, which areas of your study are covered by the protocol

A6 What methods of data collection and analysis will you adopt?
Data collection involves the use of a questionnaire, developed by the PI, which will either be used as a survey interview or posted to the occupant (see attached diagram). The aim of the questionnaire is to gather data on: occupancy; building configuration; energy use; heating and hot water systems; lighting; ventilation; perceived comfort; and occupant behaviour towards energy use (see questionnaire for more details). Where necessary, occupants will also be asked permission to contact their energy supplier to obtain actual energy use data; this is due to the high number of occupants who have pre-payment meters and therefore do not know the actual energy use in kWh's, as discovered when undertaking the previous surveys (see information sheet, consent form and questionnaire for more details). Floor area data will be obtained from CHG's stock records. Once data is collected, it will be entered into a spreadsheet to allow energy use and carbon emissions per square meter, per year to be calculated. This information will then be collated into dwelling typologies and occupancies to allow comparisons to be made and mean usage determined; this will form the pre-retrofit benchmark. Other information gathered, such as periods of the day when occupants are at home and type of heating system will then be assessed in conjunction with energy use data, to attempt to establish any patterns in low or high energy use.
A7 What remuneration (if any) will be offered to participants?
None.
A8 From which group(s) will participants be recruited and what sampling method and criteria will be used?
CHG have identified the sample group as part of their additional Arbed funding allocation. The

[1] An Approved Protocol is one which has been approved by UWIC to be used under supervision of designated members of staff; a list of approved protocols can be found at [INSERT LINK]

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additional dwellings, relevant to this application, are all owned by CHG.
A9 How many participants will be involved?
CHG is retrofitting the EWI to approximately 28 dwellings in Swansea. The final number of participants will be dependent on how many respond and agree to take part.
A10 Where and how will the participants be recruited and what method of initial contact will you use?
Participants will be contacted via a short letter requesting consent to be contacted with further information and, where willing, either a mutually convenient appointment will be made to conduct the survey interview or the questionnaire and corresponding documents will be sent to the occupant (see attached diagram for more details). The invitation letter will provide a brief description of the purpose of the research, contact details for the PI and a reply slip, which will be accompanied by a freepost return envelope provided by CHG (see attached invitation letter for more details).
A11 What previous experience of research involving human participants relevant to this project do you have?
The PI has conducted 33 interviews with occupants using a questionnaire, as per ethics approval reference: 18.01.02/11 Hopper.
A12 **Student projects only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr John Littlewood the director of studies is leading several projects that involve interviewing staff of housing associations and tenants in their properties respectively and occupants of privately owned houses in collaboration with Coastal Housing Group, which have received CSAD ethics approval. Professor Andrew Geens, is a supervisor on three other KESS funded doctoral projects at Cardiff Met, all of which have had ethics applications approved for interviews in 2011. Professor George Karani, the third supervisor for the project, has been involved in housing regeneration projects in Cardiff and supervised a research degree in the area.

B – POTENTIAL RISKS
B1 What potential discomfort or inconvenience to the participants do you foresee?
Time commitment of approximately 30 minutes by occupants to complete the survey.
B2 How do you propose to deal with the potential risks?
Where the questionnaire is to be undertaken as a survey interview, every participant will be informed of how long the interview is anticipated to take and the arrangements will only be made at a suitable time that is convenient for them. Participants will also be given contact details for the researchers so that any arrangements can be changed if the time is no longer convenient. Where the questionnaire is to be posted to the participant, this can be completed at a time that is convenient to them.
B3 Do you intend to use a questionnaire to ascertain an individual's level of physical fitness or health before accepting them as a participant? If yes, please give details.
No
B4 What potential risks to the interests of the researchers do you foresee?
Intimidating/ abusive behaviour from residents during survey interviews.
B5 How will you deal with these potential risks?
CHG will assess the suitability of residents to take part and, where possible, a member of staff from CHG will accompany the PI in face-to-face meetings with residents.

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UWIC APPLICATION FOR ETHICS APPROVAL

C – CONSENT	
C1 Will informed consent be sought from participants?	Yes
C2 If NO, explain why informed consent will not be sought	
Click here to enter text.	
C3 If YES, describe how informed consent will be obtained and attach copies of relevant documents	
Each participant will be provided with an information sheet describing the aim and objectives of the study and a consent form to sign. There are two types of consent forms attached to this application, one for where the questionnaire is filled in as a survey interview and one for where the questionnaire is posted to the participants. The consent form to be sent with postal questionnaires differs from the survey interview consent form, in that these participants are providing consent to take part in the study by filling in the questionnaire.	
C4 If you are using an approved protocol, has the approved wording for participants been included in your Participant Information Sheet?	Choose an item.
C5 If NO, why not?	
Click here to enter text.	
C6 If there are doubts about participants' abilities to give informed consent, what steps have you taken to ensure that they are willing to participate?	
Not applicable.	
C7 If participants are aged under 18, describe how you will seek informed consent	
Not applicable.	
C8 How will consent be recorded?	
Paper based form, which will be obtained and stored according to the eight Principles of the Data Protection Act 1998. In summary, these ensure that personal data is processed lawfully and fairly (1) and only for specified purposes (2). They set out information standards which specify the amount of personal data which can be held (3), that it is accurate and kept up to date (4) and how long it can be retained for (5). They also set out the rights of individuals (6), the minimum security measures which must be in place (7) and advice for sending personal data outside the European economic area (8).	

D – OTHER DETAILS	
D1 Will participants be informed of their right to withdraw without penalty?	Yes
If no, please detail the reasons	
Click here to enter text.	
D2 How will you ensure participants' confidentiality and anonymity?	
All questionnaire responses are to be identified by a number or code and the key to the code is to be kept completely separately from the data. The PI will provide confirmation in the information sheet that responses will remain completely anonymous and that no reference to the names of participants will be kept on any records (see attached information sheet for more details).	
D3 How will issues of data storage be addressed?	
To ensure compliance with Data Protection Act, participants will be informed of the personal information which will be held about them and who will have access to this information. All information gathered as part of the project, including the signed consent forms and all other forms completed by participants, will be retained by the PI and stored in a secure location at Cardiff Metropolitan University, along with all other confidential information related to the KESS PhD project; accessible for inspection if required for at least ten years after the work is completed. Non	

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UWIC APPLICATION FOR ETHICS APPROVAL

essential records will be shredded at the conclusion of the work.
D4 Are there any further points you wish to make with regard to the proposed research?
No.

NB: When submitting your application, in addition to this form your School Ethics Committee will expect to see copies of the documentation you will use during your project. Depending on what your project entails, this may include:

- Participant information sheet (See Section C)
- Participant consent form (See Section C)
- Parents information sheet (See Section C)
- Parents consent form (See Section C)
- Participant questionnaire (See A6)
- Health questionnaire (See B3)
- Letter to the organisation at which research will take place

Refer to the document *Guidelines for obtaining ethics approval* for further details on which documents you should provide and exemplar forms for your reference when compiling this information.

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Appendix X: Post-retrofit Occupant Survey Full Questionnaire and Supporting Documents

Cardiff Metropolitan University
Prifysgol Fetropolitan Caerdydd
UWIC

The Ecological Built Environment Research & Enterprise group (EBERE)

Cardiff School of Art and Design
Western Avenue
Cardiff, CF5 2YB

(Date)

Energy efficiency improvements to existing homes project

<u>Participant Information Sheet</u>

Cardiff Metropolitan University Ethic Committee Reference number: 01/02/12B-C

Dear Sir or Madam,

We would like to invite you to take part in a research project that is investigating the energy efficiency of existing homes in Swansea. This is a university research project and not a commercial or governmental survey. The research is being undertaken by the Ecological Built Environment Research & Enterprise group (EBERE) at Cardiff Metropolitan University and is being funded by the university, Coastal Housing Group and the European Social Fund through the European Union's Convergence programme administered by the Welsh Government.

We are asking residents who have received energy efficiency improvements from Coastal Housing Group through the Arbed scheme to contribute information about how they use energy in their homes. In order to do this we would like to, either conduct a face-to-face interview survey by visiting you in your home at a time which is convenient to you, or send you a questionnaire in the post, along with a pre-paid return envelope. The survey should take approximately 30 minutes and would greatly contribute to knowledge about energy use in existing homes. This is a very important aspect of our work, as it will assist us to measure the environmental impacts of existing homes before and after the improvement measures are installed, which Coastal Housing Group are managing.

Your involvement

In order to proceed, it is important that you are clear about what your participation will involve so that you are in a position to make an informed decision as to whether you wish to take part. This information sheet accompanies the questionnaire and a consent form. Where the survey questionnaire is completed through an interview, a consent form will need to be signed to participate in the study. Where the questionnaire is sent to you by post, you are providing consent by filling in and returning it to us. For both survey methods (interview and postal), consent is requested to provide permission for us to contact your energy supplier(s) to gather further information about your energy use for the 12 months before and after the improvement measures are installed. For owner-occupiers, we are also asking you to consent to the floor area of your home being measured. All necessary consents are covered in a single consent form.

Anonymity

We will take all reasonable steps to preserve your anonymity and we will respect your privacy at all times. When producing project reports and other publications based on the research, the data that we collect from your home and from interviews we conduct with you will be presented in an anonymous form. This means that we will not provide any information that would positively identify your home, you or any member of your household.

We are bound by the terms of the Data Protection Act and, unless you give your permission, we will not disclose any information we hold about you or your household to anyone outside the EBERE research team. Your data will be held securely at the University and will be destroyed after 10 years.

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.
Director of EBERE: Dr John R Littlewood jlittlewood@cardiffmet.ac.uk

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The Ecological Built Environment Research & Enterprise group (EBERE)

When we have finished the study and analysed the information, all the forms we use to gather data will be kept for 10 years since this is a requirement of one of the funding bodies for this research project.

Withdrawal

We fully understand that you may change your mind about being involved in the project and would reassure you that you are free to withdraw from the project at any time. If you feel it necessary to withdraw, all personal information will be deleted and if requested all research data relating to your home will be deleted also.

Further Information

If you have any queries about the project, or would like further information before making up your mind, please don't hesitate to contact me or one of the team at Cardiff Metropolitan University.

Jo Hopper

Tel: 029 2020 1196

Email: johopper@cardiffmet.ac.uk

School of Art and Design

Cardiff Metropolitan University

The EBERE Team of Researchers

Dr John Littlewood	jlittlewood@cardiffmet.ac.uk	Director of EBERE, Cardiff Metropolitan University	Tel: 02920 416676
Professor George Karani	gkarani@cardiffmet.ac.uk	School of Health Sciences, Cardiff Metropolitan University	Tel: 02920 416855
John Counsell	jcounsell@cardiffmet.ac.uk	School of Art and Design, Cardiff Metropolitan University	Tel: 02920 201566

The Ecological Built Environment Research & Enterprise group (EBERE)

Cardiff Metropolitan University
Prifysgol Fetropolitan Caerdydd
UWIC

CONSENT FORM

POST-ARBED 1: INTERVIEWS

Ethics Committee Reference Number	01/02/12B-C
Participant name or Study ID Number	
Title of Project	Energy efficiency improvements to existing homes project
Name of Researcher	Jo Hopper

PLEASE COMPLETE THIS SECTION BEFORE THE INTERVIEW COMMENCES

Please write your initials in each box and sign and date the declaration below:

1. I confirm that I have read and understand the information sheet dated (Date) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my relationship with Cardiff Metropolitan University or Coastal Housing Group, or my legal rights, being affected. ☐
3. I understand that relevant sections of any research notes and data collected during the study may be looked at by those Cardiff Metropolitan University employees responsible for undertaking and monitoring this research and for data protection. I give permission for these individuals to have access to my records for that purpose. ☐
4. I agree to take part in this study. ☐
5. I agree to my energy supplier(s) being contacted for more information about my energy use, if necessary. ☐
6. I agree to the floor area of my home being measured. ☐

____
Name of participant

____________________________ ________________
Signature of participant Date

Post-Arbed 1: Occupants | Ms Jo Hopper, EBERE, Cardiff Metropolitan University Tel: 029 2020 1196 Email: johopper@cardiffmet.ac.uk | Owner-occupiers: Interview

Director of EBERE: Dr J. Littlewood; Email: jlittlewood@cardiffmet.ac.uk

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POST-ARBED 1 QUESTIONNAIRE

Date: Survey reference:

1. HOUSEHOLD DETAILS

1.1. **Address:**

Postcode:

1.2. **Has the number of occupants in your home changed since the last survey?**
Date of last survey:

Yes ☐	No ☐
If yes, please specify	

1.3. **What periods of the day is your home occupied:** (Mark all that apply)

a. **During weekdays?**

Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐

b. **At weekends?**

Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐

2. IMPROVEMENT MEASURES

2.1. **What improvement measures have been fitted to your home and when were they installed?** (Mark all that apply)

External wall insulation ☐ Date (MMYY)............	Solar Photovoltaic (PV) panels ☐ Date (MMYY)............	Solar Hot Water panels ☐ Date (MMYY)............
Other (Please specify) ☐ Date (MMYY)............		Don't know ☐

Post-Arbed 1: Occupants

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3. ENERGY USE

3.1. How much and how often do you pay for ELECTRICITY in each season since the improvement measures were installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much electricity have you consumed in the last 12 months? KWh
(Please refer to your bills or statements)

3.2. Who has been your electricity supplier for the past 24 months? (If you have had more than one supplier, please state all of them here, along with the corresponding dates)

Do you consent to us contacting your supplier if we need to get more information about your electricity use?	**Yes** ☐	**No** ☐
Consent form signed	Yes ☐	No ☐

3.3. If you use MAINS GAS, how much and how often do you pay in each season since the improvement measures were installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much mains gas have you consumed in the last 12 months? KWh
(Please refer to your bills or statements)

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3.4. If you use MAINS GAS, who has been your supplier for the past 24 months? (If you have had more than one supplier, please state all of them here, along with the corresponding dates)				
Do you consent to us contacting your supplier if we need to get more information about your mains gas use?	**Yes**	☐	**No**	☐
Consent form signed	Yes	☐	No	☐

3.5. Do you use any OTHER FUEL(S) on a regular basis? (Mark all that apply or go to question 3.6)			
Bottled Gas ☐	LPG ☐	Oil ☐	House coal ☐
Wood ☐	Other (please specify) ☐		
How much and how often do you pay in each season since the improvement measures were installed?			
	Weekly	**Monthly**	**Quarterly**
Winter	**£**	**£**	**£**
Spring	**£**		**£**
Summer	**£**		**£**
Autumn	**£**		**£**
How much have you consumed in the last 12 months? (Please refer to your bills or statements)			

3.6. Do you spend more than 10% of your household income on electricity and heating for your home? This can be worked out either weekly, monthly or yearly depending on how often you pay your bills and receive your income (Mark one box only)		
Yes ☐	No ☐	Don't know ☐

(Calculation, if required)

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3.7. Do you experience any financial difficulties with paying your household utility bills (e.g. for electricity, gas, water)? (Mark one box only)				
Always ☐	Usually ☐	Sometimes ☐	Rarely ☐	Never ☐

3.8. Since the last survey, has your use of energy changed in any way? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐
If yes, please specify what has changed and the reasons for the change		

3.9. Do you know what an energy display monitor is? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐
If yes, do you think having a current energy consumption reading would help you reduce your usage? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐
If no, would you like to find out more information about them? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐

4. ROOM HEATING SYSTEM

4.1. Has your room heating system changed since the last survey? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐
If yes, please specify		

4.2. What temperature do you set your room heating system at?		
Winter °C	Summer °C	Don't know ☐

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5. HOT WATER SYSTEM

5.1. Has your hot water system changed since the last survey? (Mark one box only)

Yes ☐	No ☐	Don't know ☐
If yes, please specify		

5.2. What temperature do you set your hot water system at?

Winter °C	Summer °C	Don't know ☐

6. LIGHTING

6.1. Do you have energy saving light bulbs in your light fittings? (Mark one box only)

Yes, all ☐	Yes, some ☐ What percentage ....%	No ☐	Don't know ☐

7. VENTILATION

7.1. Have you noticed any of the following in each of the rooms listed?
(Mark all that apply)

	Condensation on windows/ walls/ ceiling	Damp patches on walls	Mould on walls/ ceiling	Damp on furniture, floor covering or clothes	Mould on furniture, floor covering or clothes	None of these problems in this room
Living room	☐	☐	☐	☐	☐	☐
Kitchen	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐
Bedroom 1	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐	☐
Bedroom 4	☐	☐	☐	☐	☐	☐

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7.2. If you are able to, do you open windows on both sides of the house to provide through ventilation? (Mark one box only)				
Always	Usually	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

8. COMFORT

8.1. How would describe the typical living conditions in your home, in terms of the overall comfort? (Mark one box on each scale, which best expresses your judgement)									
		1	2	3	4	5	6	7	
In WINTER?	Unsatisfactory	☐	☐	☐	☐	☐	☐	☐	Satisfactory
In SUMMER?	Unsatisfactory	☐	☐	☐	☐	☐	☐	☐	Satisfactory

Note: **ONLY for homes that have had external wall insulation installed**

8.2. Do you feel that your home is warmer since it has been insulated? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐

9. BEHAVIOUR

8.1. When you start to feel cold in your home, what is the first thing you do? (Mark all that apply)	
1. Put on an extra layer of clothing, such as a jumper?	☐
2. Put the heating or fire on?	☐
3. Other (e.g. put a blanket over you)? (Please specify)	☐

8.2. During the heating season (winter), do you: (Mark one box only)	
1. Leave your heating on low constantly?	☐
2. Switch on your heating as and when you need it?	☐
3. Just let the timer/programmer/thermostat control when your heating comes on and goes off?	☐
4. Other? (Please specify)	☐

8.3. Do you ever leave your windows open at the same time as when you have your heating on? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐

Post-Arbed 1: Occupants

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8.4. When you turn off electrical equipment, do you: (Mark one box only)			
Leave them on standby?	☐	Use the main on/off switch?	☐
Switch them off at the wall?	☐	Other?	☐

8.5. When you use your lights, do you switch them off when you leave a room? (Mark one box only)				
Always	Usually	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

9.5. If you have a mobile phone, do you unplug the charger when it finishes charging? (Mark one box only)				
Always	Usually	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

8.7. If you have a kettle, when you use it, you do? (Mark one box only)	
1. Only put enough water in for what you need each time?	☐
2. Put more water in than you need each time?	☐
3. Fill it right up to the top?	☐

8.8. In the WINTER, when the sun is shining into a room, do you keep the curtains or blinds open? (Mark one box only)				
Always	Usually	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

8.0. With the previous nine questions in mind, has your attitude and/or behaviour towards energy use changed as a result of the improvement measures that have been carried out on your home? (Mark one box only)					
Yes	☐	No	☐	Don't know	☐
If yes, please specify					

Post-Arbed 1: Occupants

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Note: **ONLY for homes that have had external wall insulation installed**

8.11. Have you increased the internal temperature that you keep your home at during the heating season (winter) since having the external wall insulation installed? (Mark one box only)		
Yes ☐	No ☐	Don't know ☐
If yes, why is this? (Mark all that apply)		
1. Because it is easier to do so.		☐
2. Because you need to for health reasons.		☐
3. Because it does not cost any more than before the insulation was installed.		☐
4. Because you like it warmer but couldn't afford to before you had the insulation installed.		☐
5. Other reason, please specify		☐
If no, why is this? (Mark all that apply)		
1. Because you are trying to save money on your heating bill.		☐
2. Because it does not feel as cold inside (even when the external temperature is particularly low).		☐
3. Other reason, please specify		☐

10. IS THERE ANYTHING ELSE YOU WOULD LIKE TO COMMENT ON ABOUT LIVING IN YOUR HOME SINCE IT HAS BEEN IMPROVED?

Thank you for taking the time to take part in this survey.

Post-Arbed 1: Occupants

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Appendix XI: Post-retrofit Occupant Survey Short (Postal) Questionnaire and Supporting Documents

(CHG Logo)

(Occupant address)

(Date)

Dear (Name),

Further to the improvement measures installed at your home last year, through the Welsh Government's Arbed scheme. Cardiff Metropolitan University is working with Coastal Housing Group to gather information about the impact the improvements have had on your energy consumption. In order for us to do this, we are conducting a short survey, which is enclosed with this letter. Please could you spare some time to assist us with gathering this valuable information?

Please find enclosed:

- **A participant information sheet** – this provides you with further information about the study and is for you to keep for your records. Please take the time to read this before you fill in the questionnaire and don't hesitate to contact me if you have any questions.
- Two **consent forms** – the one entitled 'Consent Form – Copy' is for you to keep for your records. For the one entitled 'Consent Form', please can you initial the boxes, print your name, sign and date at the bottom, and return it along with the questionnaire.
- **A questionnaire**, entitled 'Post-Arbed 1 Questionnaire (Short)' – please can you answer as many of the questions as you can. Please feel free to contact me, should you have any questions or need any assistance.
- **A pre-paid return envelope** – please use this to return the questionnaire and consent form.

Thank you in anticipation of you completing the questionnaire and I look forward to hearing from you. Your contribution is greatly appreciated.

Yours sincerely

Jo Hopper

Ms Jo Hopper
Cardiff Metropolitan University

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The Ecological Built Environment Research & Enterprise group (EBERE)

Cardiff School of Art and Design
Western Avenue
Cardiff, CF5 2YB

(Date)

Energy efficiency improvements to existing homes project

Participant Information Sheet

Cardiff Metropolitan University Ethic Committee Reference number: 01/02/12B-C

Dear Sir or Madam,

We would like to invite you to take part in a research project that is investigating the energy efficiency of existing homes in Swansea. This is a university research project and not a commercial or governmental survey. The research is being undertaken by the Ecological Built Environment Research & Enterprise group (EBERE) at Cardiff Metropolitan University and is being funded by the university, Coastal Housing Group and the European Social Fund through the European Union's Convergence programme administered by the Welsh Government.

We are asking residents who have received energy efficiency improvements from Coastal Housing Group through the Arbed scheme to contribute information about how they use energy in their homes. In order to do this we are requesting that you fill in a short questionnaire and return it to us in the pre-paid return envelope. The survey should take approximately 30 minutes and would greatly contribute to knowledge about energy use in existing homes. This is a very important aspect of our work, as it will assist us to measure the environmental impacts of existing homes before and after the improvement measures are installed, which Coastal Housing Group are managing.

Your involvement
In order to proceed, it is important that you are clear about what your participation will involve so that you are in a position to make an informed decision as to whether you wish to take part. This information sheet accompanies the questionnaire and a consent form. By filling in the questionnaire you are providing consent for us to use the information you disclose. The consent form is to request permission for us to contact your energy supplier(s) to gather further information about your energy use for the 12 months before and after the improvement measures are installed. For owner-occupiers, we are also asking you to consent to the floor area of your home being measured. All necessary consents are covered in a single consent form.

Anonymity
We will take all reasonable steps to preserve your anonymity and we will respect your privacy at all times. When producing project reports and other publications based on the research, the data that we collect from your home and from the questionnaires will be presented in an anonymous form. This means that we will not provide any information that would positively identify your home, you or any member of your household.

We are bound by the terms of the Data Protection Act and, unless you give your permission, we will not disclose any information we hold about you or your household to anyone outside the EBERE research team. Your data will be held securely at the University and will be destroyed after 10 years.

When we have finished the study and analysed the information, all the forms we use to gather data will be kept for 10 years since this is a requirement of one of the funding bodies for this research project.

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.
Director of EBERE: Dr John R Littlewood jlittlewood@cardiffmet.ac.uk

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Withdrawal
We fully understand that you may change your mind about being involved in the project and would reassure you that you are free to withdraw from the project at any time. If you feel it necessary to withdraw, all personal information will be deleted and if requested all research data relating to your home will be deleted also.

Further Information
If you have any queries about the project, or would like further information before making up your mind, please don't hesitate to contact me or one of the team at Cardiff Metropolitan University.

Jo Hopper

Tel: 029 2020 1196

Email: johopper@cardiffmet.ac.uk

School of Art and Design

Cardiff Metropolitan University

The EBERE Team of Researchers

Dr John Littlewood	jlittlewood@cardiffmet.ac.uk	Director of EBERE, Cardiff Metropolitan University	Tel: 02920 416676
Professor George Karani	gkarani@cardiffmet.ac.uk	School of Health Sciences, Cardiff Metropolitan University	Tel: 02920 416855
John Counsell	jcounsell@cardiffmet.ac.uk	School of Art and Design, Cardiff Metropolitan University	Tel: 02920 201566

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CONSENT FORM

POST-ARBED 1: TO CONTACT ENERGY SUPPLIER

Ethics Committee Reference Number	01/02/12B-C
Participant name or Study ID Number	
Title of Project	Energy efficiency improvements to existing homes project
Name of Researcher	Jo Hopper

PLEASE COMPLETE THIS SECTION TO GIVE PERMISSION FOR YOUR ENERGY SUPPLIER TO BE CONTACTED

Please write your initials in each box and sign and date the declaration below:

1. I confirm that I have read and understand the information sheet dated (Date) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my relationship with Cardiff Metropolitan University or Coastal Housing Group, or my legal rights, being affected. ☐
3. I understand that relevant sections of any research notes and data collected during the study may be looked at by those Cardiff Metropolitan University employees responsible for undertaking and monitoring this research and for data protection. I give permission for these individuals to have access to my records for that purpose. ☐
4. I agree to my energy supplier(s) being contacted for more information about my energy use, if necessary. ☐

Name of participant

Signature of participant Date

Post-Arbed 1: Occupants

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Tenants: Postal

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POST-ARBED 1 QUESTIONNAIRE (SHORT)

Date: Survey no:

1. HOUSEHOLD DETAILS

1.1. Address:

Postcode:

1.2. Tenure: (Mark one box only)		
Owner occupied ☐	Rented (Social landlord) ☐	Rented (Private landlord) ☐

1.3. How many people normally live in your home within the following age groups?			
Under 5 years old		18 – 65 years	
5 – 17 years		Over 65 years	

1.4. What periods of the day is your home occupied: (Mark all that apply)				
a. During weekdays?				
Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐
b. At weekends?				
Morning ☐	Lunchtime ☐	Afternoon ☐	Evening ☐	Night ☐

2. PROPERTY DETAILS

2.1. What type of home do you live in? (Mark one box only)		
Detached ☐	Semi-detached ☐	Mid-terrace ☐
End-terrace ☐	Flat ☐	Other (Please specify) ☐ ....

2.2. What type of external walls does your home have? (Mark all that apply)			
Solid ☐	Cavity ☐	Timber frame ☐	Don't know ☐

Post-Arbed 1: Occupants Short

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3. IMPROVEMENT MEASURES

3.1. What improvement measures have been fitted to your home and when were they installed? (Mark all that apply)

External wall insulation ☐ Date (MMYY)..	Solar Photovoltaic (PV) panels ☐ Date (MMYY)..	Solar Hot Water panels ☐ Date (MMYY)..
Other (Please specify) ☐ Date (MMYY)..		Don't know ☐

4. ENERGY USE

4.1. How much and how often did you pay for ELECTRICITY in each season PRIOR to the improvement measures being installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much electricity did you consume during these 12 months? KWh
(Please refer to your bills or statements)

4.2. How much and how often do you pay for ELECTRICITY in each season SINCE the improvement measures were installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much electricity have you consumed during these 12 months? KWh
(Please refer to your bills or statements)

4.3. Who has been your electricity supplier for the past 24 months? (If you have had more than one supplier, please state all of them here, along with the corresponding dates)

(Question continued overleaf)

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Do you consent to us contacting your supplier if we need to get more information about your electricity use?	Yes ☐	No ☐
Consent form signed	Yes ☐	No ☐

4.4. If you use MAINS GAS, how much and how often did you pay in each season during the 12 months PRIOR to the improvement measures being installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much mains gas did you consume during these 12 months? kWh
(Please refer to your bills or statements)

4.5. If you use MAINS GAS, how much and how often do you pay in each season in the 12 months SINCE the improvement measures were installed?

	Weekly	Monthly	Quarterly
Winter	£	£	£
Spring	£		£
Summer	£		£
Autumn	£		£

How much mains gas have you consumed during these 12 months? kWh
(Please refer to your bills or statements)

4.6. If you use mains gas, who has been your supplier for the past 24 months? (If you have had more than one supplier, please state all of them here, along with the corresponding dates)

Do you consent to us contacting your supplier if we need to get more information about your mains gas use?	Yes ☐	No ☐
Consent form signed	Yes ☐	No ☐

4.7. Do you use any OTHER FUEL(S) on a regular basis? (Mark all that apply or go to question 5.1, if applicable)

Bottled Gas ☐	LPG ☐	Oil ☐	House coal ☐
Wood ☐	Other (please specify).. ☐		

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4.8. How much of these OTHER FUEL(S) did you consume during the 12 months PRIOR to the improvement measures being installed?

4.9. How much of these OTHER FUEL(S) have you consumed during the 12 months SINCE the improvement measures were installed?

5. COMFORT AND BEHAVIOUR

Note: ONLY for dwellings that have had external wall insulation fitted

5.1. Do you feel that your home is warmer since it has been insulated? (Mark one box only)					
Yes	☐	No	☐	Don't know	☐

5.2. Have you increased the internal temperature that you keep your home at during the heating season (winter) since having the external wall insulation installed? (Mark one box only)					
Yes	☐	No	☐	Don't know	☐

If yes, why is this? (Mark all that apply)	
1. Because it is easier to do so.	☐
2. Because you need to for health reasons.	☐
3. Because it does not cost any more than before the insulation was installed.	☐
4. Because you like it warmer but couldn't afford to before you had the insulation installed.	☐
5. Other reason, please specify	☐

If no, why is this? (Mark all that apply)	
1. Because you are trying to save money on your heating bill.	☐
2. Because it does not feel as cold inside (even when the external temperature is particularly low).	☐
3. Other reason, please specify	☐

Thank you for taking the time to take part in this survey.

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Appendix XII: Post-retrofit Occupant Survey Ethics Application

UWIC APPLICATION FOR ETHICS APPROVAL

All Principal Investigators (PI) undertaking a research project which involves human participants should complete and sign this application form.

The document *Guidelines for obtaining ethics approval* gives full details of how to complete this form and is available via the research pages of the UWIC website. You should refer to this document in order to avoid unnecessary delays with your application.

As a PI, you are responsible for exercising appropriate professional judgement in this review and for operating within UEC (and any School and professional) guidelines in the conduct of the study.

Participant recruitment or data collection must not commence until ethics clearance has been obtained.

Principal Investigator:	Jo Hopper
Supervisor (if student project):	Dr John Littlewood
School:	Cardiff School of Art & Design
Type of researcher:	Postgraduate Student (no teaching)
Programme enrolled on:	MPhil/PhD
Project Title:	Energy efficiency improvements to existing homes' project

PART ONE – ETHICS REVIEW CHECKLIST

ERC1: Will the study involve NHS patients or staff?	No

If **YES**, you do not need to complete Part Two of this form. Instead, an application for ethics approval must be submitted to the appropriate external NHS Research Ethics Committee. Complete Declaration A overleaf and forward a copy of your NHS application plus Part One of this form to your School Ethics Committee for information.

ERC2: Does your research fall <u>entirely</u> within one of the following three categories: • Paper-based, involving only documents in the public domain • Laboratory based, not involving human participants or human tissue samples (eg electronics, chemical analysis) • Practice-based, not involving human participants (eg exhibitions, curatorial, reflective analysis, practice audit)	No

If **YES**, you do not need to complete Part Two of this form. Instead, complete Declaration B overleaf and send the completed form to your School Ethics Committee for information.

If **NO**, you must complete Part Two of this form and submit your application (Part One and Part Two) to your School Ethics Committee for consideration.

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DECLARATION A	
I confirm that the information contained in this form is correct My research involves human participants and ERC1 indicates I must obtain ethics clearance from the appropriate external health authority ethics committee. Signature of Principal Investigator:	
Date:	Click here to enter a date.

DECLARATION B	
I confirm that the information contained in this form is correct My research falls entirely within the categories described in ERC2 and I do not need to take further action to obtain ethics clearance. Signature of Principal Investigator:	
Date:	Click here to enter a date.
Brief synopsis of project:	
Click here to enter text.	

FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor: Click here to enter text.	Date: Click here to enter a date.
Signature of Supervisor:	

School Research Ethics Committee use only	
☐ Considered and supported	☐ Considered and not supported
Name: Click here to enter text.	Date: Click here to enter a date.

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PART TWO – APPLICATION FOR ETHICS APPROVAL

Expected Start Date:	02/04/2012
Approximate Duration:	18 months
Funding Body (if applicable):	Knowledge Economy Skills Scholarship (KESS) funded by the European Social Fund through the European Union's Convergence programme administered by the Welsh Government.
Other researcher(s) working on the project	Dr John Littlewood (CSAD), Professor George Karani (CSHS), John Counsell (CSAD)
Does your project require ethical approval from an NREC or other body?	No
If yes, please name the NREC or other body	Click here to enter text.
Does your project use Human Tissue?	No

Has CRB clearance been given?	No	If yes, which organisation holds details of the check[1]?	Click here to enter text.

DECLARATION	
I confirm that the information contained in this form is correct Signature of Principal Investigator:	Date: Click here to enter a date.
FOR STUDENT PROJECTS ONLY I confirm that I have read and agreed the information contained in this form	
Name of Supervisor: Click here to enter text.	Date: Click here to enter a date.
Signature of Supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☐ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐ Project rejected ☐
Project reference number: Click here to enter text.	
Name: Click here to enter text.	Date: Click here to enter a date.
Signature:	

[1] In cases where a CRB check has been sought by an external organisation, confirmation from that organisation that a satisfactory check has been received is required by UWIC at application stage.

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UWIC APPLICATION FOR ETHICS APPROVAL

A – PROJECT DETAILS	
A1 In order to give members of the ethics committee some idea of the nature of your research, please answer the following questions with regard to this project:	
Will you take blood or tissue samples from participants?	No
Will the study involve prolonged or repetitive testing OTHER THAN repetitive training exercises of a type which form part of the participants normal activities (such as athletics or music training)?	No
Are drugs, placebos or other substances (eg vitamins) to be administered to participants?	No
Could the study induce physiological or psychological stress or anxiety significantly greater than the participants are likely to experience in their daily lives?	No
Does the study involve participants who are unable to give informed consent?	No
Will the study involve children? (NB: Projects in professional practice involving those under the age of 18 in a public place (in school or a statutory setting) with the relevant permission are exempt)	No
Is pain or more than mild discomfort likely to result from the study?	No
Will financial inducements, other than reasonable expenses and compensation for time, be offered to participants?	No
Will deception of participants to necessary during the study?	No

A2 Briefly describe the rationale behind your project
The UK Government has set a legally binding target to reduce UK carbon emissions by 34% by 2020 and by 80% by 2050, using 1990 levels as a baseline. With over 25% of UK carbon emissions resulting from energy use in homes and over two thirds of existing homes expected to still be in use in 2050, there is an urgent requirement to address the energy efficiency of existing dwellings. Wales has some of the oldest and most energy inefficient dwellings in the UK. In recognition of this, the Welsh Government instigated the Arbed funding scheme in 2009. The aim of Arbed is to improve the energy efficiency of the top 15% most deprived homes across Wales. The funding was awarded to local authorities and housing associations across Wales to enable them to improve both publically and privately owned homes. One of the funding requirements was that monitoring and evaluation had to be undertaken to determine how effective the improvement measures were at reducing energy use, carbon emissions and fuel poverty. However, there was limited funding and no methodology set out for these assessments. To aid this issue to be addressed, the doctoral research project was developed in collaboration with Coastal Housing Group (CHG), a housing association based in Swansea, after they had won funding through the Arbed scheme. A further housing association based in Swansea, Family Housing Association (FHA), also won funding through the Arbed scheme and has provided case studies for the research project to allow their required data to be collected. Whilst renewable energy systems, such as solar photovoltaic and solar hot water panels were installed, the main method of improvement implemented by CHG and FHA was that of retrofitted external wall insulation (EWI) to pre-1919 dwellings with solid exterior walls.

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A3 What are the aims of the research?	
The aim of the research project is to investigate the impact of retrofitted EWI on energy use, carbon emissions and fuel poverty in pre-1919 solid wall dwellings. The objectives set out to meet the aim, include: assessing the cost-effectiveness of retrofitting EWI relative to energy and carbon savings and alleviating fuel poverty; examining the effects of occupant behaviour on the energy efficiency of existing dwellings that have received the retrofitted EWI; and evaluating the methods used to implement the retrofitted EWI to establish what worked well and what didn't work so well and determine the effects on costs and quality of installation. The outputs from the research project are expected to include: a methodology for engaging with occupants and stakeholders to evaluate domestic retrofit projects; a methodology for assessing the implementation of retrofitted EWI; empirical data and recommendations related to retrofitting EWI through the Welsh Government's Arbed scheme, which could have implications for the UK Government's forthcoming Green Deal; and pre-retrofit and post-retrofit domestic energy use and carbon emission benchmarks, reported as kWh/sq m/year and CO2/sq m/year, respectively, for a variety of dwelling typologies and occupancies for the geographical region of Swansea, which does not currently exist. The purpose of this application is to obtain ethical approval to gather data from occupants about their home, energy use and behaviour, 12 months after the retrofitted EWI was installed.	
A4 Will you be using an approved protocol in your project?	No
A5 If yes, please state the name and code of the approved protocol to be used[1]	
Click here to enter text.	

If your project does involve the use of an approved protocol, please indicate when answering the following questions, which areas of your study are covered by the protocol

A6 What methods of data collection and analysis will you adopt?
For occupants that participated in the pre-Arbed I surveys (as per ethical approval reference 18.01.02/11 Hopper), data collection involves the use of a (full) questionnaire, developed by the PI, which will either be used as a survey interview or posted to the occupant. The aim of the (full) questionnaire is to gather data, for example on changes in occupancy, energy use, heating and hot water systems and behaviour (see full questionnaire for more details). To increase the quantity of data collected for the research, the PI has also developed a short questionnaire to post to occupants of Arbed I dwellings that did not take part in the pre-Arbed I surveys. The aim of this questionnaire is to gather data, for example on occupancy and energy use before and after improvement measures were installed (see short questionnaire for more details). For both questionnaires, occupants will also be asked permission to contact their energy supplier to obtain actual energy use data; this is due to the high number of occupants who have pre-payment meters and therefore do not know their actual energy use in kWh's, as discovered when undertaking the initial pre-Arbed I surveys (see information sheet, consent form and questionnaires for more details). For dwellings owned by the housing associations, floor area data will be obtained from their stock records. For dwellings that are owner-occupied, participants will be asked permission to measure the floor area of their home, either at the time of the survey interview or at a mutually convenient time, where a postal questionnaire is used (see example owner-occupier consent form and reply slip for more details). Once data is collected, it will be entered into a spreadsheet and energy use and carbon emissions per square meter, per year will be calculated. This information

[1] An Approved Protocol is one which has been approved by UWIC to be used under supervision of designated members of staff; a list of approved protocols can be found at [INSERT LINK]

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will then be collated into dwelling typologies and occupancies to allow comparisons to be made and mean usage determined; this will contribute to the formation of the energy use benchmarks. Other information gathered, such as periods of the day when occupants are at home and type of heating system will then be assessed in conjunction with energy use data, to attempt to establish any patterns in low or high energy use.
A7 What remuneration (if any) will be offered to participants?
None.
A8 From which group(s) will participants be recruited and what sampling method and criteria will be used?
The full questionnaire is intended for participants of the pre-Arbed I survey. The short questionnaire will be sent to all occupants that did not take part in the pre-Arbed I survey and that have been identified by CHG and FHA as part of their Arbed funding allocation.
A9 How many participants will be involved?
A total of 33 occupants, 19 from CHG's Arbed allocation and 14 from FHA's, participated in the pre-Arbed I survey interviews and all but one have agreed to take part in the follow-up survey, which will use the full questionnaire. The reason the one participant has withdrawn from the study was due to a number issues resulting from the installation of the EWI and not as a result of the way the survey was conducted. There are approximately 299 Arbed dwellings (152 for CHG and 147 for FHA) with occupants that did not take part in the pre-Arbed I surveys and these will all be sent the short questionnaire by post. The final number of participants will be dependent on how many return the completed questionnaires.
A10 Where and how will the participants be recruited and what method of initial contact will you use?
Participants of the follow-up survey will be contacted using the same method as for the pre-Arbed I surveys (occupants sent a reply slip stating their preferred method of contact and provided corresponding details). The main method chosen by these occupants was via the telephone. Upon re-contacting these occupants, they will be offered the choice of participating in the survey as an interview, at a mutually convenient time, or to have the (full) questionnaire posted to them. For the occupants that did not participate in the pre-Arbed I survey, a letter will be sent to explain the purpose of the study, request participation and provide instructions of what to do if they agree to take part (see attached example of covering letter). Enclosed with the letter will be an information sheet, two consent forms, a reply slip (for owner-occupiers only – to arrange for floor area measurements to be taken), the short questionnaire and a pre-paid return envelope. See enclosed diagram for more details.
A11 What previous experience of research involving human participants relevant to this project do you have?
The PI has conducted 33 interviews with occupants using a questionnaire, as per ethics approval reference: 18.01.02/11 Hopper.
A12 **Student projects only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr John Littlewood the director of studies is leading several projects that involve interviewing staff of housing associations and tenants in their properties respectively and occupants of privately owned houses in collaboration with Coastal Housing Group, which have received CSAD ethics approval. Professor George Karani, the third supervisor for the project, has been involved in housing regeneration projects in Cardiff and supervised a research degree in the area.

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B – POTENTIAL RISKS
B1 What potential discomfort or inconvenience to the participants do you foresee?
Time commitment of approximately 30 minutes by occupants to complete the survey.
B2 How do you propose to deal with the potential risks?
Where the questionnaire is to be undertaken as a survey interview, every participant will be informed of how long the interview is anticipated to take and arrangements will only be made at a suitable time that is convenient for them. Participants will also be given contact details for the researchers so that any arrangements can be changed if the time is no longer convenient. Where the questionnaire is to be posted to the participant, this can be completed at a time that is convenient to them.
B3 Do you intend to use a questionnaire to ascertain an individual's level of physical fitness or health before accepting them as a participant? If yes, please give details.
No
B4 What potential risks to the interests of the researchers do you foresee?
Intimidating/ abusive behaviour from residents during interviews.
B5 How will you deal with these potential risks?
CHG and FHA will assess the suitability of residents to take part and, where possible, a member of staff from CHG/FHA will accompany the PI in face-to-face meetings with residents.

C – CONSENT	
C1 Will informed consent be sought from participants?	Yes
C2 If NO, explain why informed consent will not be sought	
Click here to enter text.	
C3 If YES, describe how informed consent will be obtained and attach copies of relevant documents	
Each participant will be provided with an information sheet describing the aim and objectives of the study and a consent form to sign, to which they will receive a copy for their records. There are four types of consent forms attached to this application, two for where the questionnaire is filled in as a survey interview and two for where the questionnaire are posted to the participants. For each method there is one for owner-occupiers and one for housing association tenants due to having to gain consent to gather floor area data from owner-occupiers only. The consent form to be sent with postal questionnaires differs from the survey interview consent form, in that these participants are providing consent to take part in the study by filling in the questionnaire. See attached example consent forms for more details.	
C4 If you are using an approved protocol, has the approved wording for participants been included in your Participant Information Sheet?	Choose an item.
C5 If NO, why not?	
Click here to enter text.	
C6 If there are doubts about participants' abilities to give informed consent, what steps have you taken to ensure that they are willing to participate?	
Not applicable.	
C7 If participants are aged under 18, describe how you will seek informed consent	
Not applicable.	
C8 How will consent be recorded?	
Paper based form, which will be obtained and stored according to the eight Principles of the Data Protection Act 1998. In summary, these ensure that personal data is processed lawfully and fairly	

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(1) and only for specified purposes (2). They set out information standards which specify the amount of personal data which can be held (3), that it is accurate and kept up to date (4) and how long it can be retained for (5). They also set out the rights of individuals (6), the minimum security measures which must be in place (7) and advice for sending personal data outside the European economic area (8).

D – OTHER DETAILS	
D1 Will participants be informed of their right to withdraw without penalty?	Yes
If no, please detail the reasons	
Click here to enter text.	
D2 How will you ensure participants' confidentiality and anonymity?	
All questionnaire responses are to be identified by a number or code and the key to the code is to be kept completely separately from the data. The PI will provide confirmation in the information sheet that responses will remain completely anonymous and that no reference to the names of participants will be kept on any records (see attached information sheet for more details).	
D3 How will issues of data storage be addressed?	
To ensure compliance with Data Protection Act, participants will be informed of the personal information which will be held about them and who will have access to this information. All information gathered as part of the project, including the signed consent forms and all other forms completed by participants, will be retained by the PI and stored in a secure location at Cardiff Metropolitan University, along with all other confidential information related to the KESS PhD project; accessible for inspection if required for at least ten years after the work is completed. Non essential records will be shredded at the conclusion of the work.	
D4 Are there any further points you wish to make with regard to the proposed research?	
No.	

NB: When submitting your application, in addition to this form your School Ethics Committee will expect to see copies of the documentation you will use during your project. Depending on what your project entails, this may include:

- Participant information sheet (See Section C)
- Participant consent form (See Section C)
- Parents information sheet (See Section C)
- Parents consent form (See Section C)
- Participant questionnaire (See A6)
- Health questionnaire (See B3)
- Letter to the organisation at which research will take place

Refer to the document *Guidelines for obtaining ethics approval* for further details on which documents you should provide and exemplar forms for your reference when compiling this information.

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Appendix XIII: Thermographic Survey Proforma

The Ecological Built Environment Research & Enterprise group (EBERE)

Thermography Building Survey proforma

Name of Thermorapher	
Type of survey	Qualitative / Quantitative External / Internal
Camera details	
Date	
Time	
Location (address)	
Property type	Detached/ Semi-detached/ End-Terrace/ Mid-Terrace/ Flat Other (Specify)……………………………………………………
Construction type	Solid walls/ Cavity walls/ Steel frame/ Timber frame/ Mixed (Specify)……………………………………………………
Orientation of property (Front / Back)	
Temperature – In	
Temperature – Out	
Relative Humidity – In	
Relative Humidity – Out	
Wind speed	

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.
Director of EBERE: Dr John R Littlewood jlittlewood@uwic.ac.uk

The Ecological Built Environment Research & Enterprise group (EBERE)

Photo no.	Thermal image no.	Description

Department of Architectural Studies, Ecological Built Environment Research and Enterprise (EBERE) Group.
Director of EBERE: Dr John R Littlewood jlittlewood@uwic.ac.uk

Appendix XIV: Arbed I Approved Technical Details

Figure 1 illustrates the manufacturer's technical detail for the eaves and verge where there is no roof overhang to protect the top of the EWI system. The detail was obtained from the BBA certificate as one was not provided to the housing association as part of the set of drawings produced for the design and build contract. As Figure 1 is a generic detail, it does not illustrate the ceiling level relative to the top of the EWI as shown in Figure 35 in section 5.2.2 on page 159 of Volume I of this thesis. As a result, it is not possible to identify any potential thermal bridging.

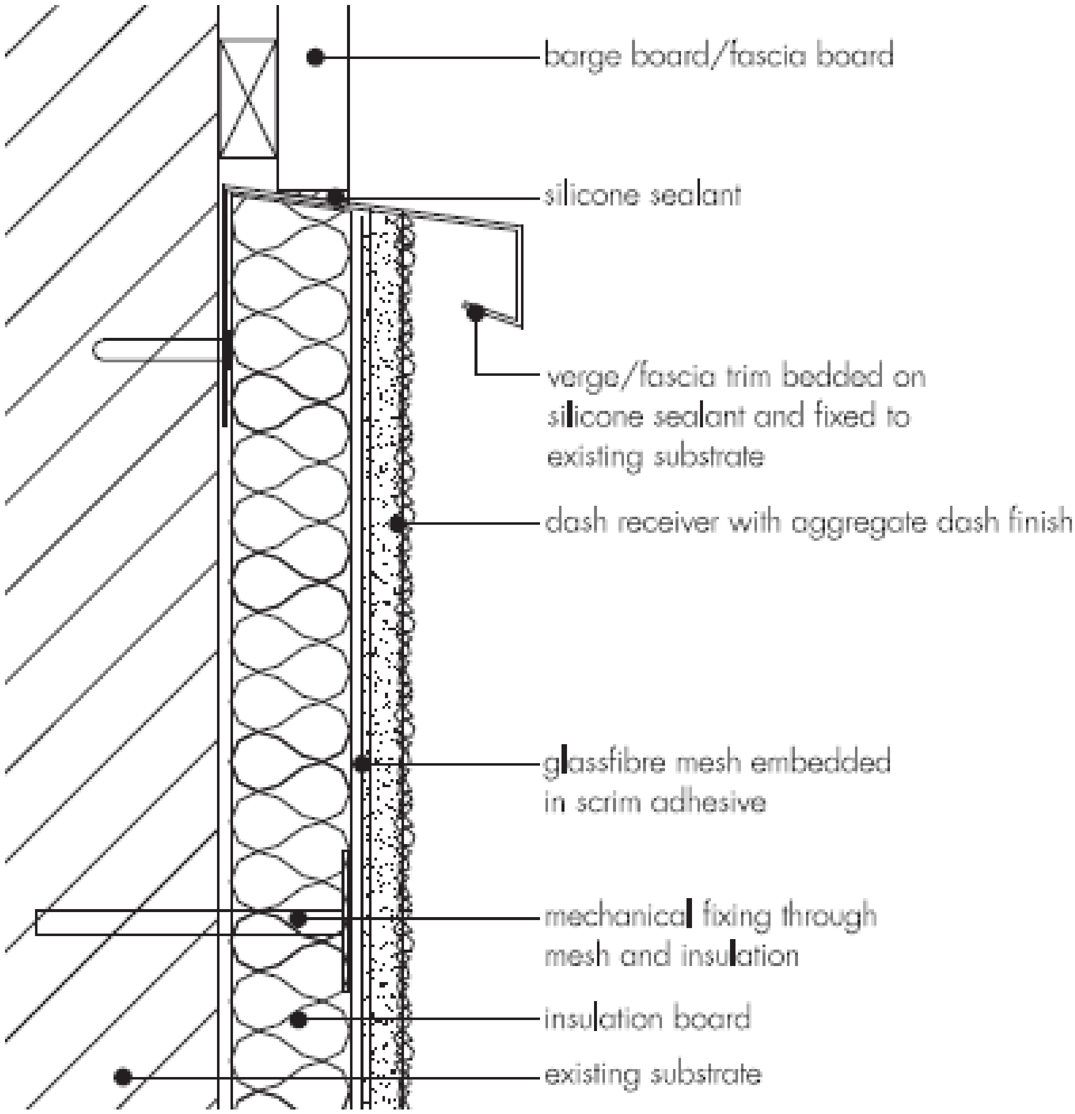

Figure 1: Manufacturer's eaves detail using capping profile (BBA, 2011)

Figures 2 and 3 illustrate the window reveal details provided by the manufacturer. The window reveal detail illustrated in Figure 2 is the option that was adopted by the contractor and thus housing associations for their Arbed I dwellings. As illustrated, the adopted window reveal detail did not consist of EWI being returned at the reveal and therefore a thermal bridge was created at these locations of the external walls. Whilst the alternative window reveal detail shown in Figure 108 consists of a reduced thickness of EWI at the reveals, this would have reduced the likelihood of thermal bridging occurring.

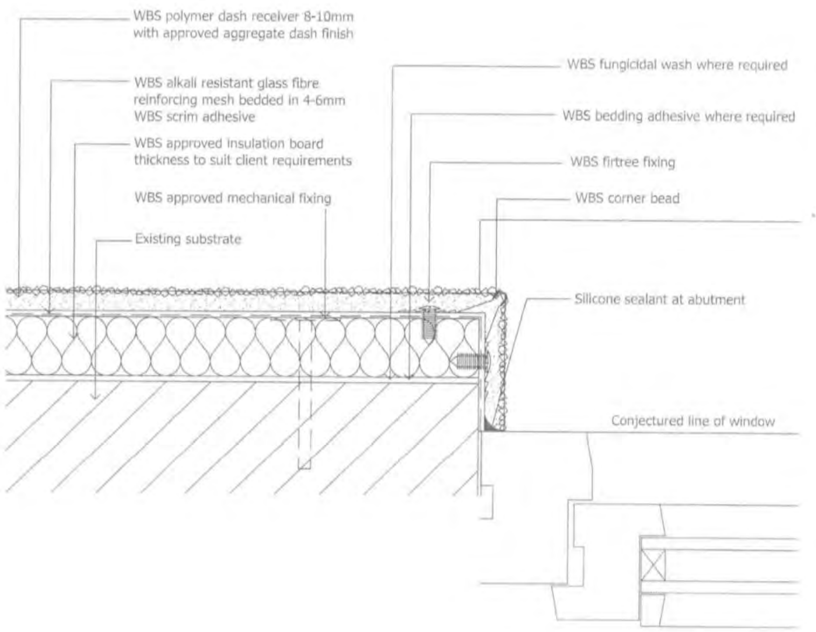

Figure 2: Adopted window reveal detail provided to the housing association by the manufacturer

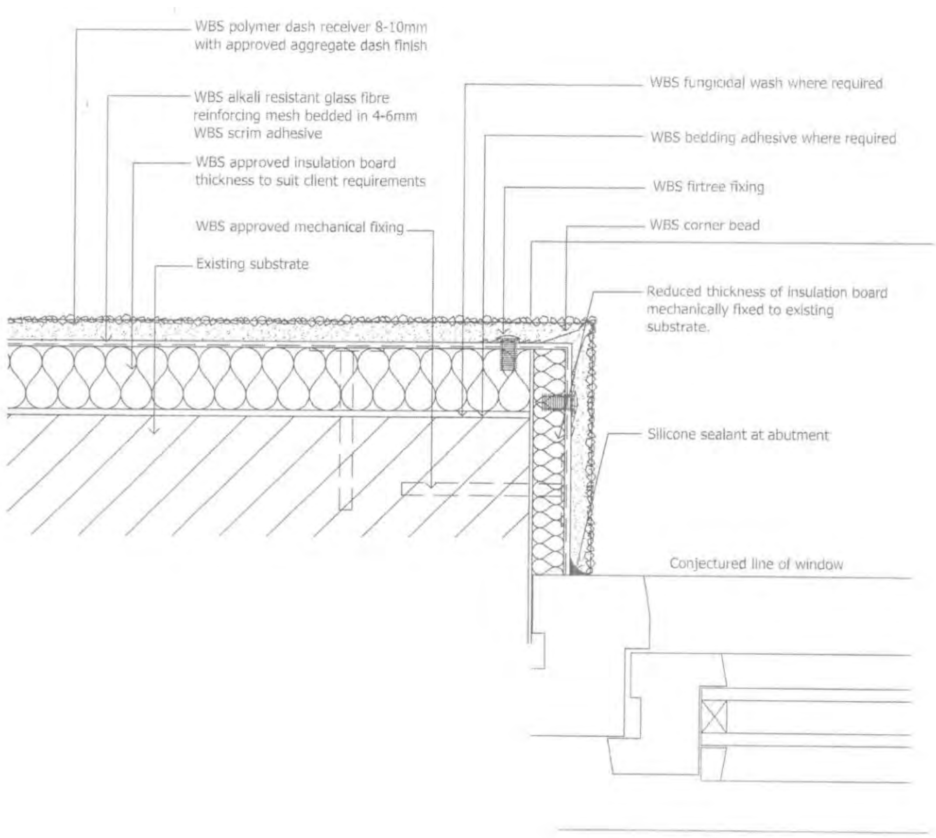

Figure 3: Alternative window reveal detail provided to the housing association by the manufacturer

Figures 4 and 5 illustrate the options for the window sill details provided by the manufacturer. As shown in Figures 37 and 38 in section 5.2.2 on pages 161 and 162 of Volume 1 of this thesis, respectively, neither thus housing association adopted either of these methods for their Arbed I dwellings. Whilst both options below appear to leave a residual pathway for a thermal bridge, the second option, illustrated in Figure 38 on page 162 of Volume 1 of this thesis appeared to overcome this issue.

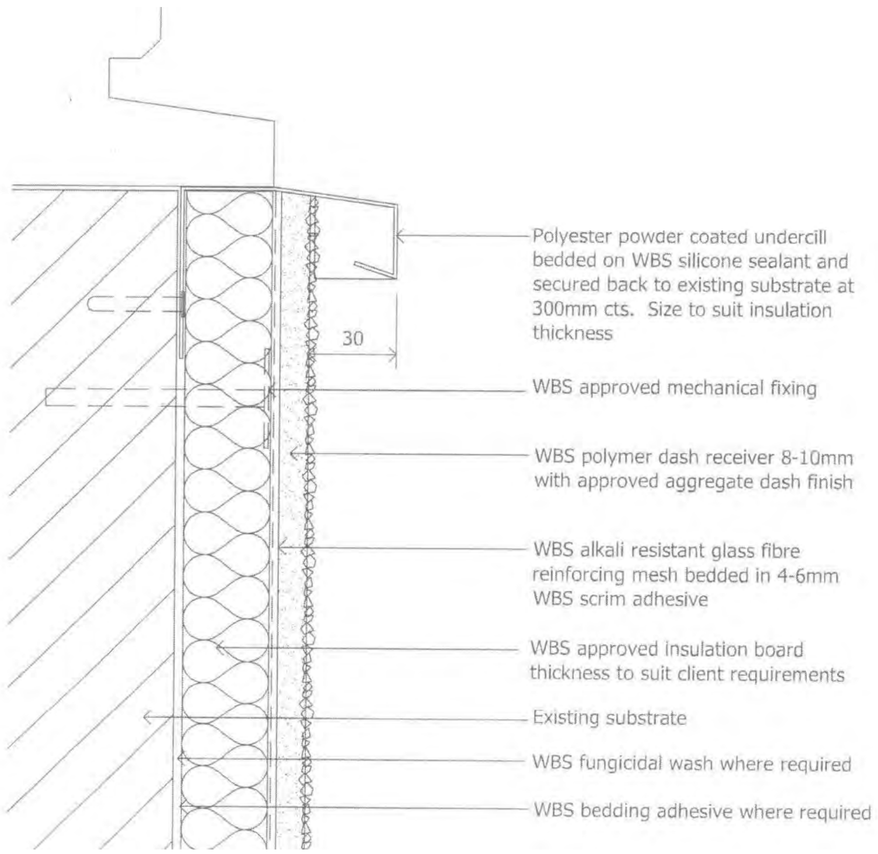

Figure 4: Window sill detail Option 1 provided to the housing association by the manufacturer

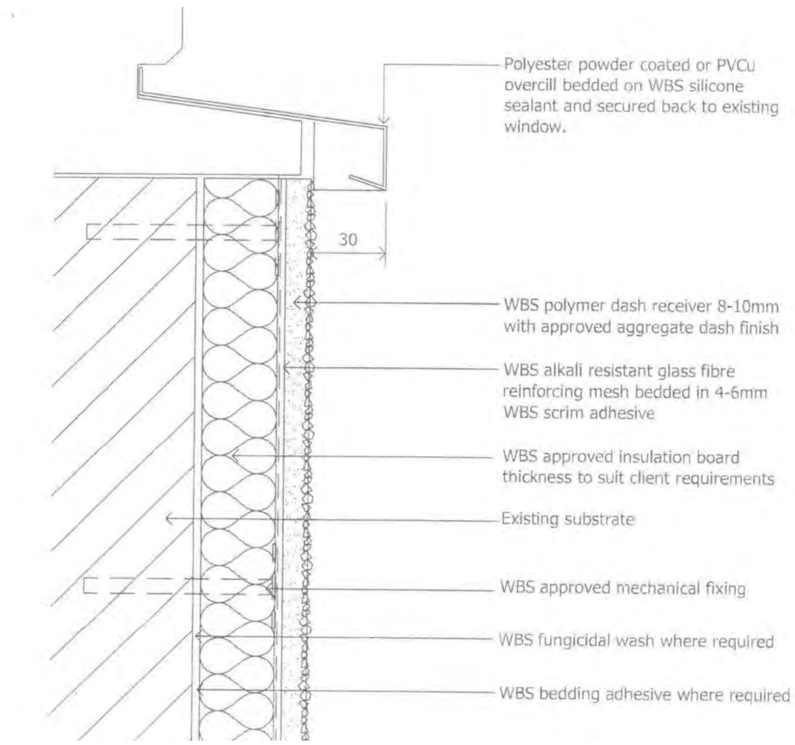

Figure 5: Window sill detail Option 2 provided to the housing association by the manufacturer

Figure 6 illustrates the external wall to pavement detail provided by the manufacturer. As with the window sills above, neither housing association adopted the method below as both chose to insulate the plinth of the wall with XPS. The method shown in Figure 6 below would have left a significant thermal bridge. Whereas the method shown in Figure 39 in section 5.2.2 on page 163 of Volume 1 of this thesis, reduced the level of thermal bridging.

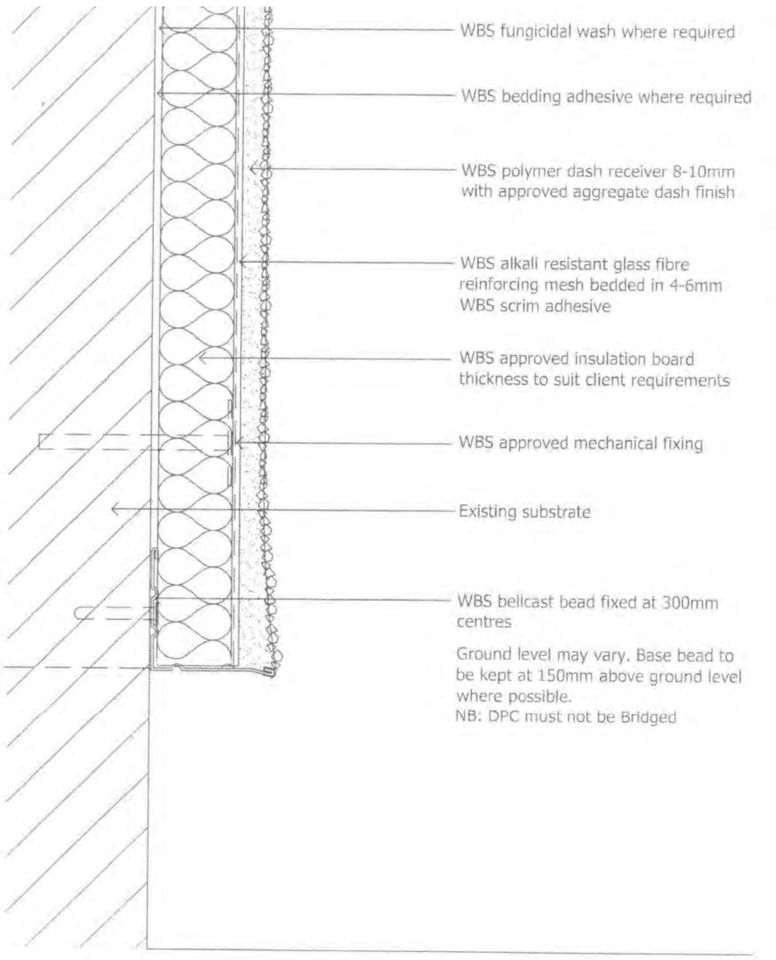

Figure 6: Pavement to wall junction detail provided to the housing association by the manufacturer