Bryan House

Phase 1 study
Post construction and early occupation

This document contains a Building Performance Evaluation report from the £8 million Building Performance Evaluation research programme funded by the Department of Business Innovation and Skills between 2010 and 2015. The report was originally published by InnovateUK and made available for public use via the building data exchange website hosted by InnovateUK until 2019. This website is now hosting the BPE reports as a research archive. Although no support or further information on the reports is available from the host, further information may be available from the original InnovateUK project evaluator using the link below[1].

InnovateUK project number	450100
Project author	Low Carbon Building Group, Oxford Brookes University for Sanctuary Green Technologies
Report date	2014
[1]InnovateUK Evaluator	N/A

No of dwellings	**Location**	**Type**	**Constructed**
Two	Bicester	Mid and end-terrace	2012

Areas	**Construction form**	**Space heating targets**	**Certification level**
Mid terrace: 123 m^2 End terrace: 88 m^2	Steel frame	See report	CSH Level 4

Background to evaluation

The Bryan House scheme was intended to be an exemplar eco-development promoting the Eco-Bicester brand. The scheme comprised a social housing development of 23 new homes in four blocks of seven houses (2 and 4 bedroomed) and 16 flats (2- 4 bedrooms). The BPE study covered two dwellings. A fabric-first approach was adopted. Innovative construction methods comprised lightweight steel frame construction with pre-insulated panels. All dwellings had photovoltaics, mechanical ventilation with heat recovery (MVHR) with summer bypass mode, and air-source heat pumps (ASHP) for all heating and hot water.

Design energy assessment	**In-use energy assessment**	**Sub-system breakdown**
Yes	Yes	No

The case study dwellings were assigned an 'as designed' Dwelling Emission Rate of 11.53 kgCO_2/m^2 per annum, equating to 92 (A) for the mid terrace dwelling and 91 (B) for the end terrace. An as-built SAP assessment generated an 'as built' assessment of 88 (B) for the mid terrace and 86 (B) for the end terrace. The reason of the deviation was located in the discrepancies between the roof areas, wall areas and floor heights that were used in the provided SAP in comparison to the architectural drawings. Higher air permeability rates were also measured in the dwellings at an average 5.5 m^3 (m^2.h), above the as-designed values of 3 m^3 (m^2.h). Thermographic testing revealed a number of thermal anomalies. Some parts of the heating systems were initially not working in both properties.

Occupant survey type	**Survey sample**	**Structured interviews**
BUS domestic	24 of 35 (68% response rate)	Yes

BUS surveys were performed on all houses in the development. Overall the survey revealed a positive opinion towards the dwellings, with the air quality in winter and the quality of light being the most appreciated elements. Also the air quality in winter scored higher than scale midpoint and BUS benchmark. Participants generally felt that the facilities met their needs well and that the dwellings were quite comfortable overall. Temperatures during winter were generally regarded as quite comfortable but less so in summer.

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1 Introduction and overview

The Bryan House scheme has been identified as an exemplar eco development promoting the Eco-Bicester brand. Modern and innovative construction methods have been selected comprising lightweight steel frame construction with pre-insulated panels. A fabric first approach was adopted for all 23 dwellings. All dwellings have MVHR with summer bypass mode and thermal sensors. Air Source Heat Pumps (ASHP) supply 100% heating and hot water to the case study dwellings and along with PV help achieve the 70% carbon reduction target. The case study dwellings have achieved an 'As designed' Dwelling Emission Rate of 11.53kgCO_2/m²/year and attained a Code for Sustainable Homes Level 4 certification.

Low Carbon Building Group (LCBG) of Oxford Institute for Sustainable Development (OISD) at Oxford Brookes University was commissioned to monitor and evaluate the social housing project during its *Post construction and initial occupancy* phase and provide key comments and recommendations.

The key objectives of the overall research programme were to:

- Close the feedback loop between design aspiration and performance in use.
- Assess, retrospectively, the procurement process and the key design and construction decisions.
- Generate a knowledge base of building performance for wider dissemination within the industry through the publication of research papers, and articles in appropriate journals.

1.1 Background to the scheme

The Construction of the Bryan House scheme in Bicester was completed in August 2012. The scheme is run in association with Cherwell District Council. The Bryan House scheme comprises a social housing development of 23 new homes in 4 blocks containing 7 houses (2, 4 bedrooms) and 16 flats (2, 3, 4 bedrooms) (Figure 1). The site is centrally located in Bicester's Conservation Area, and is a brownfield opportunity formerly occupied by redundant sheltered housing.

Figure 1 Bryan House scheme, Bicester-site plan

To identify any deviation from the design intent and map the initial occupants' reactions, the BPE study is being undertaken covering the design and construction stage as well as the post construction and early occupancy phase of the new homes. The starting point was a review of the design and specification records. Additionally, the fabric and systems' performance and the occupants' first reactions are being established. The parties involved in the process consist of the research team, the design team and the contractors (Sanctuary Housing) owned by SBC.

Two homes, house numbers 1 and 2 (Figure 2), in the Bryan House scheme are being monitored and assessed for a period of 4 months. The evaluation of two of the houses is conducted under the Technology Strategy Board's Building Performance Evaluation programme. The study of the two houses is due for completion in 2013.

Figure 2 Front view of Houses 1 and 2 in Bryan House scheme, Bicester

House 1 is an 88m^2 3 bedroom end-terrace house and House 2 is a 123m^2 four bedroom mid-terraced house (Table 1). These homes are constructed of prefabricated steel frame construction with pre-insulated panels. Timber windows with triple glazing with a U value of ≤1.2 W/m²°C were used. The details of dwelling construction are presented in Table 2.

Table 1 Case study details

	House 1	House 2
Area	88 m^2	123 m^2
Typology	3 bedroom end-terrace	4 bedroom mid-terrace
Floors	Two	Three
Occupancy patterns	Weekdays: 15:00-8:00 Weekend: 24h	Weekdays: 24h Weekend: 24h
Occupants	2 adults, 2 children	4 adults, 1 baby

Table 2 Design specifications and construction details

Windows	Timber frame, triple glazing, no trickle vents. U-value of ≤1.2 W/m²°C
External doors	Wooden with design U-value of 1.5
Internal doors	Wooden
Warm Roofs	Tile finish, 50x25mm battens, vapour resistant underlay, rafters/trusses at 600mm centres, 100mm Kingspan K7 pitched roof board between rafters, 90mm Kingspan K7 pitched roof board below rafters, vapour control layer, 12.5mm Gyproc wallboard taped and skimmed
Cold Roofs	Tile finish, 50x25mm battens, vapour resistant underlay, rafters/trusses at 600mm centres, 400mm mineral wool insulation, vapour control layer, 12.5 Guproc wallboard taped and skimmed
Ceiling	Plasterboard, Air barrier/vapour control, 100mm mineral wool quilt insulation between joists, 300mm mineral wool insulation over
Dormers	Roof(as cold roof), Wall: 0.7mm Rheinzinc/VM Zinc, 18mm sheathing on battens to provide min 25mm, vented void, breather membrane, 225x50mm timberframe with full fill Kingspan, K12 framing board between, vapour control layer/air barrier, 12.5mm Guproc wallboard
Separating walls	Two layers of 15mm sound check plasterboard, vapour control layer/air barrier, 300mm gap, Dritherm insulation 24kg/m3, 300mm gap, vapour control layer/air barrier, Two layers of 15mm sound check plasterboard
External wall	Element type: Wall - Light steel frame – hybrid. From inside: 15mmGuproc wallboard, 40mm Phenolic insulation (Fusion), vapour control layer/air barrier , 162mm EPS Panel, 70mm EPS insulation, 50mm cavity, blockwork, finish. Design U-value 0.15 W/m^{2}K
Finishes	Multi stock brick. Natural limestone with lime mortar. Through coloured render on block work, Weber render Silver Pearl ref 674
Internal Partitions	Timber/metal studwork with plasterboard
Floor	Plasterboard ceiling, 100mm acoustic mineral wool laid between steel joists, steel joist, 18mm chipboard deck on 25x50mm battens with under floor heating pipes between
Ground floor	Cube 6 EPS insulation block (depth 331mm), 1200 gauge DPM/Radon barrier, under floor heating, 90mm concrete structural topping. Design U-value 0.15 W/m^{2}K
Air Source Heat Pump	Mitsubishi, Model: Ecodan PUHZ-W85VHA2-BS, MCS HP0002/26, Net capacity 25.5 kW, Estim Annual Generation 38205 kWh
GSHP Installer	ACS Renewable Solutions Ltd.
Hot Water Cylinder	Excelsior , 150 litre, immersion heating, unvented
Ventilation	MVHR, rigid ducting. No trickle vents, ITHO Advance, Heat recovery ventilation unit

1.2 Building services and energy systems

Space heating is achieved through air source heat pumps with under floor heating, supported by PV panels and a hot water cylinder (Figure 3).

The renewables solution includes Photovoltaics and Air Source Heat Pumps. Heating output from the heat pump is served via an under floor heating system. The Photovoltaics provide energy to power the ASHP and immersions, maximising the tenant benefit of the renewables.

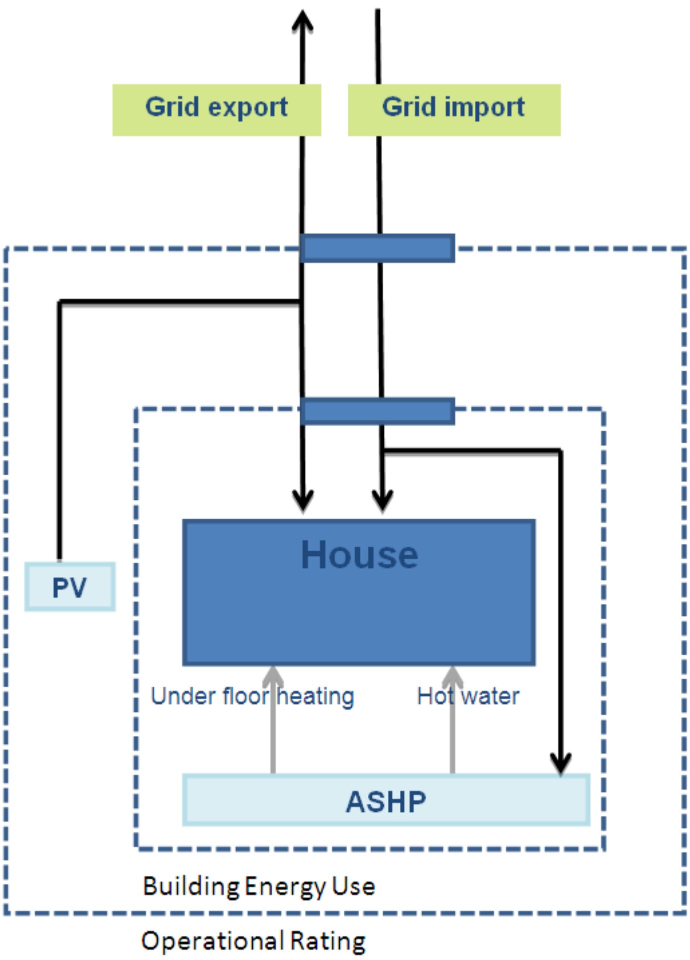


Figure 3 Building services

2 About the building: design and construction audit, drawings, SAP calculation review and review of control interfaces

The first step of the BPE study was to compare the original design package specifications to the final 'as built' as a part of a diagnostic process for understanding the design and construction intention and identify any arising issues.

To achieve this objective a series of actions were carried out which included:

- Initial meeting with the design team and client,
- SAP review,
- Drawings and specifications review,
- Design team interview and
- Close observation and review of the control interfaces.

The design and construction issues that were reviewed on site were based on:

- comparison of 'as designed' to 'as built'
- observation and spotting of emerging issues
- usability and manageability of proposed design solutions in particular moving parts, electrical components and their control interfaces
- usability and performance of the construction materials

The following sections present the research method, findings and recommendations made.

2.1 Comparison of 'as designed' and 'as built' performance

A review of the design documentation that included architectural drawings (Architect David J Stewart Associates), design specifications and construction drawings (Fusion) was undertaken. These early design and construction observations are considered to be valuable in the next steps of the research were fabric loss and energy use has to be measured and evaluated. Drawings, construction details and specification documents were provided in liaise with the design team.

A careful study of the design drawings and specifications was combined with a walkthrough in the dwellings, revealing issues that would not be apparent with only a drawings review. By combining the two aspects the apparent differences were mapped and investigated with the dwelling owners and architects in order to establish the deviation reasons. It should be noted that during this walkthrough the loft was not inspected.

The walkthrough was performed on the 22nd January 2013.

2.1.1 Visual aspects

2.1.1.1 Similarities

From a visual aspect the houses did not present any apparent differences from the architectural drawings (Figures 4, 5, 6):

- Both the elevations and plans were executed following the architectural drawings without major deviations.

- Doors and windows in the houses are located in the positions indicated in the designs and are opened in the way that is indicated.

- The dimensions of the internal spaces after construction were measured on site and were found to be in accordance with the designs.

- The materiality of the built houses also matches the specifications provided by the architects, both indoors and outdoors.

Figure 4 Front and back elevations of Houses 1 and 2.

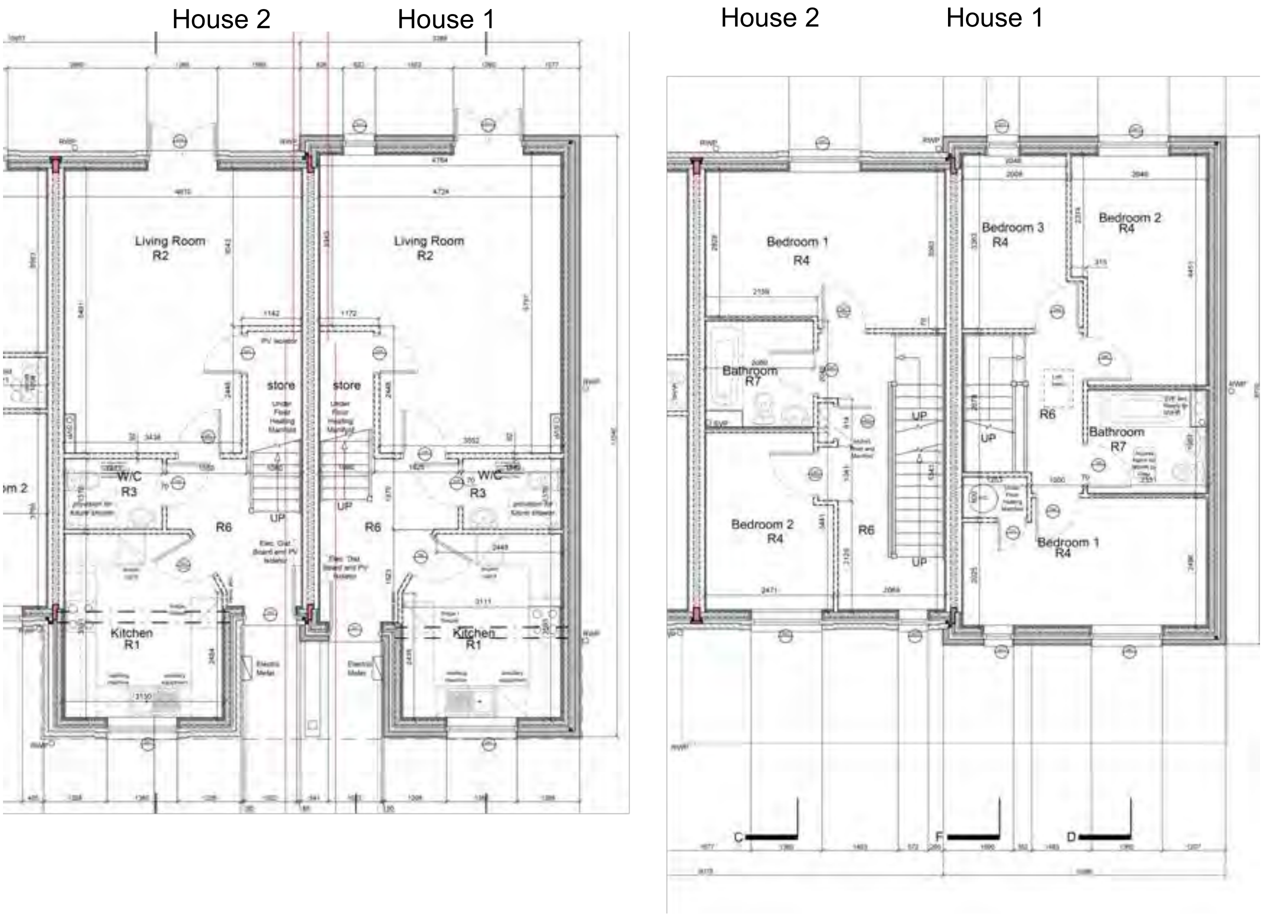


Figure 5 Left: Ground floor plans, Right: First floor plans

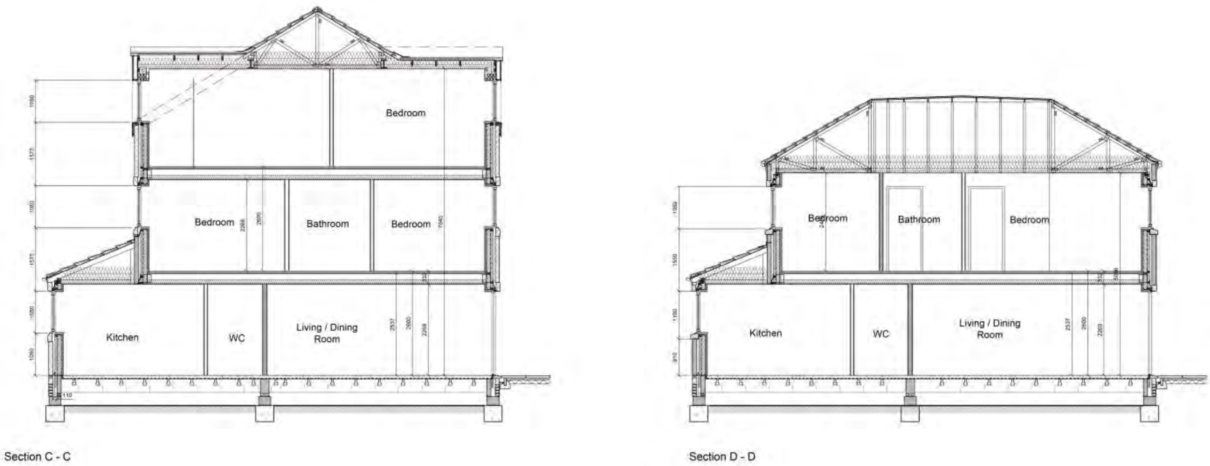


Figure 6 Left: Longitudinal section of House 2, Right: Longitudinal section of House 1.

2.1.1.2 Deviations

Small deviations from the architectural designs can be noticed in the dwellings that are related to construction.

- Floor finishing had not been provided in House 2
- In House 2 WC a small wall was added to the back of the toilet, possibly in order to provide additional pipe space, thus not allowing the future installation of a shower, as provisioned by the architects (Figure 8).
- In House 2 some additional plasterboard soffits were used to cover a construction flaw in the staircase leading to second floor (Figure 7).
- The mechanical equipment is located in cupboards that are accessible to the occupants and are being used as storage space. After discussion with the architects it has been pointed out that due to changes in the energy strategy of the houses (decision to use ASHP instead of gas boilers), space that was originally designed for storage had to be used as space for the ASHP mechanical equipment and the hot water cylinder. This resulted in the MVHR unit being placed in the loft and the hot cylinder in the dedicated storage space (Figure 9).

Figure 7 House 2: additional plasterboard soffits used to cover a construction flaw in the staircase

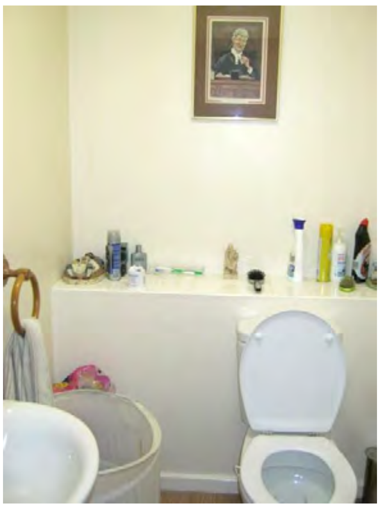


Figure 8 House 2: additional wall used in WC

Figure 9: Mechanical equipment located in storage space cupboards.

2.1.2 Construction detailing and performance

Even though visually the houses appear to have followed the design specifications, great discrepancies can be noticed between the design intent and the actual construction detailing, which might have an impact on the real performance of the two houses.

- The on-site inspection revealed that the building is not as air tight as it was originally intended and that there are several air leakages, common in both the houses. Air leakage was observed through the sockets, the ceiling lights, around the piping and through the floors and windows. These points will be further explored and identified through the air tightness and smoke pencil tests, which will provide us with more detailed information.

2.2 SAP calculations review

The Standard Assessment Procedure (SAP) is adopted by Government as the UK methodology for calculating the energy performance and CO_2 emissions of dwellings. In the case study project the SAP ratings were high and located in the range between 91 B for House 1 (end-terrace) and 92 A for House 2 (mid-terrace).

To ensure that existing calculations accurately reflected the design of the dwelling and identify any design aspects that could affect the energy performance but were not captured adequately, they were reviewed by the research team as follows:

- SAP specifications were compared to the provided specification notes, reports, and drawings. Table 3 summarizes the results.
- The SAP calculations were repeated for two different housing types with the use of STROMA software and the results were compared to the existing ones (Table 4). Air permeability rates measured in the post-completion air permeability testing (Section 3.3) were used.

Table 3 Discrepancies between provided SAP calculations and specification notes and drawings

Provided SAP	Notes & Drawings
• Calculated y value = 0.15 W/m^{2}K	• Initial design proposal y value=0.04 W/m2K
• House 1 External Walls Area = 89.7 m^2	• House 1 External Walls Area = 94.5 m^2
• House 2 External Walls Area = 77.4 m^2	• House 2 External Walls Area = 78.2 m^2
• House 1 Roof Area = 46.5 m^2	• House 1 Roof Area = 50 m^2
• House 2 Roof Area = 53 m^2	• House 2 Roof Area = 59 m^2
• Ground Floor Height 2.31 m	• Ground Floor Height 2.26 m
• Floors Height 2.62 m	• Floors Height 2.26 m

Table 4 Comparison of 'as designed' SAP with 'as built' SAP

Dwelling type	Provided SAP rating y=0.15 W/m^{2}K	Review SAP **'As built'**
House 1 (3bed end terrace)	91 (B)	86 (B)
House 2 (4 bed mid terrace)	92 (A)	88 (B)

2.3 Photographic survey

The photographic survey was undertaken from outside to inside for both properties to capture the physical features of the house and areas of interest.

Figure 10 Front view of case study houses.

Figure 11 Permeable access path and vegetation leading to the case study houses

Figure 12 Air source heat pump located near the bicycle shed in the rear garden

Figure 13 Rear facade of case study houses: No.1: two storey, end-terrace and No.2: three storey, mid-terrace

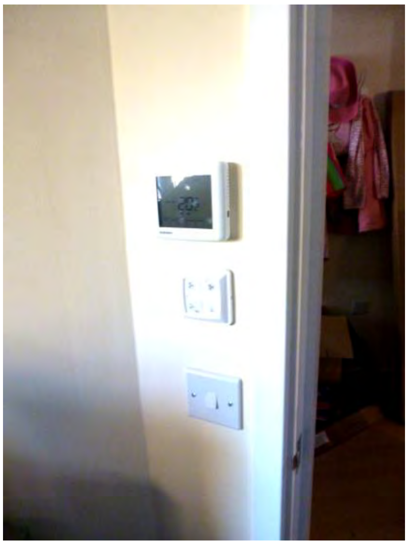


Figure 14 (Left) Room thermostat and ventilation boost control located near the doorway and above the light switch

Figure 15 Hot water tank with immersion heater

Figure 16 Solar PV generation meter

Figure 17 Control system for under floor pipework

Figure 18 MVHR Boost control: Top RHS is for boosting the ventilation, Bottom LHS is for normal operation, Bottom RHS is for fixed time-period boosts

Figure 19 Room thermostat

Figure 20 Extract ventilators in the kitchen

Figure 21 Carbon monoxide alarm

2.4 Review of control interfaces

Control interfaces are the part where the users meet the technology of the building. The usability of local controls for lights, heating, cooling and ventilation largely dictate the performance of a house in terms of:

- User satisfaction
- Avoiding discomfort
- Rapid response
- Thermal comfort
- Assisting management
- Energy efficiency

A review of control interfaces took place on 14th February 2013 to investigate the relationship between the design and usability of controls and the potential effect they can have at the dwelling's occupancy.

The control's design principles were evaluated in terms of their:

- Location
- Clarity of purpose
- Degree of fine control
- Intuitive switching
- Indication of system response
- Useful annotation

2.4.1 Heating and hot water controls

The usability of heating and hot water controls is not intuitive and needs instructions to use it properly. Clarity of purpose and labelling could be improved. The degree of fine control is good but the system override is unclear. The interaction of the Heating and hot water programmer and timer with the individual room thermostats should be communicated to the occupants in order to improve energy efficiency.

2.4.1.1 Heating and hot water programmer

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

No intuitive programming, needs instructions. Instructions were not provided on the control. There is no indication that the lid should be opened. The buttons are small, not easy to use. It is a difficult set of symbols to interpret intuitively. Need to read manual. Very poor accessibility. No light provided in the cupboard. Mitsubishi Electric panel works with Honeywell timer.

2.4.1.2 Heating and hot water timer

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

No intuitive programming, needs instructions. Instructions were not provided on the control. There is no indication that the lid should be opened. The buttons are small, not easy to use. It is a difficult and set of symbols to interpret intuitively. It is a 7 day timer that offers up to three on/off switchings per day. 'Holiday' button allows the user to switch off their heating for a specified number of days. Unclear if it overrides the individual room thermostats. Need to read manual. Very poor accessibility. No light provided in the cupboard. Honeywell timer overrides Mitsubishi Electric panel timer.

2.4.1.3 Heating room thermostat

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

One in each room, located next to door. It is slightly complicated. Not intuitive to use. High level of fine control and automatic settings. Settings for different hours of the day and days of the week. Additional setting for vacations. Occupants reported that this thermostat gets overwritten and temperature gets turned on even though the thermostat is set at off. In House 2 some thermostats were off and were not calling for heat but the heating was on. This issue was further investigated during the commissioning review which revealed that the thermostats are not properly connected to the heating system.

2.4.1.4 Heating system switch

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Clear and intuitive switching. Well labelled. No indication of system response. Located at one side of the tank.

2.4.1.5 Immersion heater tank

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Difficult to access. Cupboard space used as storage. No indication of system response.

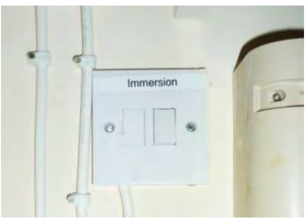
2.4.1.6 Immersion heater timer panel

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

It is a difficult set of symbols to interpret intuitively. Need to read manual.

2.4.1.7 Immersion heater switch



Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Clear and intuitive on/off. Well labelled. No indication of system response on switch, need to check the tank to see if it is on. Located very close to the tank.

2.4.2 MVHR controls

The MVHR unit is located in the loft in a very narrow and inaccessible space making its operation and maintenance very difficult. The MVHR system purpose is not clear and there is no indication of system response or whether any fault is occurring. The manual is located in a pocket inside the unit but the position of the unit makes it difficult for the occupants to have access to it. No indication of when filters need to be changed. Users were unaware of the location of the unit. The position of the diffusers in the bedrooms creates draughts that make the occupants highly uncomfortable and led them toclosing the grills.

2.4.2.1 MVHR boost

Criteria	Poor	Excellent
Clarity of purpose		
Intuitive switching		
Usefulness of labelling & annotation		
Ease of use		
Indication of system response		
Degree of fine control		
Accessibility		

Comments

The purpose of the control is not clearly labelled. Unclear when the operation is on/off. No indication of system response. The lights that are located on each option indicating that it has been selected are not functioning in either house. In house 2 the MVHR unit was not in operation. Position is good, next to the door in kitchen and bathrooms but its purpose is unclear. The three icons indicate different fan power/speed. The timer button does not give any indication for how long it operates. The user needs to have read the manual.

2.4.2.2 MVHR diffusers

Criteria	Poor	Excellent
Clarity of purpose		
Intuitive switching		
Usefulness of labelling & annotation		
Ease of use		
Indication of system response		
Degree of fine control		
Accessibility		

Comments

One in each room. Not easy for occupants to know whether the diffuser is a supply or an extract or whether it is set properly. Their location in the bedrooms is very poor as it is directly above the beds and creates unpleasant feeling. In House 1 the occupants had closed all the vents as a result of that even though the unit was still working. In House 2 the MVHR unit was not working.

2.4.2.3 MVHR control unit panel

Criteria	Poor	Excellent
Clarity of purpose		
Intuitive switching		
Usefulness of labelling & annotation		
Ease of use		
Indication of system response		
Degree of fine control		
Accessibility		

Comments

Located in the loft. Extremely difficult to access. MVHR Unit in House 2 is not working even though it is plugged. No indication of when filters need to be changed and unit needs maintenance. Not enough space provided for proper fitting and maintenance. Filters easy to remove but not clearly indicated. Used needs to read manual.

2.4.3 Electrical equipment controls

Light switches and control panel are intuitive to use and have good labelling and annotation. Problems have been reported with the fire alarm of House 1. Additionally, the purpose of a red switch located in both houses has not been identified and occupants were unaware of its use.

2.4.3.1 Electric panel

Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching					■
Usefulness of labelling & annotation					■
Ease of use				■	
Indication of system response		■			
Degree of fine control					
Accessibility					■

Comments

The labelling of the electric panel is thorough and clear. Clear labelling for power, lights and appliances. No indication of system response. Further details were required and were written by hand to describe the end use by floor. Installation and inspection sticker present but no operation sticker supplied on the panel.

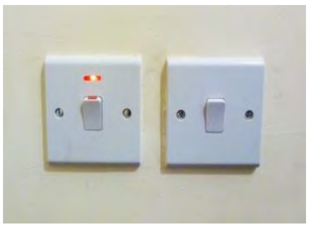
2.4.3.2 Main PV switch

Criteria	Poor				Excellent
Clarity of purpose		■			
Intuitive switching					■
Usefulness of labelling & annotation			■		
Ease of use					■
Indication of system response		■			
Degree of fine control					
Accessibility					■

Comments

The purpose of the PV switch is not clear although on/off operation on the switch is clearly labelled and intuitive. Its location next to the PV meter next to the electric panel might give a hint on its purpose. No indication of system response.

2.4.3.3 Lights and switches



Criteria	Poor				Excellent
Clarity of purpose				■	
Intuitive switching					■
Usefulness of labelling & annotation		■			
Ease of use					■
Indication of system response			■		
Degree of fine control	■				
Accessibility					■

Comments

Typical switches on /off throughout. Very intuitive to use. None labelled but not needed as there is one light to control. No fine control.

2.4.4 Passive controls

The purpose of the windows and doors is clear. The locking mechanism for the windows is not particularly intuitive but it provides safety for kids. Good level of fine control in windows.

2.4.4.1 Main door

Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching					■
Usefulness of labelling & annotation					
Ease of use					■
Indication of system response					■
Degree of fine control		■			
Accessibility					■

Comments

Typical door. Door easy to open, no degree of fine control on how much aperture.

2.4.4.2 Windows

Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching		■			
Usefulness of labelling & annotation	■				
Ease of use	■				
Indication of system response					■
Degree of fine control				■	
Accessibility				■	

Comments

Windows hard to open and operate. Need to press button on handle to operate. Kids safety provided. There are three positions to control aperture and cleaning position. No clear labelling.

2.5 Conclusions and key findings

2.5.1 Key findings from 'as built' and 'as designed' comparison

- From a visual aspect the houses did not present any apparent differences from the architectural drawings.
- Small deviations from the architectural designs can be noticed in the dwellings that are probably related to construction flaws.
- The hot water tank and the main controls for the ASHP are located in cupboards that were originally designed to be storage space. The decision to use an ASHP instead of a gas boiler (as originally planned) led to loss of some dedicated storage space in the dwellings. This issue was further discussed with the architect during the design team interview and walkthrough (Section 4).
- Some discrepancies can be noticed between the design intent and the actual construction detailing.

2.5.2 Key findings from SAP review

- In the 4-bed end-terraced house a four point difference was observed between the existing SAP rating and the revised STROMA rating which led to the downgrading of the predicted energy efficiency of the dwelling in scale B of the SAP assessment.
- In the 3-bed mid-terrace house a five point difference was observed between the existing SAP rating and the revised STROMA rating.
- The reason of the deviation was located in the discrepancies between the roof areas, wall areas and floor heights that were used in the provided SAP in comparison to the architectural drawings. Also, this is related to the effect of the higher air permeability rates that were measured in the dwellings (average 5.5 $m^3/h*m^2$) instead of the as designed value of 3 $m^3/h*m^2$ (Section 3.3). The SAP review was revised following the results of the air permeability testing undertaken for the purposes of this study.

2.5.3 Key findings from photographic survey and walkthrough

The initial walkthrough and photographic survey revealed some issues that were then further investigated through the fabric testing and the commissioning review. The main issues that came up were the following:

- Occupants in both properties were aware of how to control the room thermostats and MVHR boost.

- House No.1 reported air draughts coming in through the electrical sockets, which was verified during the air permeability testing and smoke testing (Section 3.3).

- Both properties had received two sets of user guides – one which is property specific and another general one from sanctuary housing; occupants expressed reluctance to look through such a large document. This was taken into account during the evaluation of guidance offered to the occupants and the physical handover process (Section 5).

- The MVHR boost control for the kitchen in House No. 2 is not working and has been noted by Mark Ashburn, Sanctuary Housing for further follow up. The commissioning review that followed revealed that the MVHR unit was not working and actions were taken to replace it (Section 7).

- Some parts of the heating systems were initially not working in both properties but have since been rectified. This issue was again brought up during the commissioning review that revealed that the room thermostats were not properly connected to the heating system (Section 7).

2.5.4 Key findings from review of control interfaces

- The usability of heating and hot water controls is not intuitive and needs instructions to use it properly. Clarity of purpose and labelling could be improved. The degree of fine control is good but the system override is unclear. The interaction of the heating and hot water programmer and timer with the individual room thermostats should be communicated to the occupants in order to improve energy efficiency.
- The room thermostats provide a high level of fine control and automatic settings but are not very intuitive to use. Occupants in both houses reported that the thermostats are not very efficient at controlling the room thermostats as the heating is on even when the thermostat setting is low and the thermostat is not calling for heat. This issue was further investigated during the commissioning review which revealed that the thermostats were not properly connected to the heating system (Section 7).
- The MVHR unit is located in the loft in a very narrow and inaccessible space making its operation and maintenance very difficult. The MVHR system purpose is not clear and there is no indication of system response or whether any fault is occurring. The manual is located in a pocket inside the unit but the position of the unit makes it difficult for the occupants to have access to it. No indication of when filters need to be changed. Users were unaware of the location of the unit. The position of the diffusers in the bedrooms creates draughts that make the occupants highly uncomfortable and they have subsequently closed the grills.
- Light switches and control panel are intuitive to use and have good labelling and annotation.
- Kitchen appliances labelling seems clear and intuitive. Poor indication of system response in some models.
- Purpose of windows and doors is clear. The locking mechanism for the windows is not particularly intuitive but it provides safety for kids. Good level of fine control in windows.

2.6 Recommendations

- Provide adequate space for mechanical equipment and extra dedicated storage space from the initial design stage.
- Take extra care in detailing and finishes during construction to avoid air leakage paths and construction flaws.
- It is important to update SAP worksheets in case of changes in construction or design details that could affect the energy performance of the dwelling. Review SAP according to as built air permeability values taken from air permeability tests after construction.
- Use a clear controls strategy that should be defined during the design stage.
- No need to provide so many room thermostats in this type of housing. Opt for a simpler approach.
- Place the MVHR unit in a more easily accessible space and allow enough space for maintenance and filter change.
- Careful commissioning of all systems and controls after construction. Take extra care in connecting wireless thermostats with the heating system.

3 Fabric testing

3.1 Thermographic survey

A series of thermograms were taken showing the various elevations of the buildings and for the purposes of this survey, images were primarily taken of the external walls and internal surface that exhibited any thermal anomalies. The environmental conditions and building fabric properties were entered into the thermal imaging reporting software and the relevant corrections were made. The survey was undertaken on 14 February 2013, mid to late afternoon, and whilst the properties were occupied. The digital images shown are for reference purposes.

The details contained in this report are in accordance with the simplified testing requirements of BS EN 13187:1998 Thermal Performance of Buildings – Qualitative detection of thermal irregularities in building envelopes – Infrared method (ISO 6781:1983 modified). In accordance with the TSB requirements all thermographic images are in the full colour rainbow-hi pallet, and the work was undertaken whilst the properties were occupied.

Table 5 Environmental conditions during time of survey

Time of survey	
Parameter	Measurement
Internal Temperature	House No.5 24°C House No.11 24°C
External Temperature	5°C
Wind speed	Nil
Precipitation	Nil

3.1.1 Thermograms and observations

The thermograms of this report show a number of thermal anomalies, and more detail is supplied against each image. In general terms these anomalies were considered to be as a result of the build process and further investigation is needed.

For information the thermograms contain where applicable analysis in the form of spot temperatures and area temperatures (minimum and maximum).

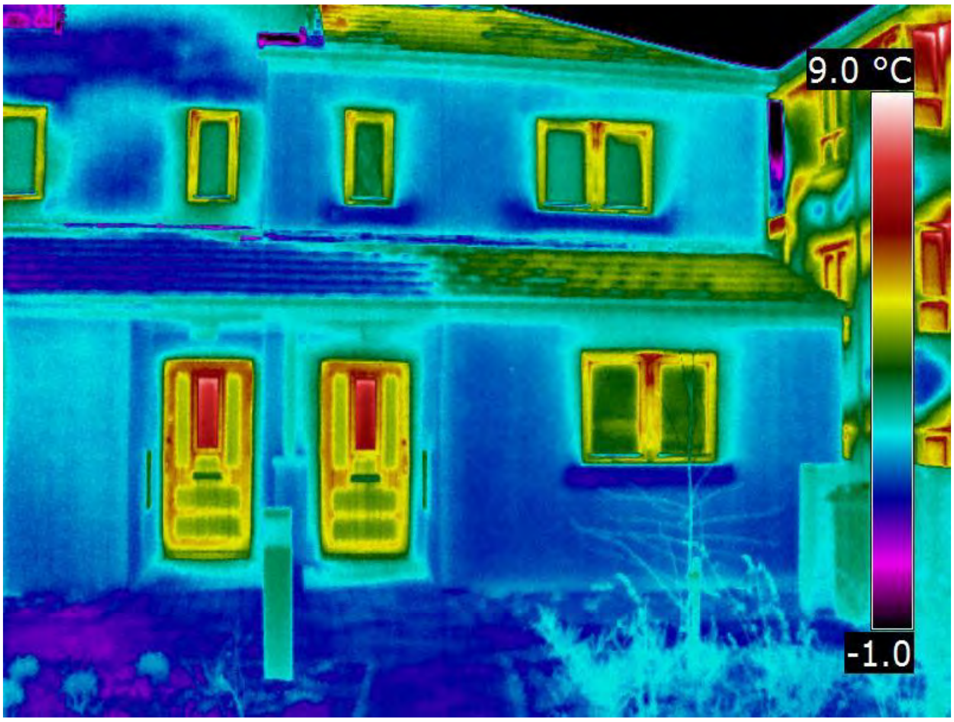


Figure 22 No.1 front (east) elevation thermogram. Note: No thermal abnormalities are evident in the walls. The elevated temperature in the front door is typical for design, and the elevated temperatures in the upper centre of the windows is likely to be due to poor fitting.

Figure 23 No. 1 front (east) digital photograph.

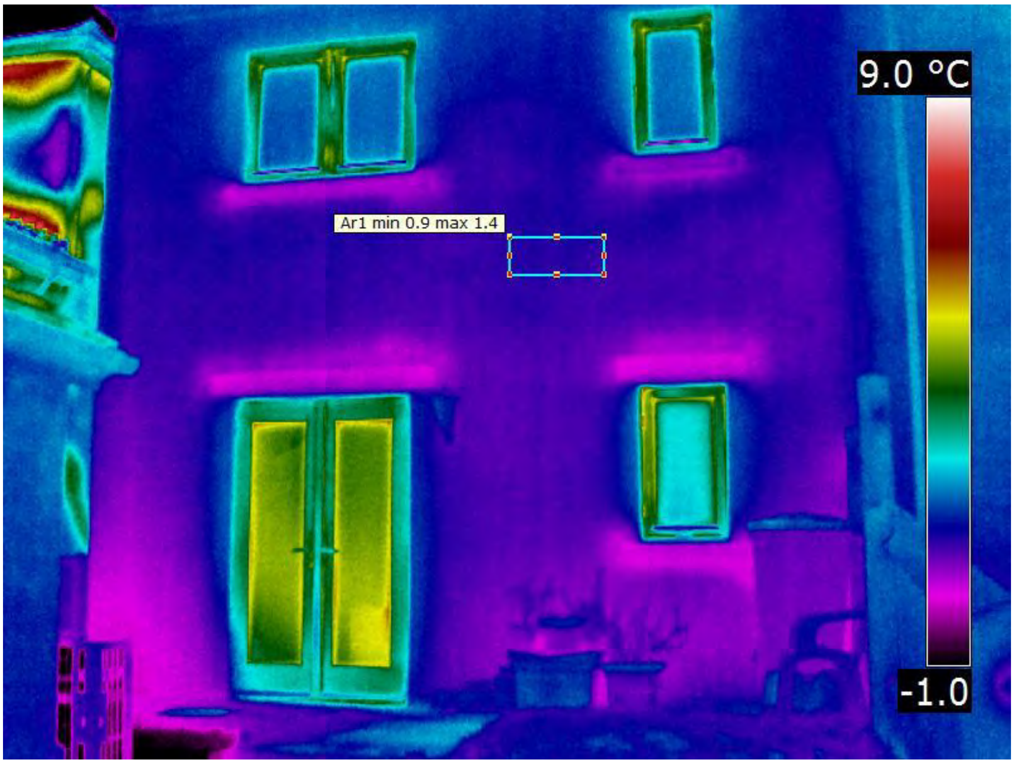


Figure 24 No.1 rear (west) elevation thermogram. Note: No thermal abnormalities are evident in the walls.

Figure 25 No.1 rear (west) digital photograph.

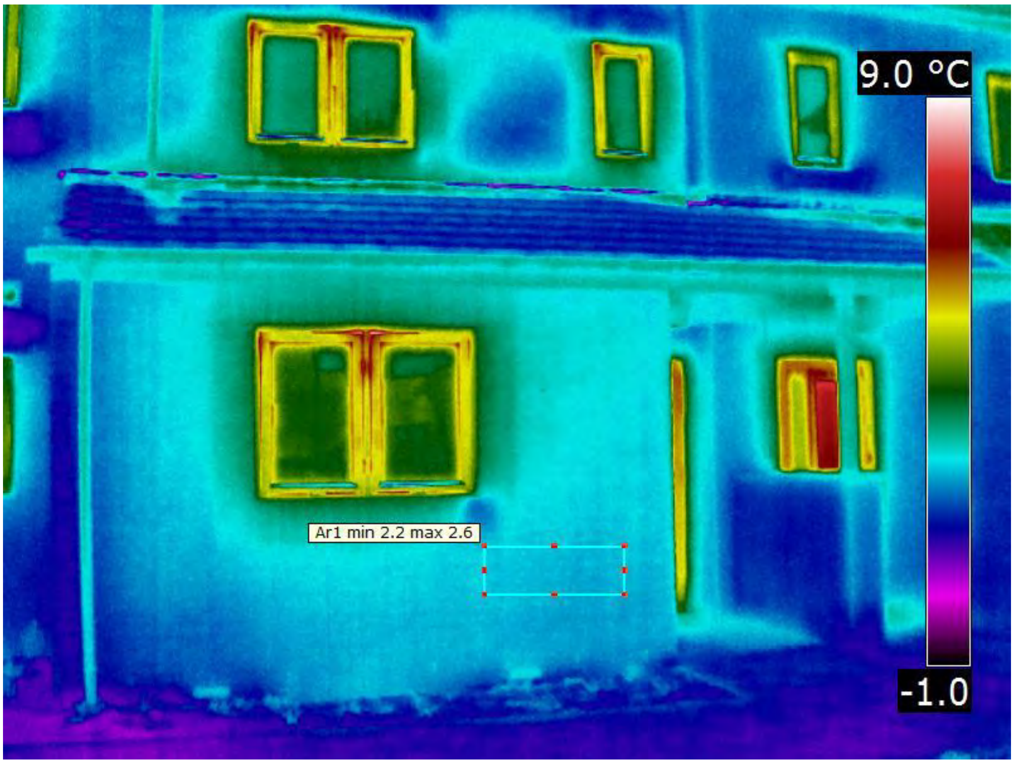


Figure 26 No.2 front lower (east) elevation thermogram. Note: No thermal abnormalities are evident in the walls.

Figure 27 No. 2 front lower (east) digital photograph.

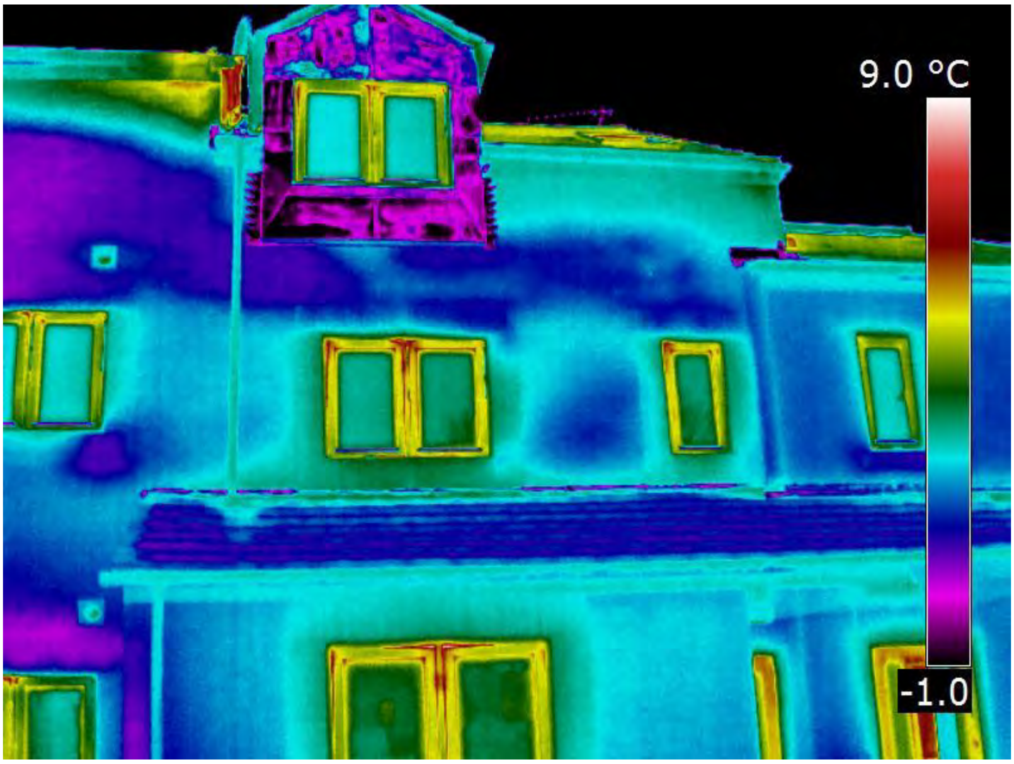


Figure 28 No.2 front upper (east) elevation thermogram. Note: The upper bedroom temperatures show as being low due to the material of construction and the reflectance of the sky temperature. Similarly the upper wall appears to be a lower temperature due to reflectance from the sky temperature.

Figure 29 No.2 front upper (east) digital photograph.

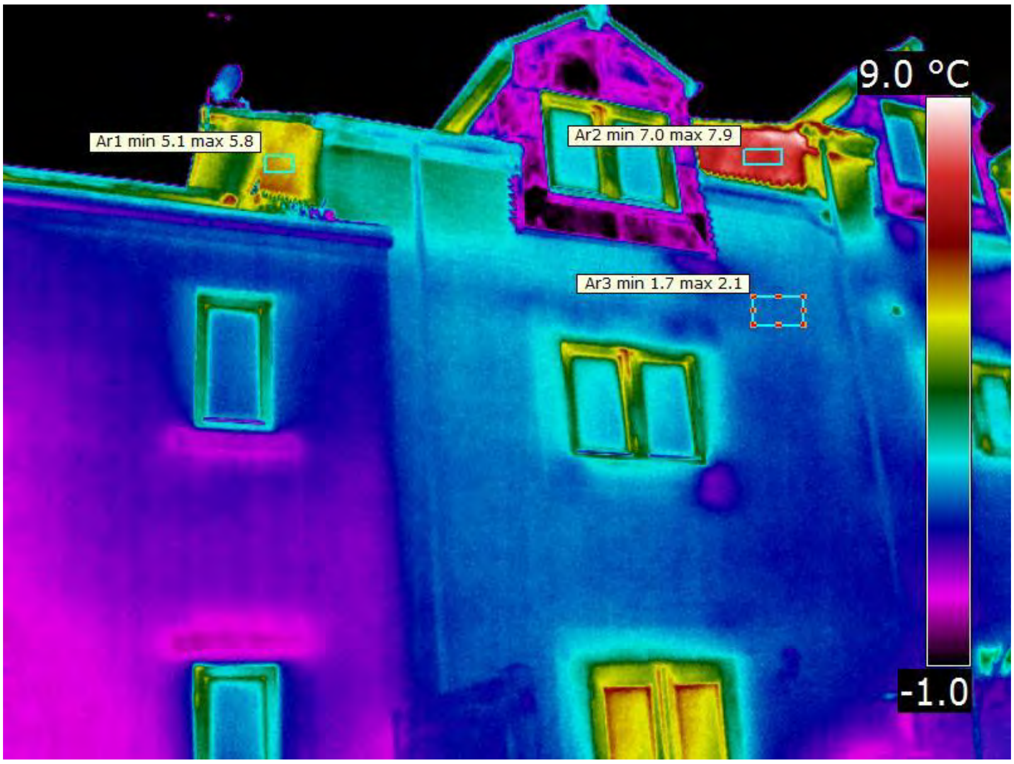


Figure 30 No. 2 rear upper (west) elevation thermogram. Note: Elevated temperatures were observed on the north walls between properties 1 & 2 as well as 2 & 3. Area temperature boxes are shown on the image for comparative purposes.

Figure 31 No. 2 rear upper (west) digital photograph.

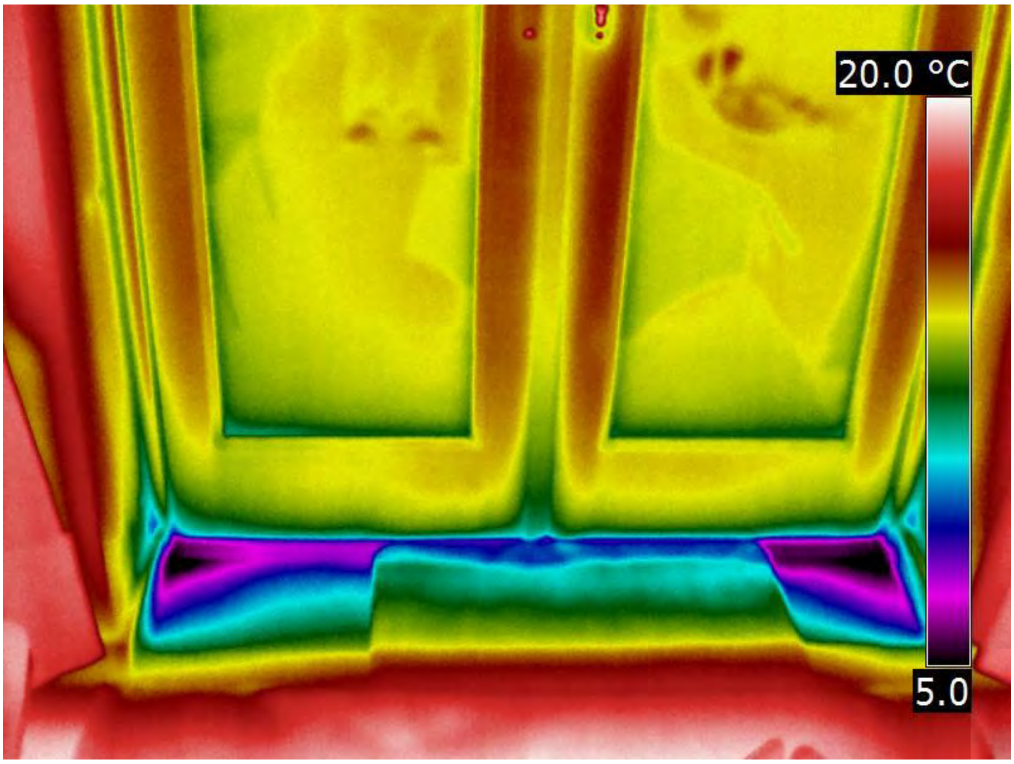


Figure 32 No. 2 rear patio doors lower (internal) thermogram. Note: Thermal bridging across threshold and different temperature scale used from image 17. Similar characteristics also observed in property No. 1.

Figure 33 No. 2 rear patio doors lower (internal) digital photograph.

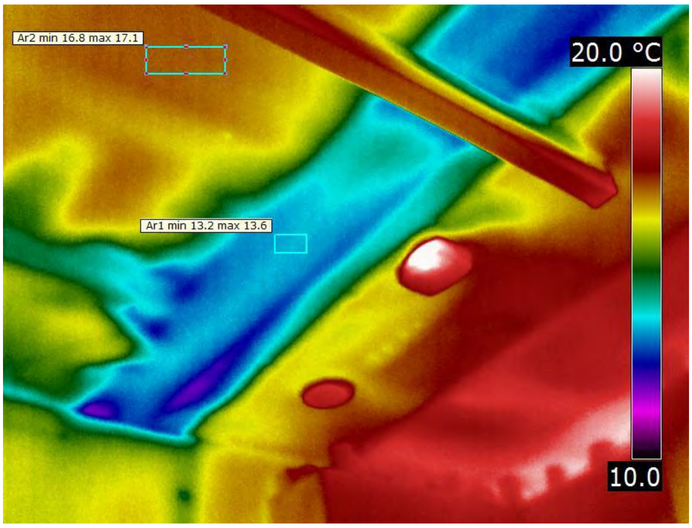


Figure 34 No. 2 kitchen ceiling thermograph (south view). Note: Image shows cold bridging from structural beam in ceiling. The same was observed in House 1 kitchen ceiling

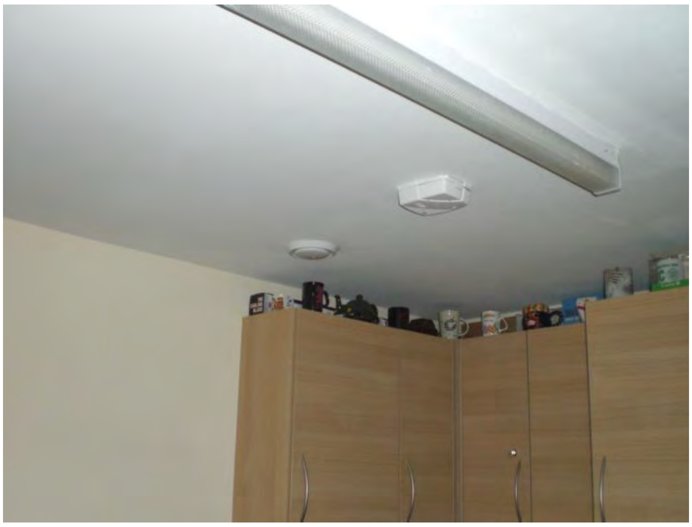


Figure 35 No. 2 kitchen ceiling digital photograph

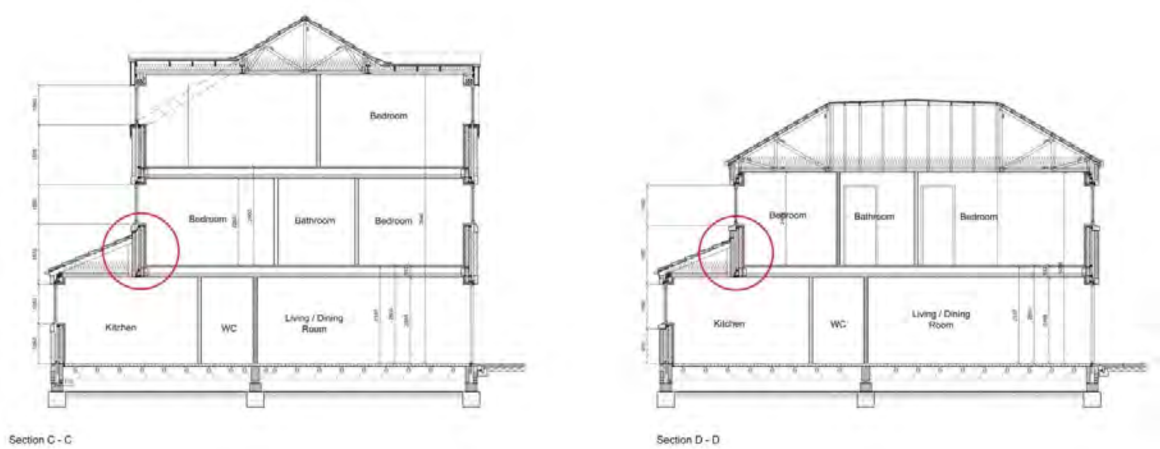


Figure 36 Section through dwelling kitchens with the bean above the ceiling highlighted

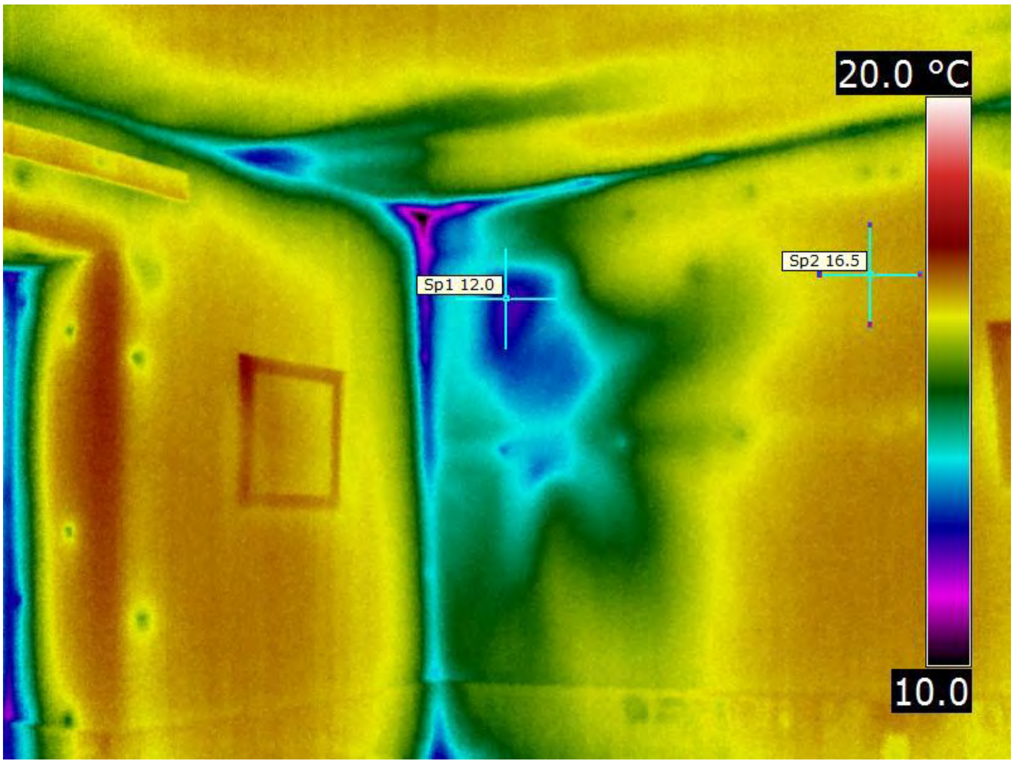


Figure 37 No. 2 kitchen wall thermograph (south view). Note: Cold spot identified on wall is an irregular shape probably due to air movement within the structure

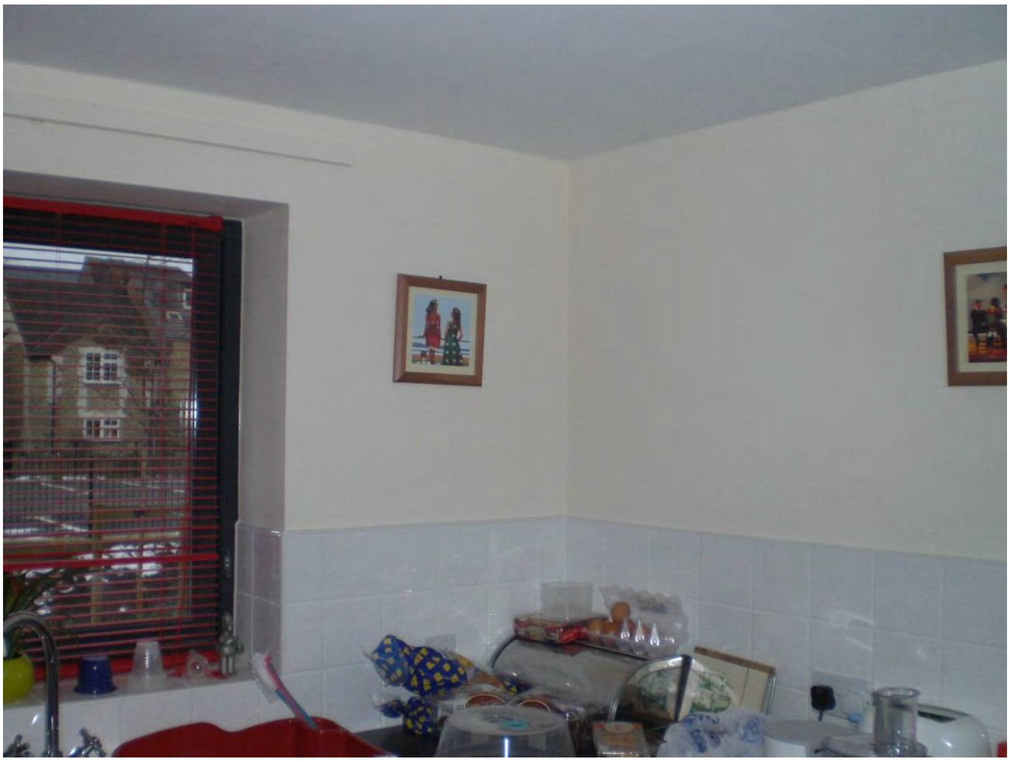


Figure 38 No. 2 kitchen wall digital photograph (south view).

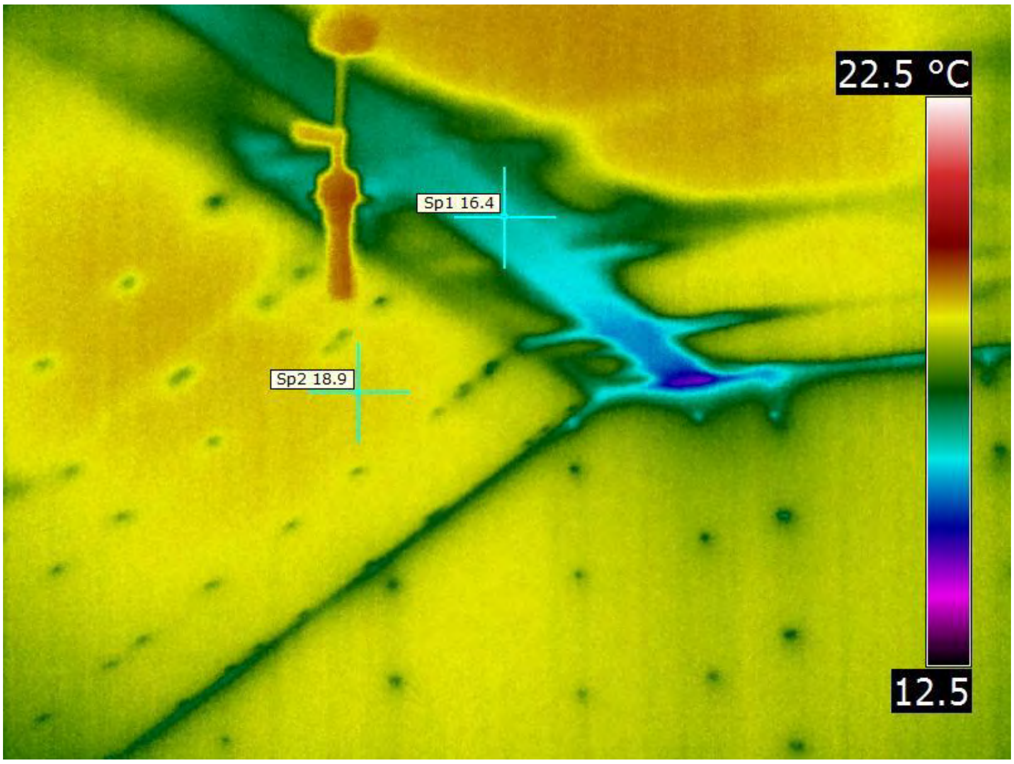


Figure 39 No. 3 bedroom ceiling (north) thermograph. Note: Image shows cold bridging from beam above ceiling. Similar image also is viewed (south) towards other end of room and similar characteristics were observed in bedroom 4.

Figure 40 No. 3 bedroom ceiling (north) digital image.

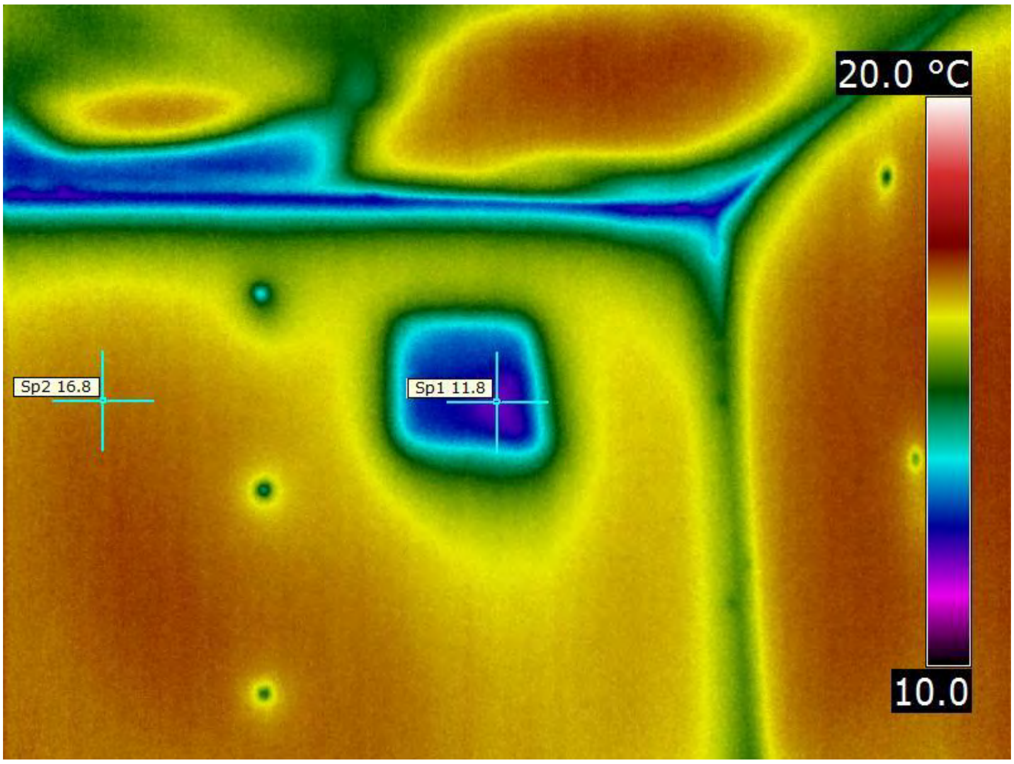


Figure 41 No. 1 Kitchen wall thermograph (north view). Note: Cold area identified on wall in an area similar to property No. 2.

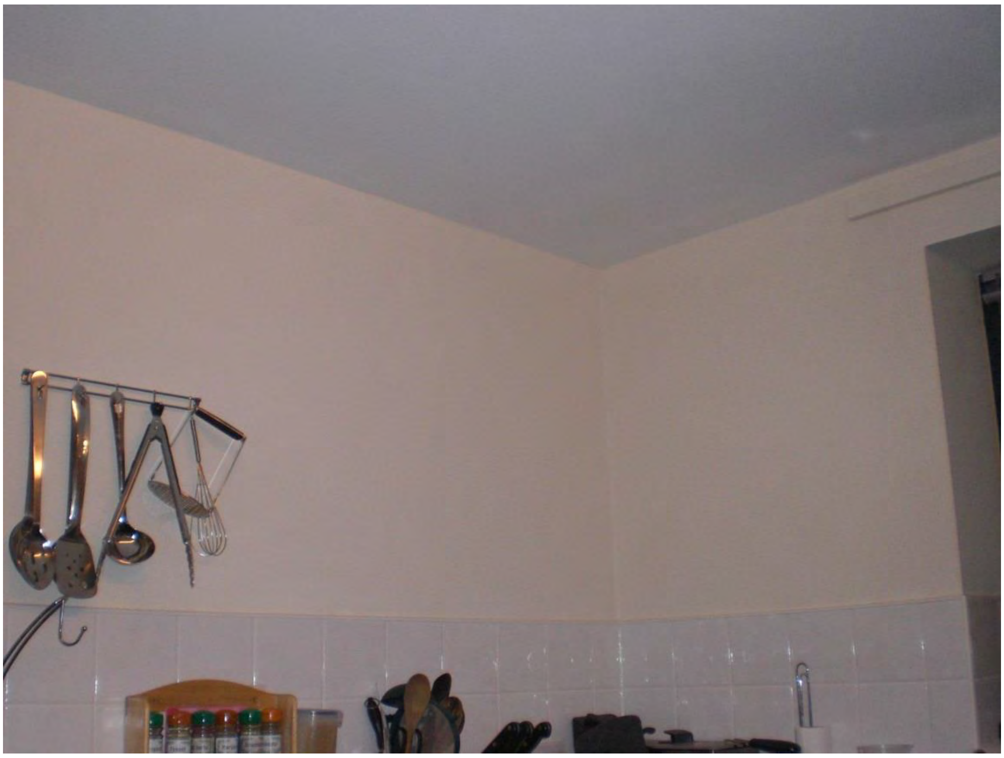


Figure 42 No. 1 Kitchen wall digital photograph (north view).

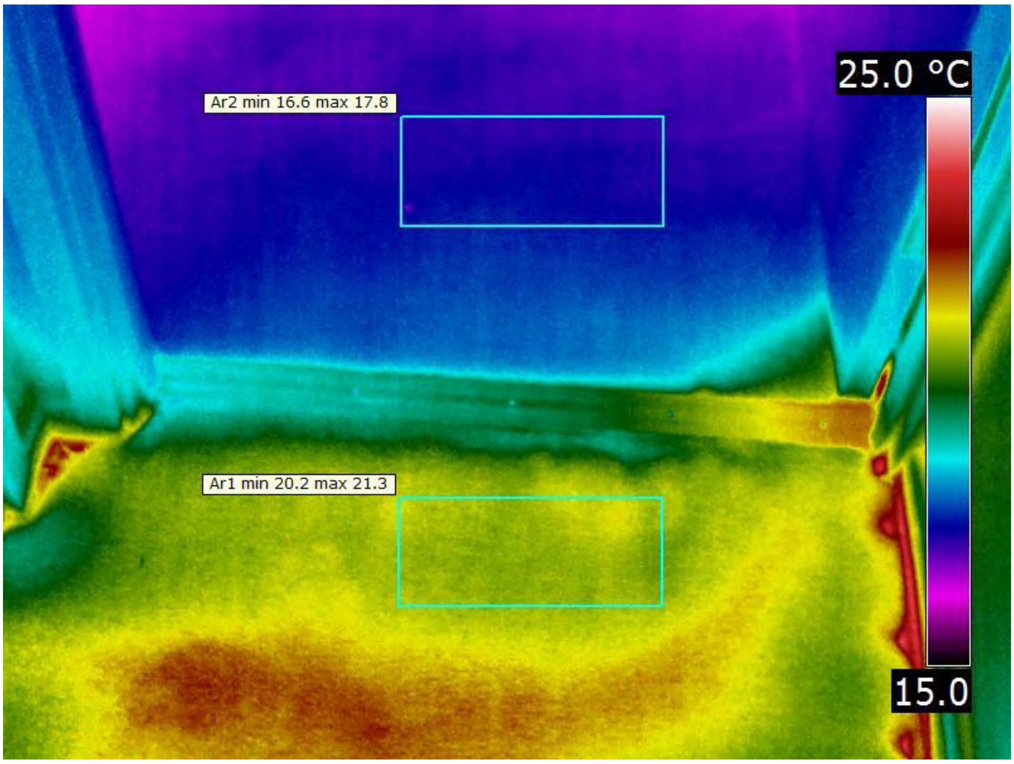


Figure 43 No. 1 landing to bedroom 1 floor interface thermogram. Note: Resident of property 1 commented during survey that bedroom 1 was always cold compared to remainder of house. The thermogram confirmed that this phenomena despite the controller within the space calling for heat. Further investigation of this fault is therefore recommended.

Figure 44 No. 1 landing to bedroom 1 floor interface digital image.

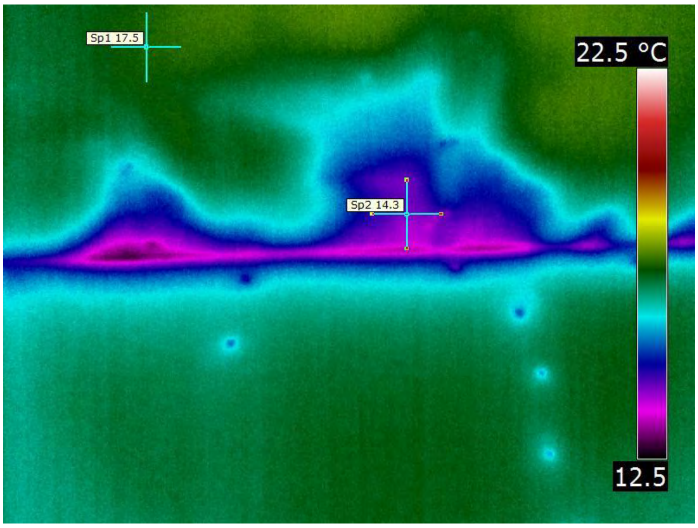


Figure 45 No. 1 bedroom 2 ceiling (centre north) thermogram. Note: Cold area possibly due to missing roof insulation or insulation not located correctly between roof joists. No digital image available of area.

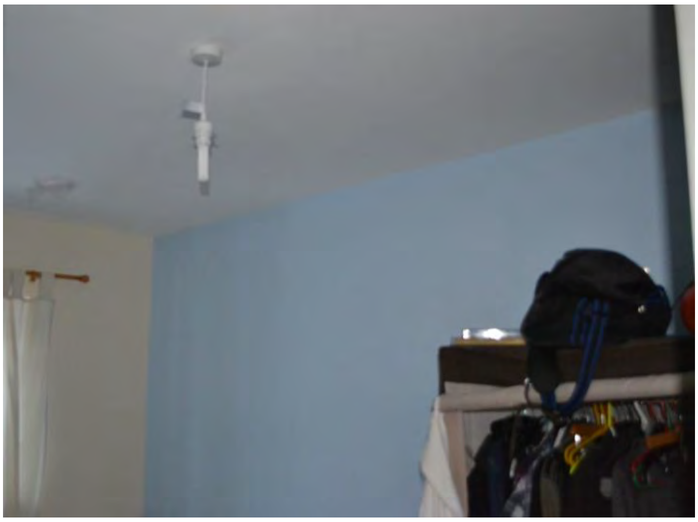


Figure 46 No. 1 bedroom 2 ceiling (centre north) digital photograph.

Figure 47 Roof insulation is not distributed well resulting in insulation gaps.

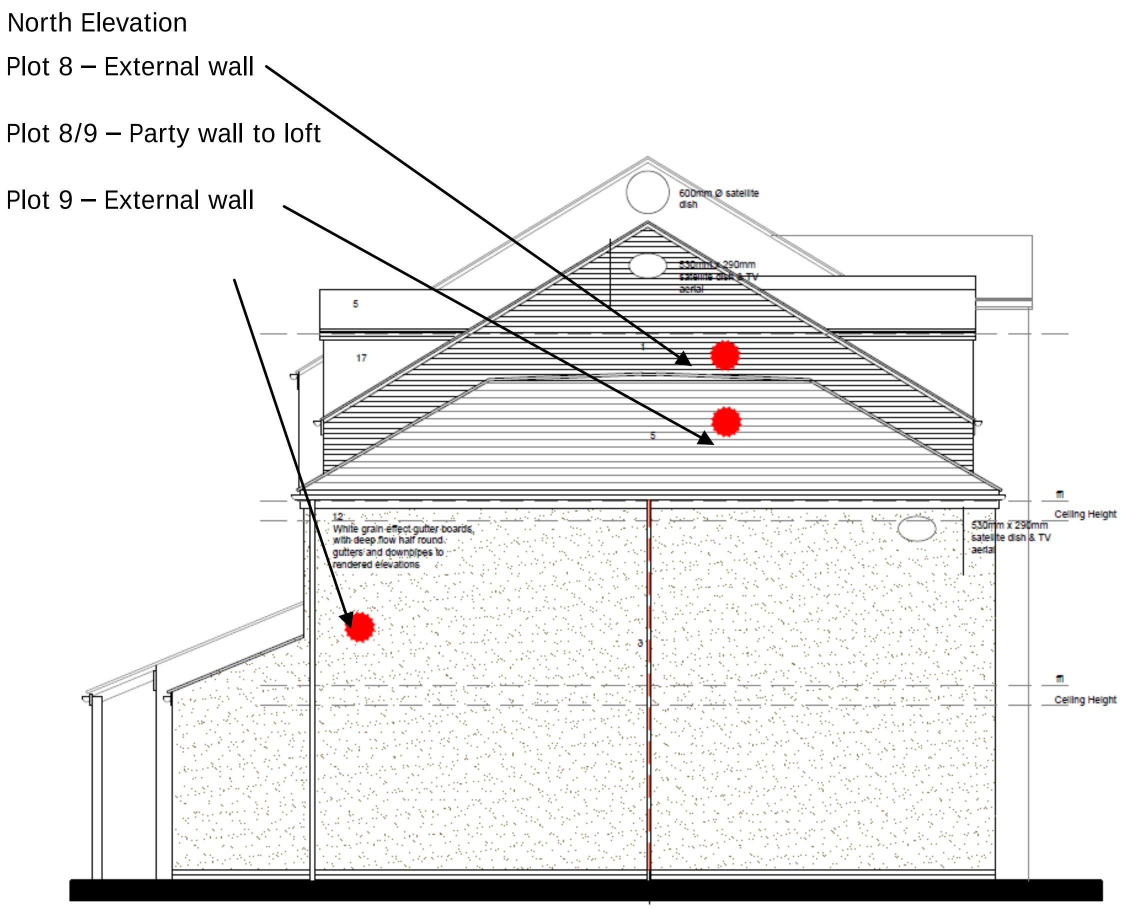
3.2 In situ U-value measurement

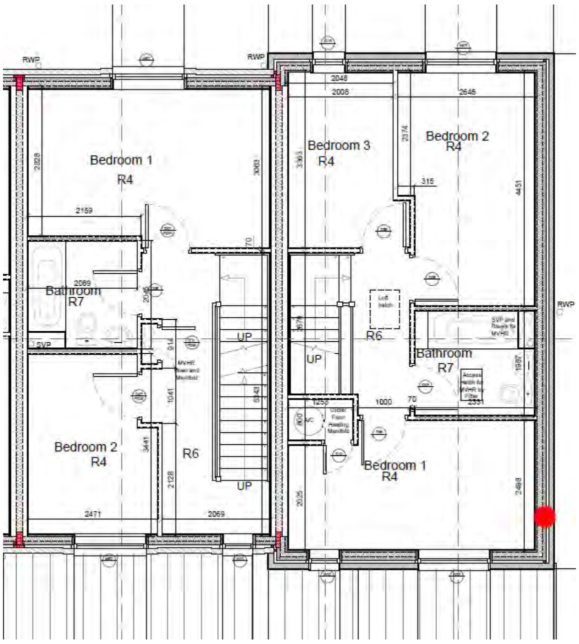
The U-values were determined by placement of Hukseflux HFP01 sensors on north facing walls using the "Average method" detailed in ISO 9869:1994, Thermal insulation – Building elements – In-situ measurement of thermal resistance and thermal transmittance. For calculation purposes internal/external air temperatures were recorded within the dwelling adjacent to the sensors and outside adjacent to the corresponding wall space. Measurements were recorded over a two week period whilst the properties were occupied. The data reported is the final seven days of measurement, with the first seven days data excluded to allow for stabilisation of the instrumentation.

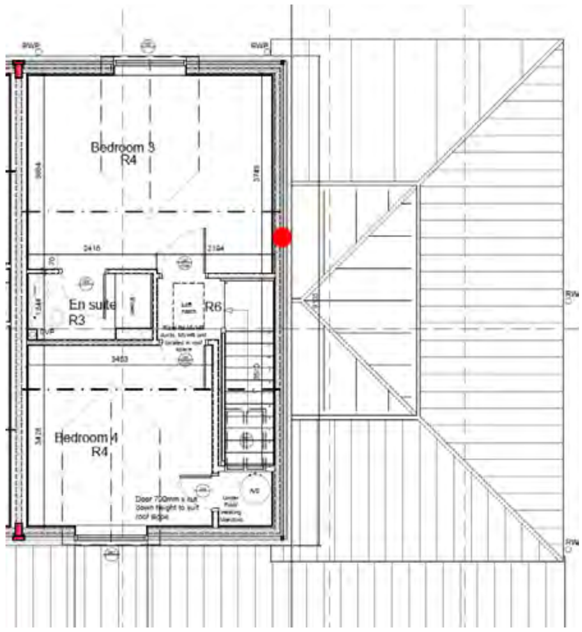
Heat flux measurements were taken at 1 minute logging intervals. The Hukseflux sensors were positioned on the construction elements using custom built sprung clamps that allowed free flow of air around the sensor. Proprietary thermal compound was used to ensure good thermal contact.

Tests were undertaken to establish the "as built" U-value of three walls as detailed below.

The following elevation details the measurement locations (Figure 48):







Plot 9 – External wall

Plot 8/9 – Party wall

Plot 8 – External wall

Figure 48 In situ U-value measurement spots and installation kit

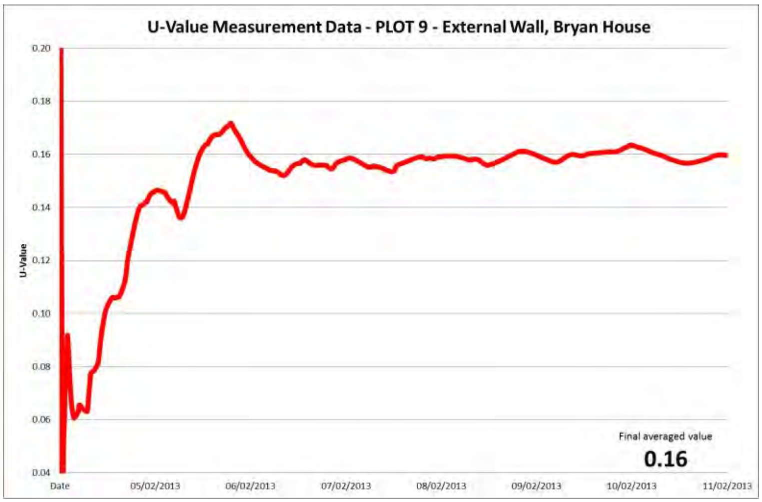


Figure 49 U-value measurements House 1, external wall

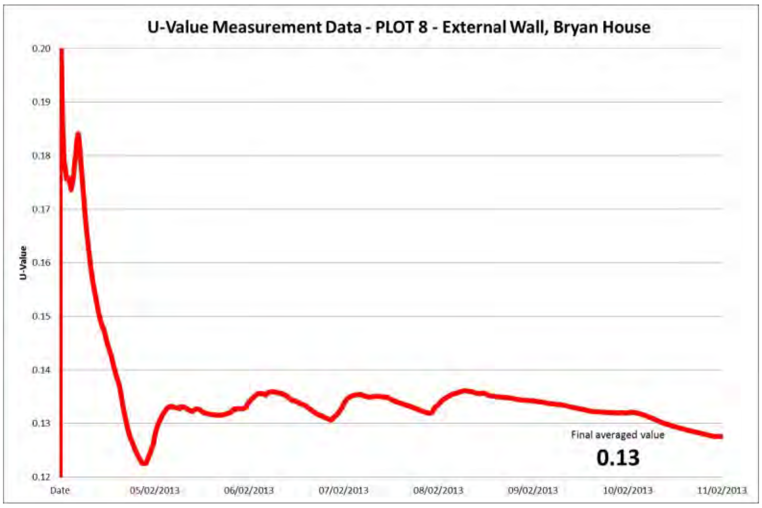


Figure 50 U value measurements House 2, external wall

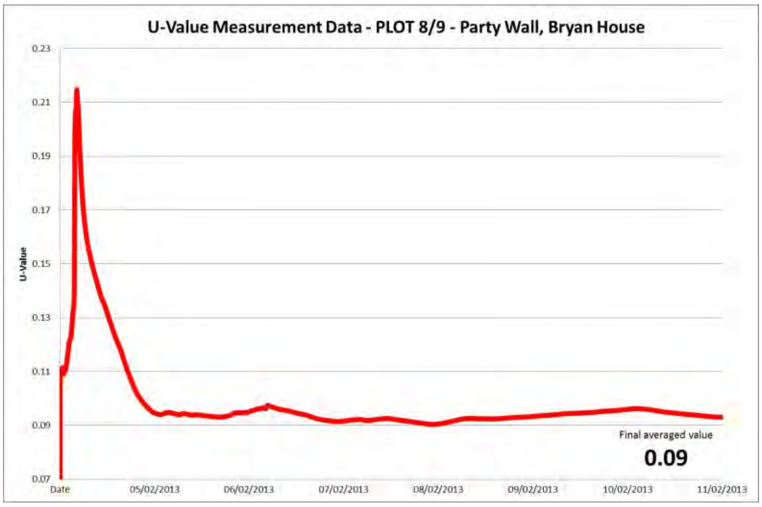


Figure 51 U value measurement party wall

The in situ measurements of the wall U-values showed values very close to those intended at the design stage (Table 6).

Table 6 Comparison of design U-values and in situ U-value measurements

Wall detail	Design wall U-Value W/(m^2K)	Final averaged U-Value W/(m^2K)
Plot 9 – North Facing External Wall	0.15	0.16
Plot 8 – North Facing External Wall	0.15	0.13
Plot 8/9 – Party Wall to Loft Space	Not stated	0.09

3.3 Air permeability testing and smoke testing

An important parameter of the heat loss in a dwelling is the air exchange rate through the building envelope. A part of this rate is necessary in order to provide adequate ventilation, however the amount of the incoming fresh air should be controlled by a well-designed ventilation system. In some cases this fortuitous air movement is uncontrolled and additional to the designed ventilation causing an unnecessary increase to the total heat loss.

To quantify air-leakage rate through the building envelope two standard air leakage tests were carried out during depressurisation and pressurisation (at 50 Pa).

The survey was undertaken on 22nd January 2013 whilst the properties were occupied.

The measured average air-permeability rate of both dwellings when tested using the method contained in ATTMA standard TS1 failed to meet the initial design criteria of 3m^3/(h.m^2). However, they were both significantly less than the national building standard of 10 m^3/(h.m^2) (Table 7).

The testing kit was placed on the main door of each dwelling (Figure 52). During testing the internal doors were open, the windows were closed and the ventilation terminals were sealed.

Table 7 Air permeability measurements

Air-permeability values	House 1	House 2
Design air permeability m^3/(h.m^2)	3.00	3.00
Average measured air permeability m^3/(h.m^2) Depressurisation Test	**5.24**	**5.97**
Average measured air permeability m^3/(h.m^2) Pressurisation Test	**5.75**	**5.91**
Energy Saving Trust Recommendation for CSH Level 5 (EST, 2008)	3.00	3.00
UK Building Regulation Best practice	5.00	5.00
UK Building Regulation Good practice	10.00	10.00

Figure 52 Air permeability testing kit

A fan pressurisation test is a useful quantity assessment indicator of air leakage in a building although it does not directly identify its location. In order to attain an overall image of air leakage paths in the building envelope it can be combined with visualization methods such as smoke visualization. The smoke pencil test revealed several air leakage paths (Figure 53) (Tables 8, 9).

Figure 53 Smoke pencil test

Table 8 Air leakage paths identified in House 1

Bathroom	Shower boxing crack, toilet boxing crack, bath panels and shaving lights, ceiling rose
Bedroom	Windows, electrical outlets, skirting, tank cupboard, ceiling rose
Bedroom 3	Window, electrical outlets, skirting (above, below), ceiling rose
Bedroom 2	Electrical outlets, skirting, windows, ceiling rose
Hall	Consumer unit
Kitchen	Behind units, windows, lights, electrical outlets
GF toilet	Toilet boxing, light, ceiling rose
Lounge	French door, electrical outlet, ceiling rose, skirting
Cupboard	Service hole

Table 9 Air leakage paths identified in House 2

Bedroom 3 en-suite	en-suite: toilet boxing, ceiling rose, shower tray, light fitting
Bedroom 3	skirting perimeter, windows, ceiling rose, electrical outlets
Upper hall	penetrations into floor void, loft hatch, electrical outlets
Bedroom 4	Electrical outlets, skirting, windows, ceiling rose
Mid hall	ceiling rose, windows, electrical outlet, TG floor
Bedroom 2	windows, electrical outlets, ceiling rose
Airing cupboard	high level boxing
Bathroom	toilet boxing, bath panel, light fitting
Bedroom 1	electrical outlets, skirting, windows, ceiling rose
Kitchen	window, electrical outlets
GF toilet	toilet waste pipe not sealed
Lounge	French doors below metal threshold, electrical outlets, skirting, ceiling rose

3.4 Conclusion and key findings

3.4.1 Key findings from the thermographic survey

The thermograms revealed that the houses are generally well insulated with small heat loss through the envelope. A number of thermal anomalies were revealed and are generally considered to be a result of the construction process and detailing in some cases. It is important to know that the same observations were made in both properties.

External thermograms:

- No thermal anomalies are evident in the walls with the exception of the party walls between the properties of different height where some heat loss was observed.
- Elevated temperatures around the window frames are likely to be due to poor fitting.
- Front door heat loss is due to low insulation and design of door.

Internal thermograms:

- Thermal bridging across threshold was observed in both properties.
- A cold bridge from a beam in the ceiling of the kitchen was identified in both houses. This is due to the detailing of the kitchen roof. It should be noted that part of the kitchen ceiling is exposed as the kitchen extends beyond the floor above it. The steel beam was not insulated resulting in a cold bridge.
- Cold spot or irregular shape in the walls and corner of House 2 kitchen indicates air movement within the structure.
- Cold bridge from steel beam in the ceiling of the top bedrooms in House 2 was also identified. This is due to detailing.
- Square solid area in House 1 kitchen wall indicates that an insulation panel is missing. This is possibly due to a mistake during construction.
- Cold spots identified on House 1 ceilings indicate that roof insulation is missing. This was further investigated during the commissioning review and a visit in the loft revealed that the loft insulation has been misplaced, possibly be the occupants, to make room for storage. It could also be that the insulation was never distributed in the roof space properly.

3.4.2 Key findings from in situ U-value measurement

The U-values measured on site indicate that the envelope is well insulated and that design aspirations were met. Actual wall U-values are very close to those specified at the design stage.

- In House 1 the measured U-value of the north facing external wall is 0.16 W/m^{2}K, compared to 0.15 W/m^{2}K specified at design stage.
- In House 2 the measured U-value of the north facing external wall is 0.13 W/m^{2}K, compared to 0.15 W/m^{2}K specified at design stage

3.4.3 Key findings from air permeability and smoke testing

- Both houses failed to meet the design air permeability of 3 m^3/hm^2 and were measured to have between 5.27-5.91 m^3/hm^2.
- However, they were both significantly less than the national building standard of 10 m^3/hm^2.
- High air permeability might indicate that there is no need for the use of the MVHR system.
- The smoke pencil test revealed several air leakage paths through skirting boards, electrical outlets, plasterboards, light fittings loft hatch.

3.5 Recommendations

- Pay more attention to detailing to avoid thermal bridging in roof joints and thresholds.
- Opt for rapid diagnostics to quickly identify mistakes and omissions during the construction phase.
- Carefully distribute layers of insulation in roof space and select the appropriate type of insulation for this space.
- Consider using a front door of higher specifications and insulation levels in future projects.
- Carefully design detailing for exposed areas of party walls.
- Maintain the good levels of insulation in walls and follow this construction process in future projects as it was proven to work relatively well.
- Take care during construction to reduce air leakage paths.
- Perform accurate and reliable air permeability tests in all properties right after construction and quickly take measures to address deficiencies.

4 Key findings from the design and delivery team walkthrough

4.1 Design team interview and walkthrough

The design team interview and walkthrough was conducted on 9 April 2013. Two separate interviews were conducted and were coupled with an onsite walkthrough. The interviewees were: the owner/developer of Bryan house scheme, who is Head of Development for Sanctuary group, and one of the architects from DJSA who was involved in the project from the beginning. The same set of questions was asked to both interviewees.

4.1.1 Performance aspects

4.1.1.1 Design intentions

Owner/Developer:

- Deliver a scheme that was designed to be energy saving and cheap to live in
- Deliver an exemplar Code for Sustainable Homes Levels 4 and 5 scheme
- Design a traditional looking scheme that is very sustainable and is in harmony with its surroundings

Architect:

- The two blocks facing onto Chapel Street, would be more traditional as it's a conservation area the other two blocks on the rear side would be more contemporary looking.
- Do a split of Code 4 and Code 5 in a traditional looking scheme

4.1.1.2 Strategies to achieve design intentions

Owner/Developer:

- Developed the sustainability strategies simultaneously with the design process
- Fabric first approach
- Investigated the possibility of district heating system and CHP (but ruled it out)
- Designed individual heating systems.
- Opted for maximum level of control and flexibility for residents

Architect:

- Strategies were developed by an environmental consultancy firm and included a mix of renewables and fabric performance
- Fabric first approach
- PVs
- Opportunity for Sanctuary to test out the ASHP
- Could not put a gas main due to a brook in site. Originally were going to use gas boilers with PVs but had to split the strategy to gas and PVs on one side and ASHP and PVs on the other side.

4.1.1.3 Learnings from past projects

Owner/Developer:

- Had not done Code 4 and 5 before, but had done Code 3.
- Had good experience from PVs and solar hot water.
- Not very familiar with MVHR and ASHP systems.

Architect:

- Had done Code level 3 homes for Sanctuary before.
- Believed that getting fabric first is a good starting point.
- Had not used steel frame before but are satisfied with it.
- The scheme was originally designed to be timber frame as the architects were more familiar with it.

4.1.1.4 Design intentions related to sustainability and costs

Sustainability/ Low Energy/Low Carbon

Owner/Developer:

- Achieving Code Level 4 and 5.
- In some of the Level 4 wanted to achieve an even higher level of CO_2 reduction.
- Reduce energy bills for tenants and give them flexibility.
- Tackle the problem of fuel poverty.

Architect:

- Achieving Code Level 4 and 5.
- Provide for low energy during use, reduce bills.
- Mileage of materials and embodied carbon was not taken into account.

Cost benefits/Life cycle costing

Owner/Developer:

- Life cycle costing and a Building for Life calculation, as required. The scheme was also Lifetime Homes standard as well, which was a planning requirement.

Architect:

- Fabric first approach to cut on energy consumption during use.
- Life cycle costing of materials was not considered.
- Limited the palette of materials down to three: stone, render and brick. Limited use of stone due to costs.

4.1.1.5 Built product compared to original design intentions

Space planning

Owner/Developer:

- The build product has matched the original design intentions on space planning.

Architect:

- The build product has matched the original design intentions on space planning.
- Orientations were chosen mainly based on the proximity to the neighbours and how it stood on site rather than any sustainability criteria.

Sustainability

Owner/Developer:

- Still in the process of getting results back.

Architect:

- Do not know yet.

Comfort and Control

Owner/Developer:

- User Guide information not as simple as it could be.
- Not completely satisfied with the control mechanisms.
- Some tenants give positive feedback.

Architect:

- Not involved in the decision making process regarding controls.

- Helped develop strategies which were then taken on by the contractor and they then decided on the specific controls and the strategy they were supposed to work.
- The position of controls and systems was partly the contractor's decision: Had originally envisioned the MVHR unit to be in the bedroom cupboards instead of the loft. The decision to place the MVHR unit in the loft was taken on site, by the contractor.
- The hot water tanks were also supposed to be in the bedroom cupboards. But there was not enough space. The boilers were originally going to be in the kitchens, if they were going to be gas boilers.
- Not fully aware of sizing to provide for adequate space.

Flexibility

Owner/Developer:

- Depends on typology. In some houses good in some houses more restricted.

Architect:

- Quite good. In some cases not very successful.

4.1.1.6 Changes from the original design

Owner/Developer:

- Didn't make any significant changes.

Architect:

- Changed to steel frame from timber frame. That increased the wall thicknesses to a great degree of what had been originally planned for, and so did have to go back and get the planning amended. This was before we went on site.
- Internal layouts remained the same.
- The steel beams on the roofs were a late addition to the design and that is probably why issues like thermal bridging and detailing have not been addressed properly.
- Originally going to use gas boilers placed in the kitchen. The change from that strategy had an impact on storage space in cupboards.
- The appearance of the scheme turned out to be slightly more traditional than the original intention.

4.1.1.7 Possibility of repeating this design

Owner/Developer:

- Would repeat this design with some adaptations for this specific user group.

Architect:

- Would repeat this design with slight changes to internal layouts and the location of services systems.
- Not have the MVHR unit in the loft.
- Would use steel frame and wall construction again.

4.1.1.8 Things that should be done differently

Typology

Owner/Developer:

- Think about using conventional heating systems and ventilation systems for this type of user group

Architect:

- Reducing typologies mixture would reduce complexity and costs.

Space planning

Owner/Developer:

- Each site has different constrains
- Planning in this site is good despite its difficult shaped and the mix of house types

Architect:

- Ensure that storage spaces are enough and that layout of fittings is adequate.
- Ensure fine level of coordination between space and the technologies that are going in.

Technology

Owner/Developer:

- Rethink the use of MVHR and ASHP
- Would use PV again
- Building fabric is good
- Promote tenant education.

Architect:

- Had it been known from the start that ASHP would have been used, maybe some more thought could have gone into the position of them, instead of just placing them randomly in the back garden. And some bin stores had to be adapted for the flats to take the ASHP, as the flats do not have private gardens.
- Also, in the future, would think more about the positioning of the MVHR grills and room furniture.

Comfort and Control

Owner/Developer:

- Look at different controls for this type of user group.

Architect:

- Getting clearer understanding of systems.
- Develop a specific strategy early in the design process.

Materials

Owner/Developer:

- Light steel construction was good in terms of speed of construction, flexibility, delivery and execution.

Architect:

- Would use these materials again.

4.1.1.9 Ventilation strategy and MVHR use

Owner/Developer:

- MVHR in order to get the Code Level required.

Architect:

- It is MVHR, we were not involved in the development of that strategy.

4.1.2 Comfort and control

4.1.2.1 Built product compared to design aspirations on comfort and control

Heating strategies

Owner/Developer:

- Good so far. Haven't received a lot of complaints

Architect:

- Underfloor heating works well but some of the feedback is not positive

Ventilation strategies
Owner/Developer:
- Problematic in some houses.

Architect:
- MVHR unit not performing as expected.
- Would reconsider The position of the MVHR outlets.

Lighting strategies
Owner/Developer:
- Struggled with design to achieve the daylight calculations for the Code Level.
- Low energy fittings for artificial lighting we are using everywhere.

Architect:
- Intention to achieve a high level of natural daylight levels but unsuccessful.
- Planning constrains for windows of certain proportions and sizes to fit with the context.
- The roof light above the staircase works well.

4.1.3 Flexibility and space standards

4.1.3.1 Built product compared to design aspirations on flexibility and space standards

Owner/Developer:
- Good in terms of space standards and flexibility.
- HQIs were done.

Architect:
- Building has met the design aspirations on flexibility and space standards.

4.1.4 Operation and usage patterns

4.1.4.1 Performance of operational controls (programmers, lights, ventilation controls, temperature settings)

Owner/Developer:
- More complicated than intended.

Architect:
- Were not involved in the selection of controls or the development of a strategy for them.
- No consultant on board to design the 'masterplan' of the systems.

4.1.5 Maintenance

4.1.5.1 Issues related to maintenance, reliability and reporting of breakdowns

Owner/Developer:
- Nothing really major occurred. Normal amount of call-outs

Architect:
- Not involved in that process.

4.1.5.2 Access to help service

Owner/Developer:

- Easy access. 24h 7days a week repairs line in use and a tenancy services officer to contact

Architect:

- Not involved in that process.

4.1.5.3 Issues logged in a record book

Owner/Developer:

- Call centre logs enquiries for repairs etc. During this defects period calls are passed directly to main contractor

Architect:

- Not involved in that process.

4.1.6 Energy management

4.1.6.1 Does the energy and water consumption of the dwelling meet the original expectations?

Owner/Developer:

- A waiting to have enough data to analyse over a 12 month period

Architect:

- Do not know yet.

4.1.7 General

4.1.7.1 Best aspects of the houses

Owner/Developer:

- They do set out to achieve the Code Levels intended.
- Building fabric first approach has worked very well.
- Their physical and their setting is positive and demonstrates that you can have a Code Level 4 or 5 house that it can look like a traditional building.
- Some positive feedback from the occupants

Architect:

- Good size of the rooms
- Good public spaces
- Good overall appearance of the schemes
- Very good fabric

4.1.7.2 Worst aspects of the houses

Owner/Developer:

- The MVHR.
- Site constrains and difficult ground conditions that we faced
- Challenging mixture of typologies

Architect:

- The coordination and complexity of services.
- Did not have all the information needed form the start.
- Issues regarding electricity consumption, ASHP and the MVHR
- Air tightness is lower than expected.

4.1.7.3 Communication between project team members

Owner/Developer:

- Not excellent communication between ourselves and the main contractor. Not satisfied with the execution of the project by the main contractor, in terms of project management. Delivery was at least three months late.
- Good to have an independent sustainability consultant to advise us on certain things.

Architect:

- In general it was good.
- The coordination with Mansell and the contractors doing the steel frame worked well. Had regular meetings on and off site and got all the details sorted.
- The lack of an M&E consultant, an electrical subcontractor, a heating subcontractor didn't work so well. Coordination in some cases coordination was unsuccessful.
- Regarding services communication was not so good.

4.1.7.4 Lessons to be learned about the design features and technologies in the building (during construction, commissioning)

Owner/Developer:

- To look carefully about control mechanisms and the level of technology we are putting in.
- Maintain the fabric first approach
- Reconsider the use of more conventional heating and ventilation systems.
- Find ways to educate tenants more effectively

Architect:

- Do the coordination of details while in the design than trying to deal with these issues on site,
- Think more about space requirements for systems and allowing enough robustness, room and flexibility in the initial design: to allow enough wall thickness, enough storage areas, to make junctions simpler, so if decisions are made later on there is still space to deal with them.
- Not involved during commissioning.

4.1.7.5 Sustainability features and potential learning for the design community

Owner/Developer:

- To be careful about the levels of technology they include, depending on whether it is an owner occupied or a tenant.
- Building fabric first approach is good.
- Example of a well-designed traditional looking building in a conservation area which is still very energy efficient.

Architect:

- The fabric approach, with adding some better detailing to avoid thermal bridging
- The understanding of how the ASHP and the MVHR unit work together

4.2 Conclusions and key findings

- The owner and the developer had good level of communication between them.
- Design intent was clear to both the developer and the designers. Both feel that they have achieved it successfully.
- Design intention was to achieve a Code Level 4 and 5 scheme with a traditional appearance that would fit well within its surroundings.
- None of the team members had any prior experience in the design and construction of Code Level 4 and 5 housing .
- The design team members were not familiar with MVHR and ASHP systems and these systems were 'included' in order to achieve the higher levels of the Code.
- Both the developer and the architect agreed that controls especially the individual room thermostats and master stat, have been over-engineered and interfaces are not very usable. Same findings have been revealed through the usability survey of control interfaces.
- The design team agreed that the best aspects of the houses are the fabric, their physical position and their planning.
- Design team members agreed that the MVHR unit was not performing as expected and were sceptical about using it again in the future.
- The architect believes that a more defined strategy regarding systems and services at an earlier stage would have helped in providing better spaces for services.
- The architect suggested that certain changes in the heating and ventilation system strategies led to complications and inadequate space provisions.
- The developer believed that better education of occupants was required for such high-performing low energy dwellings.
- The design team agreed that the best aspects of the houses were the fabric, their physical position and their planning.
- The worst aspects of the houses were considered to the performance and usability of controls and the performance of the MHVR system.

4.3 Recommendations

- Promote good communication between the design team, owners and developers.
- Feed forward experience from previous developments to encourage a continuous cycle of learning and improvement.
- Continue to follow a fabric first approach in future projects, as it has been proven to work relatively well. Attention to detailing is important to avoid thermal bridging in roof joints and thresholds.
- Maintain good standard of design and layout and generous space standards.
- Provide adequate space for mechanical equipment and extra dedicated storage space from the initial design stage.
- Have a well-defined strategy on services, systems and controls that is agreed with all stakeholders at an earlier stage. Any proposals for re-design that arise during construction should be subject to proper approval by the design team, owners and developers.
- Locate the MVHR fan unit in a more accessible space and allow enough space for maintenance and filter change.
- Reconsider the need for MVHR systems in buildings that do not achieve the design air-permeability target. Deeper understanding of the ventilation and airtightness strategy should be encouraged.
- Review the Home User Guide to provide simple, clear, accurate and useful information to occupants on how and when to change the settings of the heating system seasonally. Architects to develop a visual Home User Guide in collaboration with the home owners.

5 Evaluation of guidance offered to the occupants and the physical handover process

5.1 Overview of handover process and any guidance offered to the occupants

The handover process for House No.1 & No.2 was conducted by Mark Ashburn, Reinvestment Surveyor, Sanctuary Housing Association in the following phased format:

- Move-in: Letting agent gives key and briefly shows them around the house; handover documents are provided at this stage.
- One month post Move-in: Mark visits each house to give a demonstration of controls
- Two months post Move-in: Official handover tour primarily focussed on heating & controls; clearing any doubts and noting any issues.

5.2 Home User Guide evaluation

The user guidance provided at move-in had two sections:

- Home user manual specific to the development with appendices on public transport, local amenities, product information and certificates (Figure 54).
- General guide on tenancy from the Sanctuary Housing Association (Figure 5).

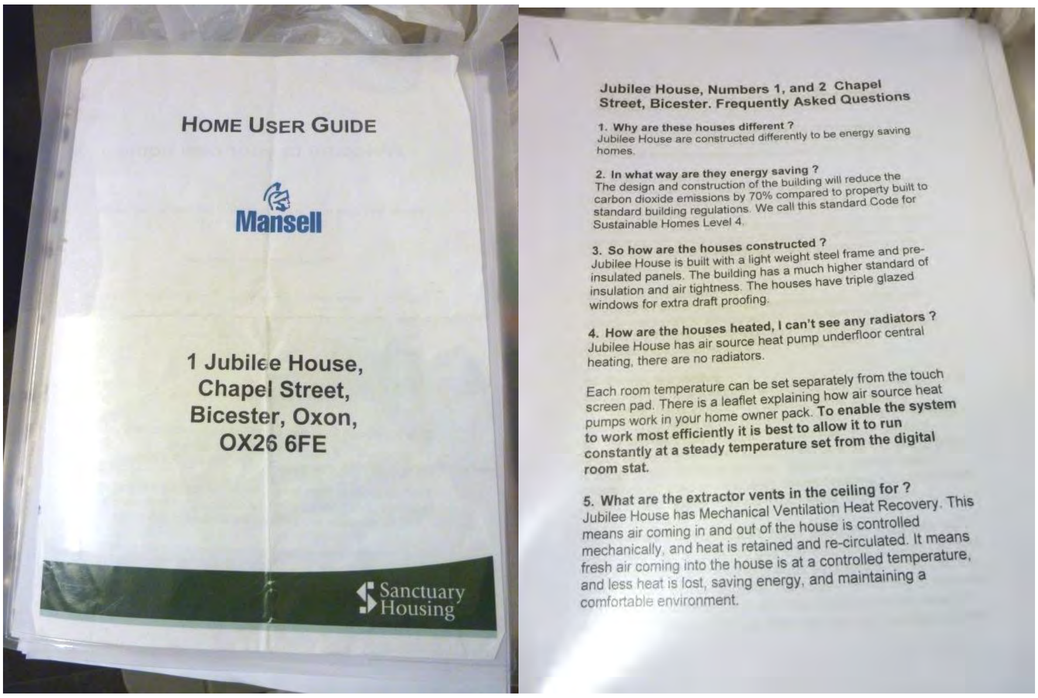


Figure 54 Home user guide given to the tenants by Sanctuary housing when they move in

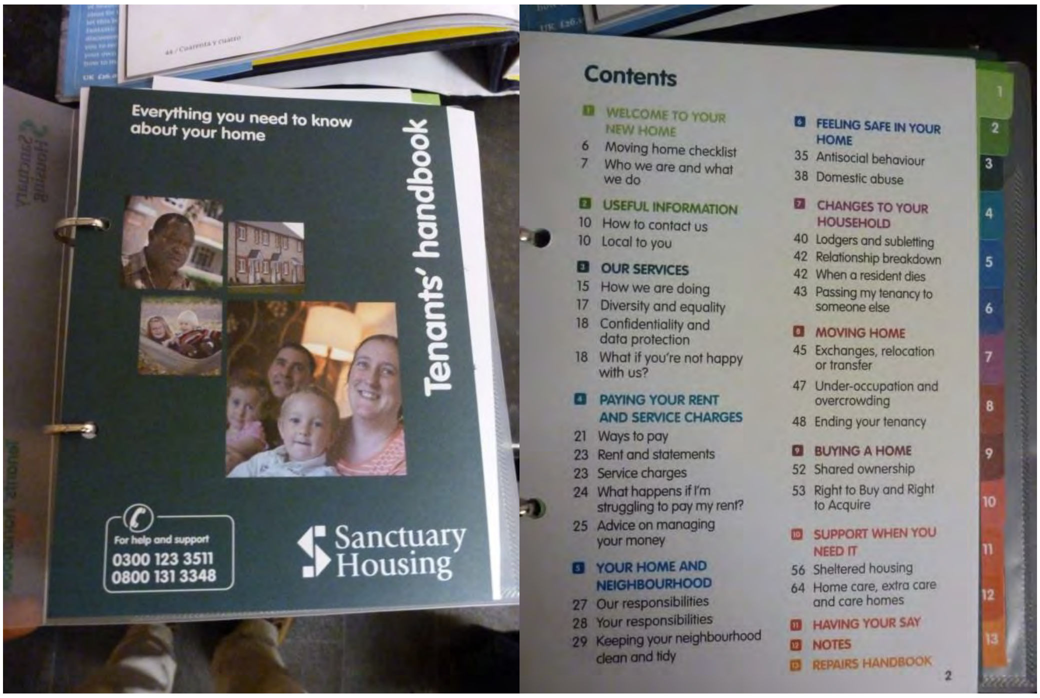


Figure 55 Tenants Handbook for all Sanctuary tenants

5.2.1 Findings

The following findings are specific to the Home user manual:

- Good contents list, but missing page numbers and some topics (drainage, energy saving fittings).
- Black and white photos available showing emergencies shut off locations; however no plans were given as the locations are different for each unit.
- A well written 'Frequently Asked Questions' Section explains the basics of various sustainable features in the development.
- The services page contains some conflicts/errors. The FAQ section explains that the houses use an Air Source Heat Pump with under-floor heating but the services section explains where to switch off the gas and location of radiators/ boilers. This could be quite confusing.
- Heating systems are explained in one paragraph; occupants are not advised to time immersion heaters/ other electricity based activities to coincide with periods of peak PV production. However this was explained during the handover.
- Ventilation only explained in the FAQ section. Although the user manual for the MVHR system is included in the appendices.
- No explanation of PV system or capacity; this was mentioned in the handover. General product information sheet included in appendices.
- Information on energy saving light bulbs, energy saving measures and responsible purchasing is provided. Supplier information for energy efficient light bulbs provided, this is commendable.

- Monitoring information is not provided in the home user manual as this is common to the entire development. Information on monitoring is provided in the participant information sheet provided by OBU.

- Information on composting, council collection day and materials to be recycled provided. Information on the location of the compost bin, time spans for composting etc. is not provided

- No information on water recycling is provided. Residents advised to use water butts to save money in the energy saving section.

- Contact information and webpage links provided. Clear troubleshooting guidelines are provided as well as what to check for heating/ plumbing / electrical problems. The troubleshooting section could be improved with pictures showing the 'normal' setting for each system.

5.2.2 Recommendations

- Maintain the overall good list of topics covered.

- Maintain the FAQs section.

- Add page numbers.

- Adding colour photos would be useful.

- It is not necessary to provide air testing, installation manuals and electrical certificates etc. to the occupants in a single folder as this increases the size of the manual and the perceived complexity.

- A well formatted, colour, booklet version of this information is more likely to be read. The home user guide should not be long in size but should provide basic information on how to operate the systems in the house in a straight forward and graphically clear way.

- The home user guide is best to be designed by the architects who are more experienced in providing information in a graphical way.

- Errors such as information on gas heating needs to be checked and changed according to property, instead of using the same user guide for the whole development.

5.3 Handover demonstration tour

The demonstration tour conducted two months post move-in on 13 December 2012 was observed by two evaluators from Oxford Brookes University; Professor Rajat Gupta and Dr.Hu Du (Figures 56, 57). No separate guidance document was provided during this tour as user guidance was previously provided at the move in.

Figure 56 Handover tour in House No.1: explaining the ventilation boost controls

Figure 57 House No.2: explaining the thermostat controls

5.3.1 Findings

- The demonstration tour was focussed on heating and ventilation system and controls; with a brief overview of the PV system.
- The demonstration tour was not conducted room by room; some information was previously made available at the move in and in the guidance document. This information was not reiterated or co-related at the demonstration tour. For example, the user manual contained information on appliances and warranties including energy labelling; location of stop cock; operation of rear door and lighting and lighting controls. However, this was not mentioned during the handover demonstration tour.
- The working of the Air Source Heat Pump (ASHP) was not explained although the impact of the ASHP on bills and the need for the under-floor heating was covered. Optimal utilisation of the under-floor heating including appropriate set points was clearly mentioned. Maintenance requirements for this type of system, such as the importance of not drilling through the floors or external fabric was mentioned in the guide but not re-iterated during the tour.
- The control interfaces for ventilation boost and temperature setting was demonstrated and explained well; occupants expressed doubts which were clarified, but were not asked to demonstrate their understanding.
- The role of PV and how to maximise PV generated electricity use by switching the water heater on at times when PV production is high was clearly explained.
- The lack of demonstration of the location of water and electricity meters and stop cocks was a significant deficiency.

- Utility company information was provided in the user guidance document, however, the certificates could be explained during the tour.

- The occupants were aware of whom to approach regarding issues and emergencies. This information is also provided clearly in the guidance document. The troubleshooting protocol was also clearly laid out by the demonstrator.

- Occupants in both properties reported having received the handover guidance but they seemed reluctant to read it (perhaps due to the voluminous nature of the document).

- The demonstrator's explanations were clear and simple; the occupants may have been more relaxed if the demonstration tour followed an informal, sit-down discussion of the important sections of the handover documents. This will help them understand what information is available in the document for future reference.

5.3.2 Recommendations

- It would be beneficial to combine an overview of the guidance documents with the demonstration tour.

- The demonstration tour focussed on heating and ventilation controls. This may be due to the fact that occupants have lived in the house for over 2 months when this tour occurred, and were already aware of basic features. However, the following issues need to be addressed (at least briefly) in the handover:
  - Security access and safety issues
  - Water efficiency
  - Deliveries, recycling and waste disposal management
  - Furniture, spares and cycle storage
  - Space use and future expanding potential
  - Regular maintenance issues
  - Soft and hard landscape maintenance
  - Personal transport options
- It would be useful to ask occupants to demonstrate the use of controls and focus on a more hands-on approach.

- The phased approach to handover is commendable; however, the structure of the handover and time intervals between the different demonstrations need to be reviewed.

- Ideally, a group induction tour conducted immediately after construction and before move-in should be arranged to induct the occupants about the common facilities, issues and external features. A brief overview of the house along with the detailed home user manual and quick overview guide (sample attached) should be provided a few days before the move-in when the keys are handed over. A detailed demonstration must be conducted within the first two weeks of occupation, where the occupants are led through the user manual and given a room-by-room demonstration of features and controls. A follow up tour conducted in the first two months after occupation will help clear any doubts and occupant demonstration of controls will ensure that they understand how to control the various systems.

6 Occupant surveys using standardised housing questionnaire (BUS) and other occupant evaluation

6.1 Occupant satisfaction survey using BUS questionnaires

The BUS questionnaire method was used to map the reactions of the occupants in the entire development on Chapel Street, Bicester. The questionnaires were distributed on 3rd June 2013. Some of the occupants filled them in and returned them the same day, whereas others were provided with pre-paid envelopes and were asked to return the questionnaires through post. We obtained a total of 24 responses out of 35 questionnaires delivered (68%).

The purpose of the survey is to understand how well the dwellings meet the occupants' needs, the perceived level of comfort within the dwellings and the degree of control the occupants feel they have over the energy and water-saving features of their home. The questionnaire prompted occupants to comment on the building's image and layout, the control and daily use of the energy and water-saving features and any lifestyle changes since moving to the property. Their responses were then rated in terms of effectiveness and additional comments were made were needed. The survey also collects comments made by the respondents under each of the categories. The summary of these comments are shown in tables.

The questionnaire variables are compared with their respective scales midpoint and BUS benchmarks to provide a slider showing green/amber/red lights depending on the comparison with upper and lower limits of the scale midpoint and benchmark. The benchmark used is the UK 2011 domestic benchmark which forms of multiple domestic sites (i.e. multiple dwellings) in the UK. The benchmark includes dwellings of various typologies and age.

6.1.1 The building overall

The overall picture of the survey (Figure 58) revealed a positive opinion towards the dwellings, with the air quality in winter and the quality of light being the most appreciated elements. Also the air quality in winter scored higher than the benchmark. Participants generally feel that the facilities provided meet their needs well and that the dwellings are quite comfortable overall. Temperatures during winter are generally regarded as quite comfortable but less so in summer.

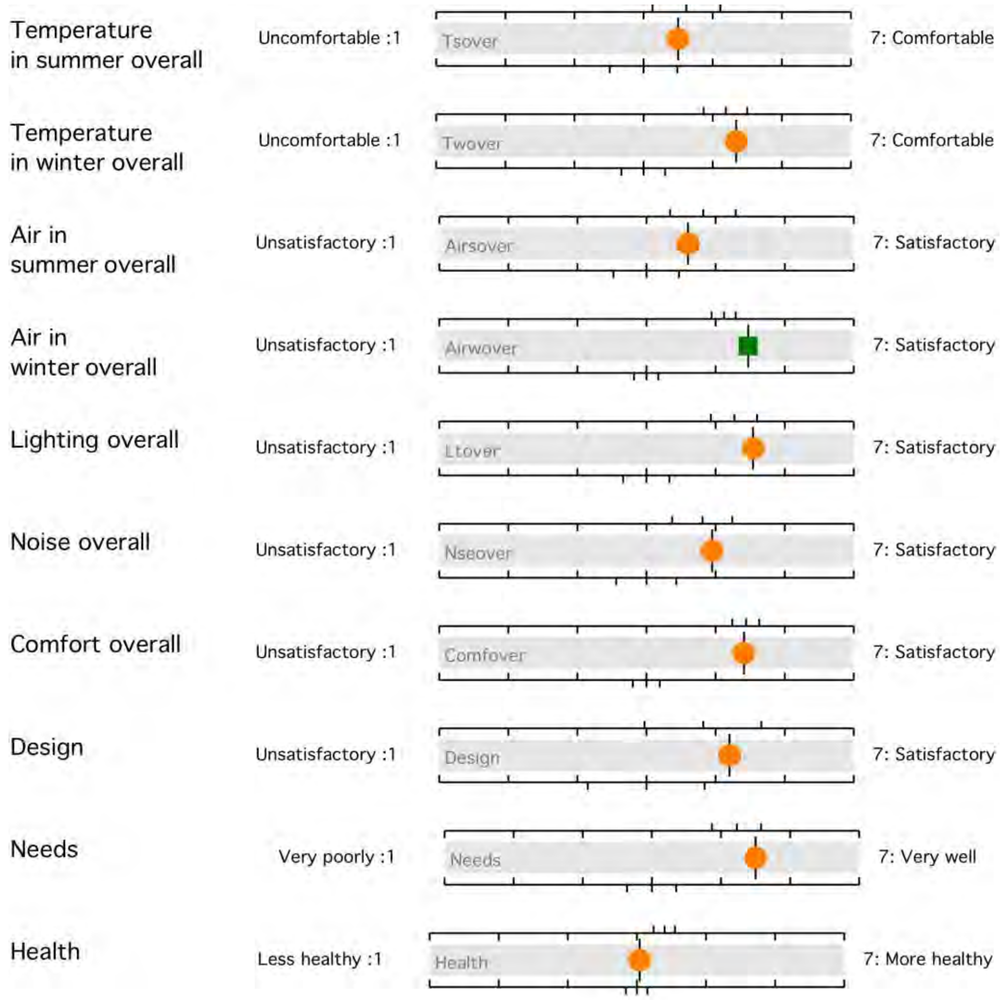


Figure 58 Overall findings

6.1.1.1 External appearance

Respondents rated the building's appearance favourably with 15 out of 24 (20%) respondents finding the appearance satisfactory (Figure 59). However, some of the comments received, pointed out that the external space is not maintained properly.

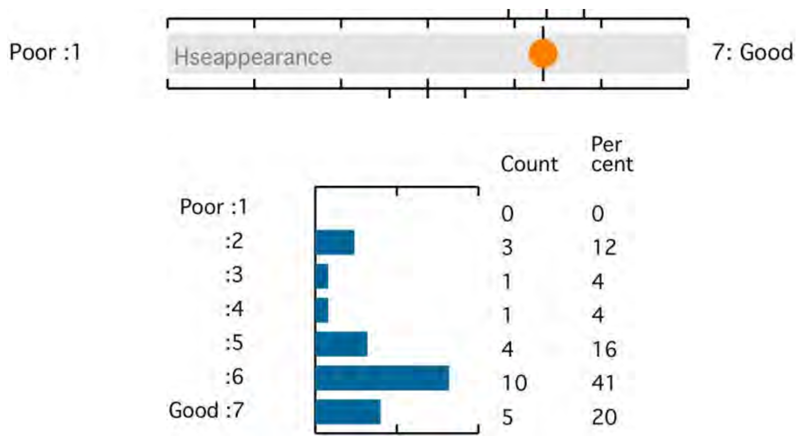


Figure 59 External appearance, slider and histogram

6.1.1.2 Layout

The layout was rated as quite good on average with only 5 out of 24 (20%) respondents finding the layout ‘good’ (Figure 60). Contradictory comments were received about the open plan kitchen, with some of the occupants appreciating it and others not.

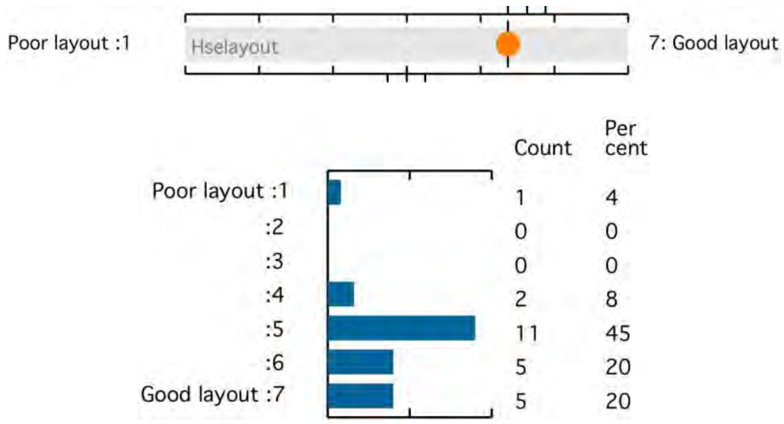


Figure 60 Layout, slider and histogram

6.1.1.3 Location

The location was one of the most appreciated aspects of the development with the majority (14 out of 24) of the respondents being fully satisfied with it (Figure 61). The building location scored higher than the benchmark.

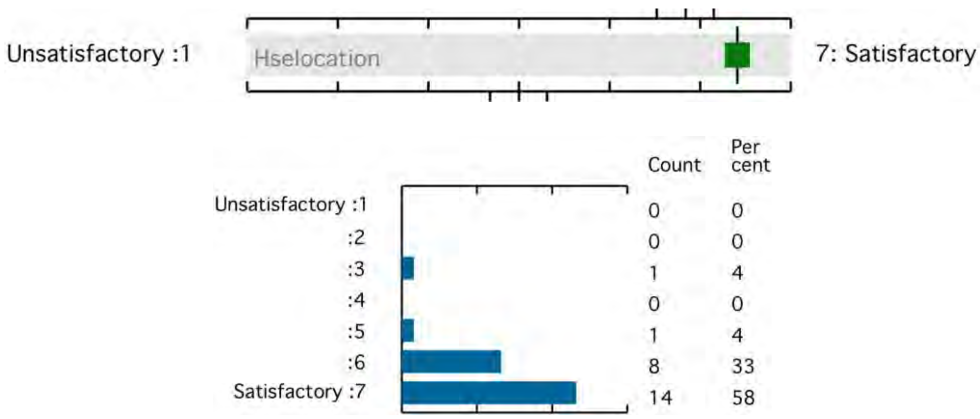
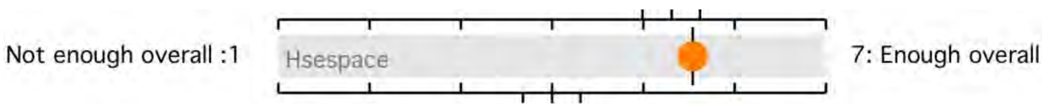


Figure 61 Location, slider and histogram

6.1.1.4 Space

Respondents rated the space of the dwellings as satisfactory with almost 7 out of 24 (29%) respondents finding it enough overall (Figure 62). None of the respondents feels that there is not enough space overall.



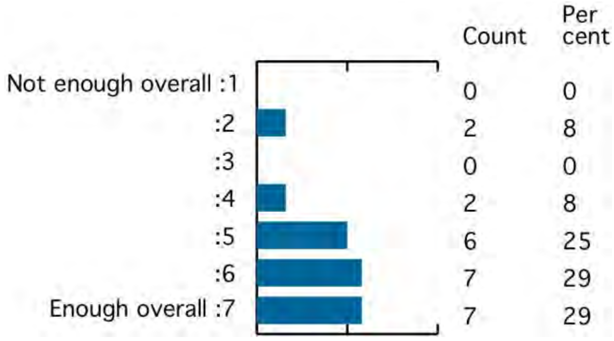


Figure 62 Space standards, slider and histogram

6.1.1.5 Storage

The building storage score is the same as the scale midpoint. Contradictory answers were received regarding the amount of storage space with 4 out of 24 (16%) respondents finding it more than enough and another 4 respondents (16%) not finding it enough (Figure 63). This might be a result of the different storage space standards between the flats and the terraced houses and is also related to the number of occupants living in each property. In general, the occupants of the flats feel there is not enough storage space, whereas the occupants of the terraced houses are more satisfied with the amount of dedicated storage space.

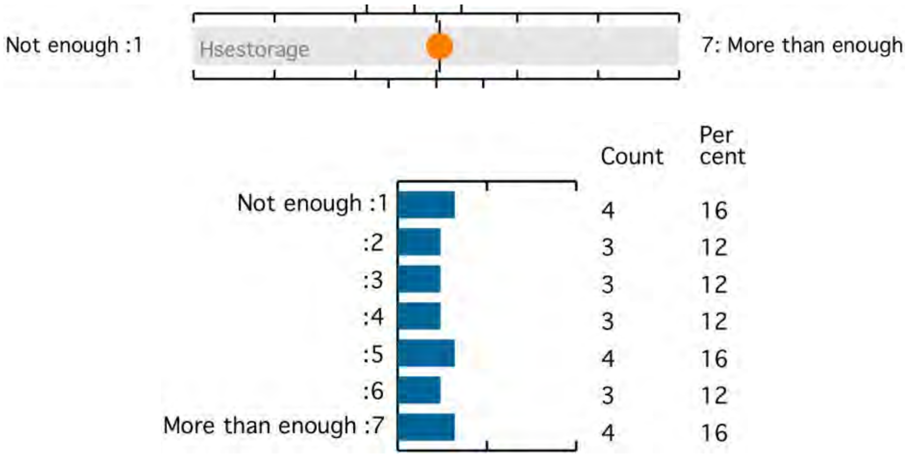


Figure 63 Storage, slider and histogram

6.1.2 Comfort, design and needs

6.1.2.1 Comfort overall

The degree of comfort that users experience within a building is a very important parameter of post occupancy evaluation. Participants were asked about their perceived comfort within the building in relation to the air temperature, air quality, noise, lighting, ventilation and level of personal control. The respondents were generally positive about overall comfort with 5 out of 24 respondents (20%) being fully satisfied. In terms of comfort the building scored within the benchmark (Figure 64).

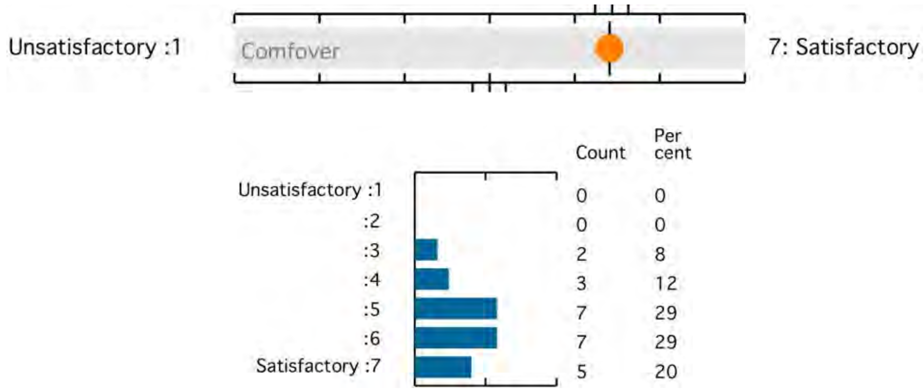


Figure 64 Comfort overall, slider and histogram

6.1.2.2 Design

The design of the dwellings was rated positively, with the score sitting at the higher end of the benchmark. 5 out of 24 respondents (20%) are fully satisfied (Figure 65).

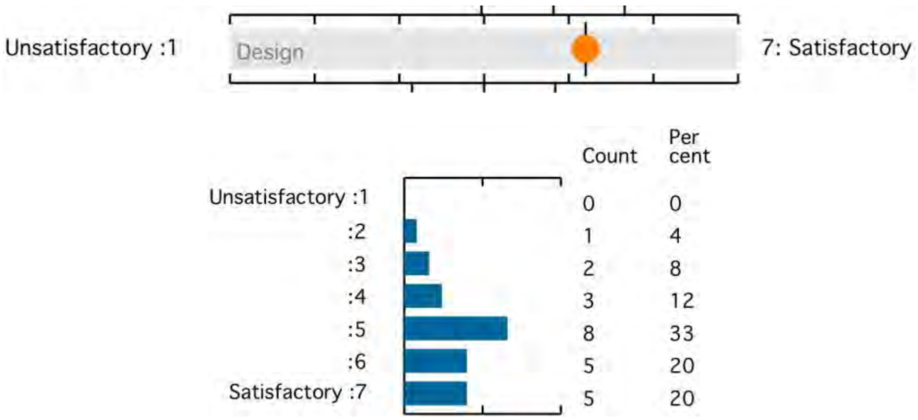


Figure 65 Design, slider and histogram

6.1.2.3 Needs

The needs of the users tend to be well met generally although only 3 out of 24 respondents (12%) are fully satisfied (Figure 66).

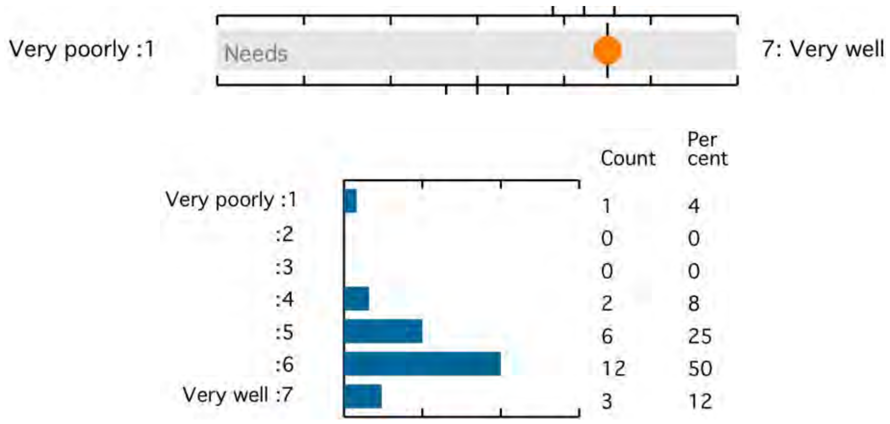


Figure 66 Needs, slider and histogram

6.1.3 Air temperature and quality

In general, the summer and winter temperature conditions are perceived as comfortable but less so in summer than winter (Figures 67, 68). During both periods, the building scores sit within the benchmark. Only 6 out of 24 respondents (26%) in winter and 5 out of 24 (20%) in summer are fully comfortable.

6.1.3.1 Temperature in winter: overall

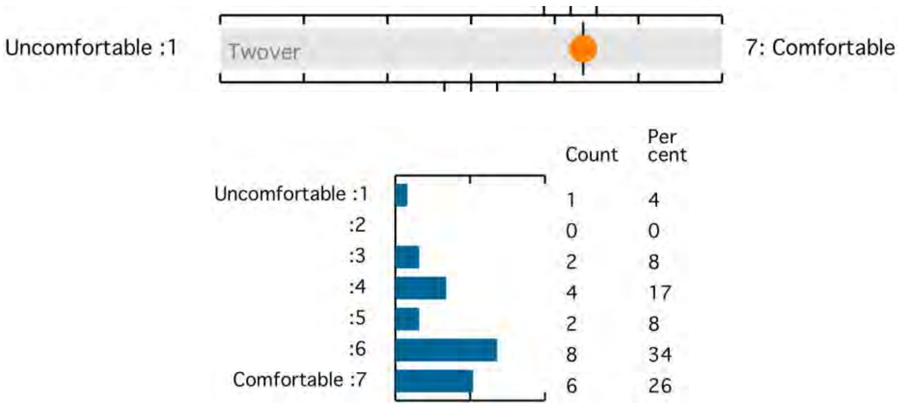


Figure 67 Temperature in winter overall, slider and histogram

6.1.3.2 Temperature in summer: overall

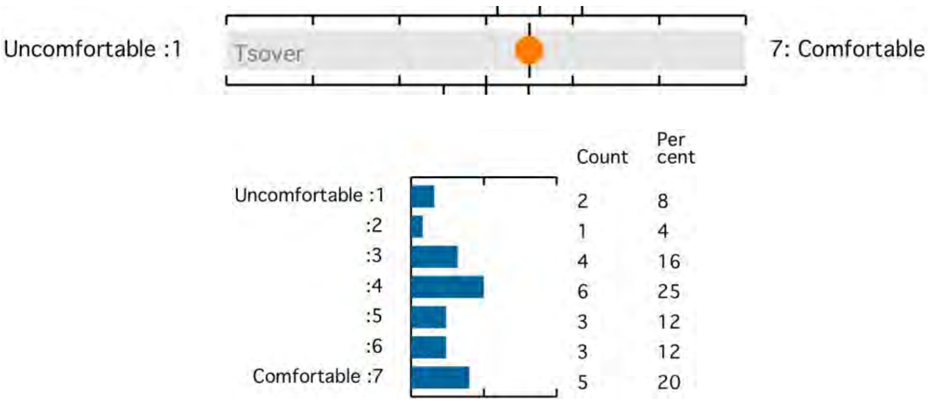


Figure 68 Temperature in summer overall, slider and histogram

6.1.3.3 Temperature detail variables in winter/summer

Summer temperatures are perceived as hot and variable during the day, indicating that the dwellings are not very adaptable to warm weather conditions. This might be due to the lack of shading devices, lack of cross ventilation and light-weight construction system (with low thermal mass) of the dwellings.

Winter temperatures are perceived as comfortable, scoring above the benchmark (Figure 69). This is mostly due to the high insulation standards of the building fabric and low heat loss coefficient. However, the winter temperature is perceived to be variable possibly due to lack of thermal mass in the construction system.

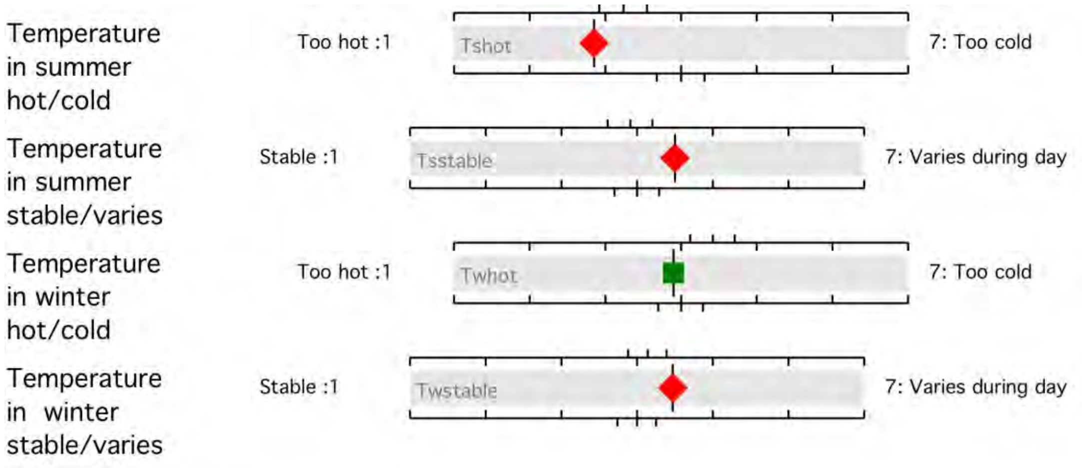


Figure 69 Temperature detail variables in winter/summer.

Many comments were received about heating, as occupants feel they cannot control temperatures effectively. Some occupants complain that it gets very hot in the dwellings and that the heating system continues to operate even when the thermostats are turned down. The same was pointed out by the occupants in the case study houses and after on-site inspection it was discovered that the thermostats are not communicating with the heating system properly. From the comments that were received it seems that this problem is common in other properties in the development. This is being addressed by Mansell (building contractor).

Heating
• *'Cannot control heating effectively.'* • *'Difficult to control temperature. Either too hot or too cold.'* • *'Gets very hot.'* • *'Heats up even when thermostats are turned down.* • *'Too cold in winter, too hot in summer. '* • *'Heating has failed a couple of times.'*

Cooling/Ventilation
• *'Air vents do not work well'* • *'Does not cool down easily' (x2)* • *'Gets very hot in flat.'(x3)* • *'More air/ventilation needed '(x3)* • *'Ventilation too noisy at night'.* • *'The flat gets very hot in the summer but when I open the windows it is ok'.*

6.1.3.4 Air quality in winter: overall

In winter, air is perceived as quite satisfactory by the majority of the respondents with 8 out of 24 (34%) being fully satisfied (Figure 70). Air quality in winter scored higher than the benchmark. This indicates that the MVHR system is performing well in providing the dwellings with fresh air (although occupants in the two case study houses have had issues with the operation of their MVHR systems).

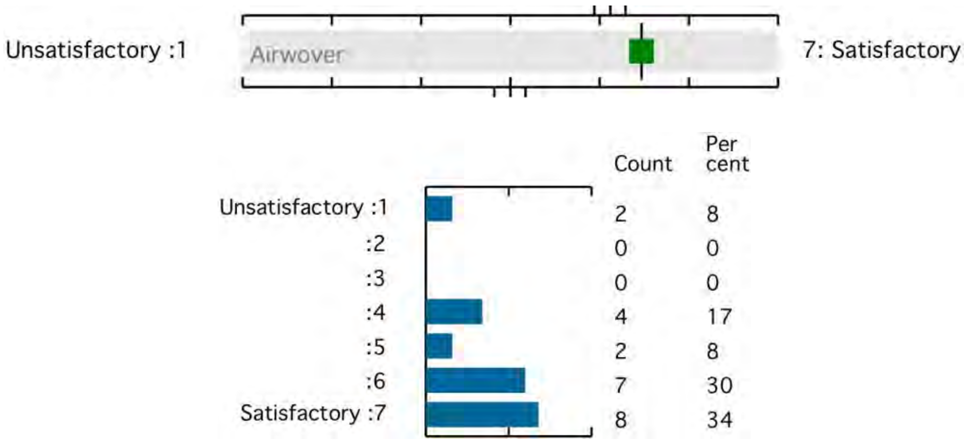


Figure 70 Air quality in winter overall, slider and histogram

6.1.3.5 Air quality in summer: overall

Air quality in summer was rated favourably but only 4 out of 24 respondents (17%) are fully satisfied (Figure 71). The score sits towards the middle of the benchmark.

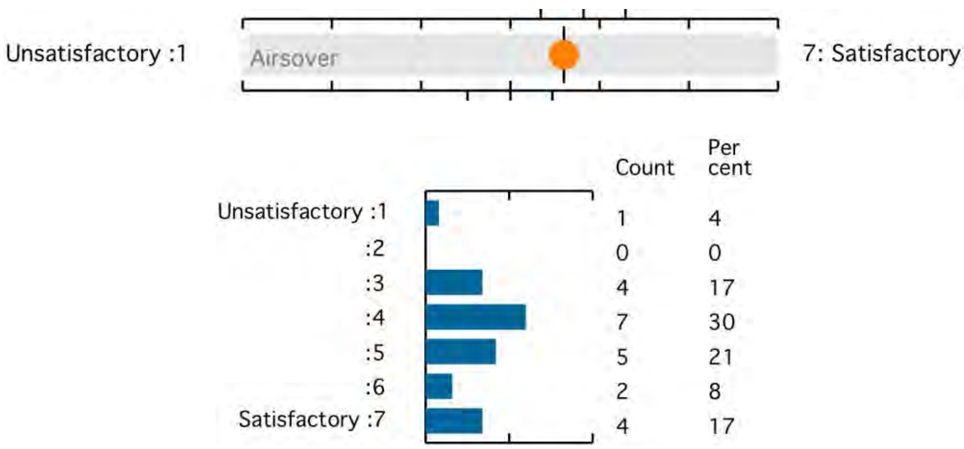


Figure 71 Air quality in summer overall, slider and histogram

6.1.3.6 Air quality detail variables in winter/summer

In summer, air is perceived as slightly dry and still. In winter, the humidity levels were rated as satisfactory (neither dry nor humid), scoring above the benchmark. The parameter indicating air fresh/stuffy scored close to the scale midpoint in both seasons. Smells are not a problem scoring towards the upper end of the bechmark in both summer and winter (Figure 72).

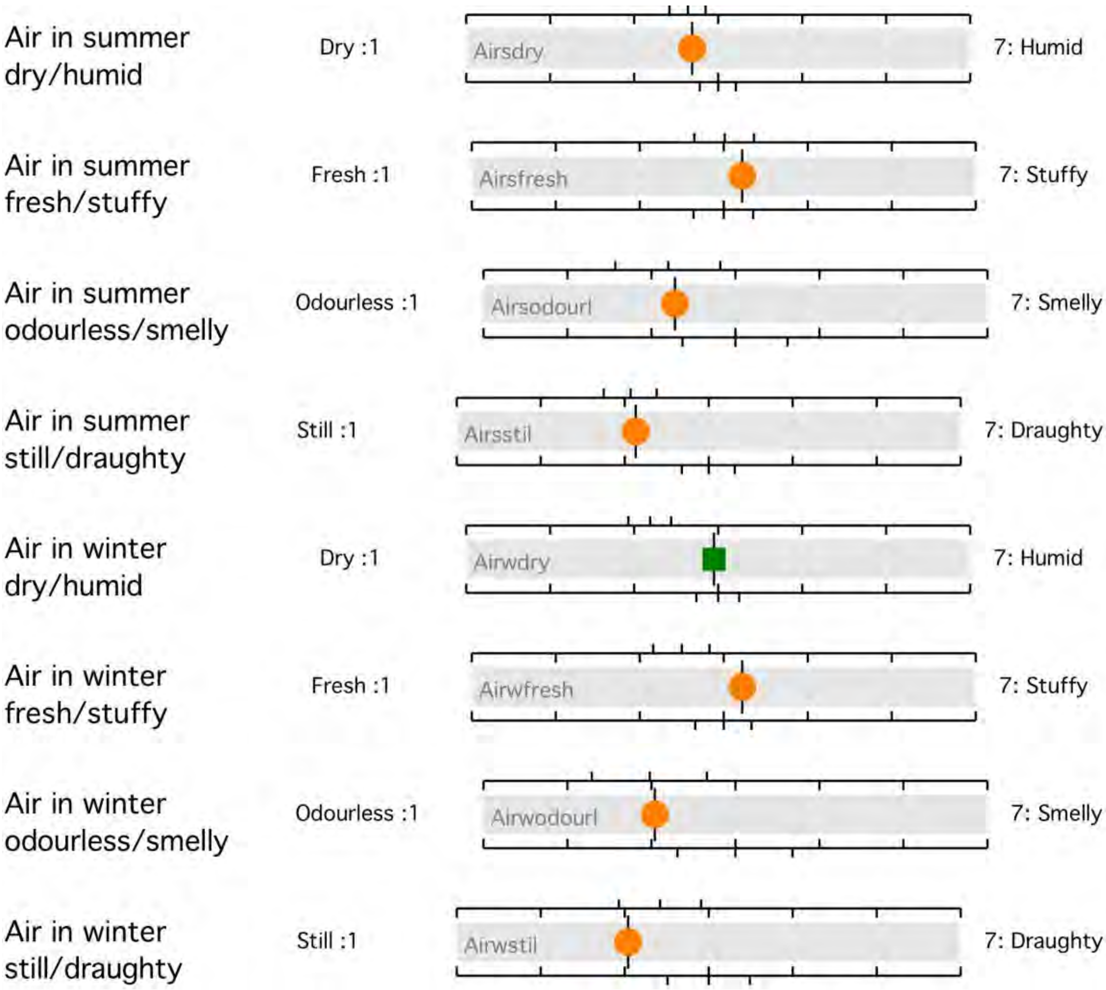


Figure 72 Air quality detail variables in summer and winter

6.1.4 Lighting

Lighting levels appear to be satisfactory overall with 9 out of 24 respondents (37%) being fully satisfied (Figure 73). The quality of light is one of the most appreciated elements of the building and scored at the higher end of the benchmark. However, natural light falls below the benchmark (Figure 74), with 11 out of 24 respondents (45%) being fully satisfied and 7 out of 24 (29%) finding it ‘little’. This contradiction is probably due to the different orientations of the dwellings. Artificial lighting was regarded as satisfactory by the majority of the respondents (14 out of 24) (Figure 75).

6.1.4.1 Lighting overall

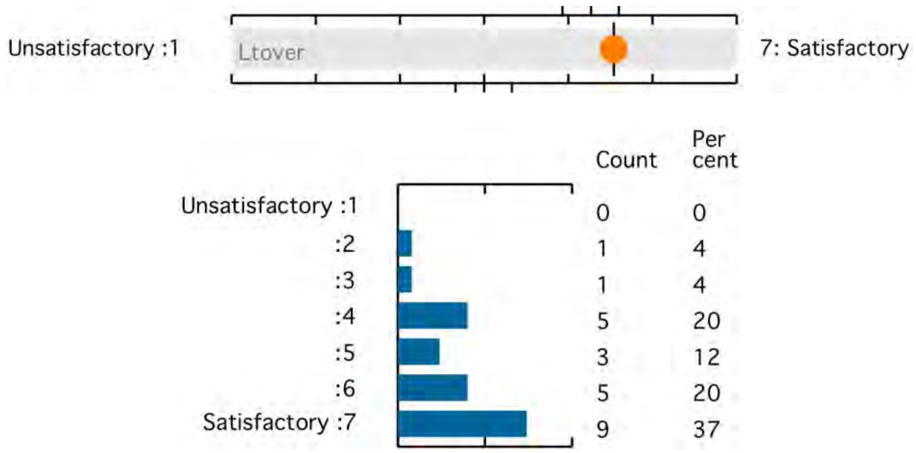


Figure 73 Lighting overall, slider and histogram.

6.1.4.2 Artificial/natural lighting

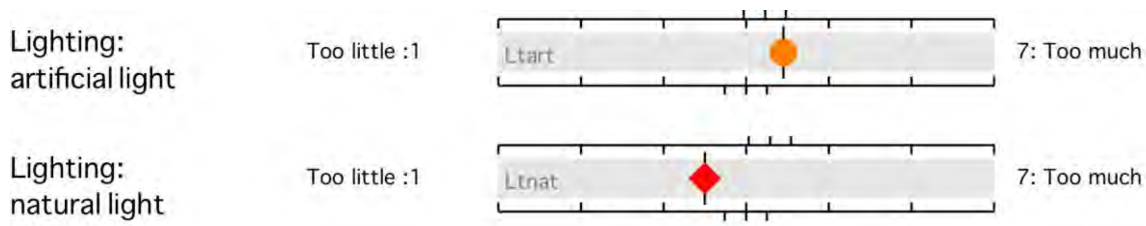


Figure 74 Artificial/natural lighting slider.

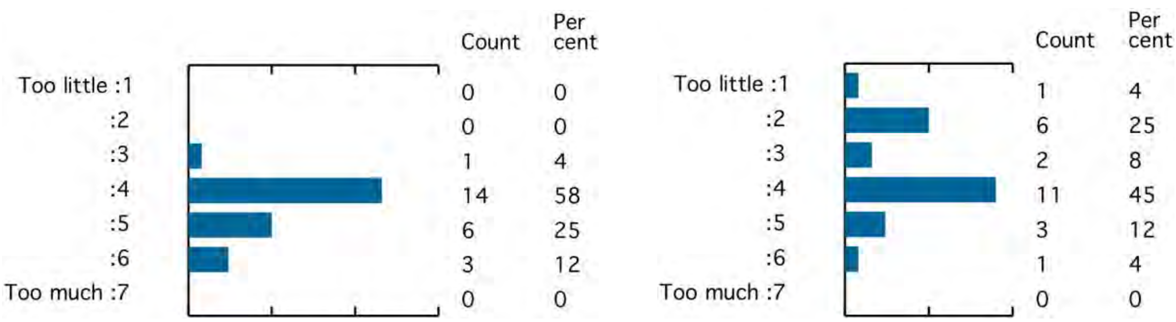


Figure 75 Artificial lighting (left), Natural lighting (right) histograms.

6.1.5 Noise

No major noise issues were pointed out as overall noise is regarded as quite satisfactory; with 6 out of 24 respondents (25%) being fully satisfied (Figure76). Noise from outside is not a problem for the majority of the respondents and was rated above the benchmark (Figure 77). Noise from neighbours is generally regarded as quite high, scoring at the upper end of the benchmark and with 3 out of 24 respondents (12%) finding it excessive (Figure 78). Noise from other people is generally regarded as slightly high and scored towards the middle of the benchmark. 16 out of 24 respondents (66%) feel that noise levels from other people are acceptable and only 4 out of 24 respondents (16%) feel it is high (Figure 79).

6.1.5.1 Noise overall

Figure 76 Noise overall.

6.1.5.2 Noise from outside

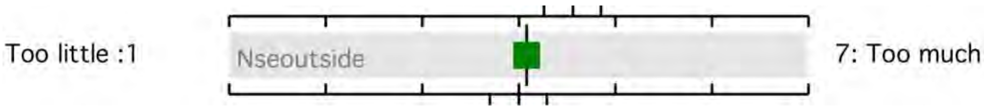


Figure 77 Noise from outside.

6.1.5.3 Noise from neighbours

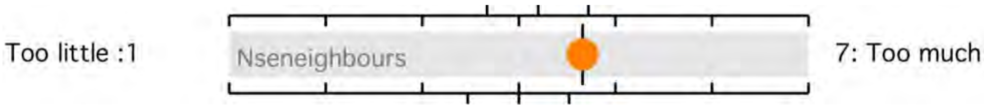
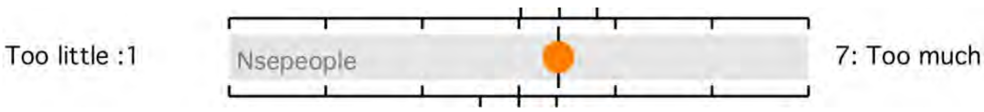


Figure 78 Noise from neighbours.

6.1.5.4 Noise from other people



Apart from one comment received, no particular noise issues from the MVHR were reported in the occupant survey. However, during the interviews, occupants in House 1 reported noise coming from the MVHR system and pointed out that they would have preferred to turn off the MVHR system due to noise and draughts coming from the supply grills.

Figure 79 Noise from other people.

Noise
• *'When windows and doors are closed noise is not a problem.'* • *'Too much noise from walking around above.'* • *'The triple glazed windows keep the flat quiet inside.'* • *'Noisy ventilation'* • *'External noise loud but when windows are closed it is very quiet inside.'*

6.1.6 Personal control

Control over cooling was rated negatively on average, with 5 out of 24 respondents (22%) feeling that they do not have any control over it. Control over heating and ventilation both scored close to the scale midpoint. Only 4 out of 24 respondents (17%) feel they have full control over heating and 6 out of 24 (25%) feel they have very little control (Figures 80, 81). Comments pointed out the lack of control over heating. With regards to ventilation results vary greatly, with 6 out of 24 respondents (26%) feeling in full control. Control over lighting was rated positively on average with the majority of the respondents (16 out of 24) feeling in full control.

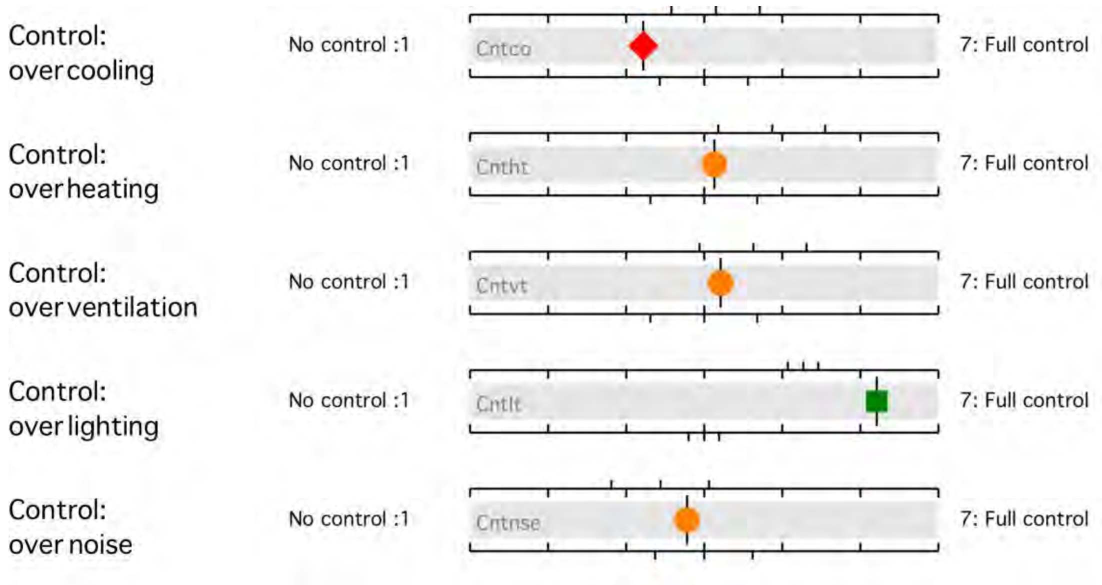


Figure 80 Personal control

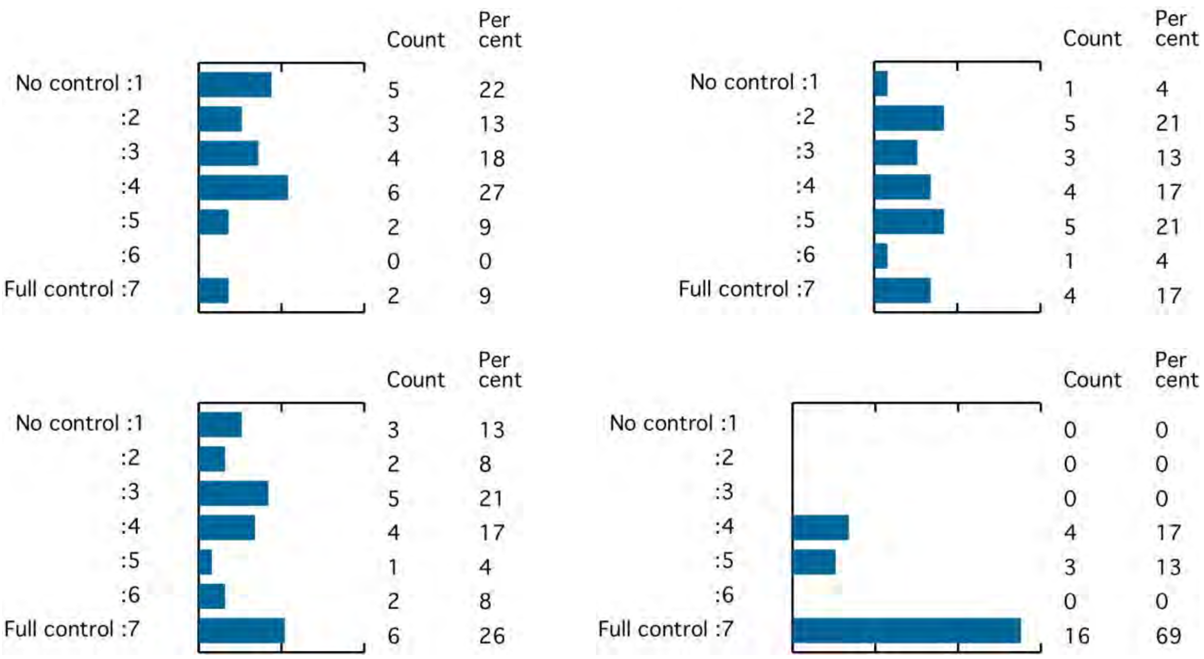


Figure 81 Control over cooling (top left), heating (top right), ventilation (bottom left), lighting (bottom right).

Control
• *'Finding it difficult to adjust temperature.'* • *'Have control over heating but still too hot'.* • *'No temperature control. Even if you set a temperature at the thermostat the house decides otherwise.'*

6.1.7 Utilities costs

6.1.7.1 Electricity

Respondents generally feel that electricity costs are similar to those in their previous accommodations, with the score sitting close to the scale midpoint. 4 out of 24 respondents (18%) feel that electricity costs in the new homes are much higher than their previous ones (Figure 82). Respondent's comments pointed out that Ewgecos made them more aware of their energy consumption.

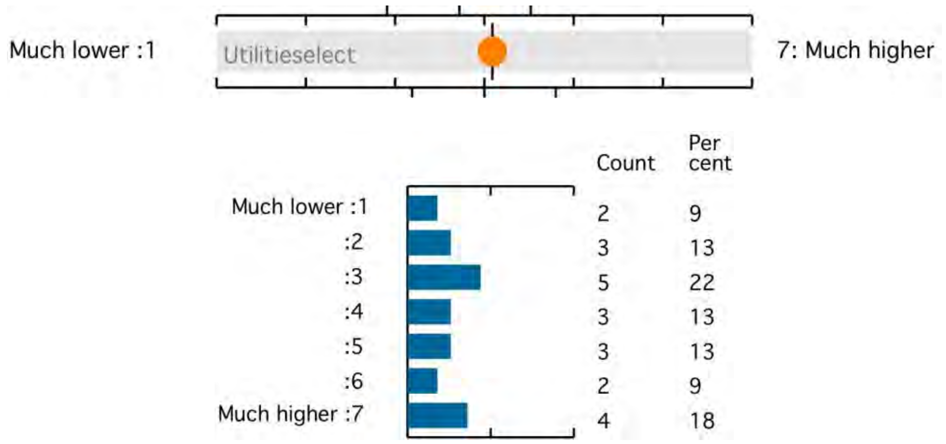
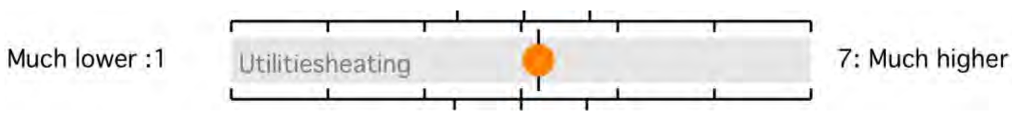


Figure 82 Electricity costs, slider and histograms.

6.1.7.2 Heating

Respondents generally feel that heating costs are similar those in their previous accommodations, with the score sitting close to the scale midpoint. 4 out of 24 respondents (18%) feel that the heating bills in the new homes are much higher than their previous ones (Figure 83).



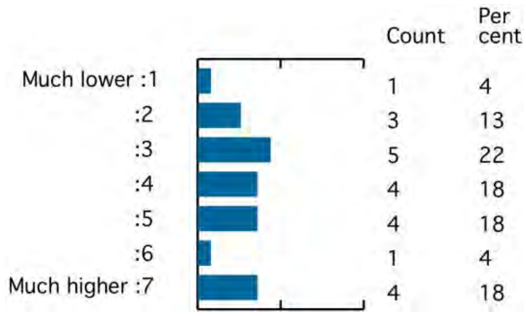


Figure 83 Heating costs, slider and histograms.

6.1.7.3 Water

Respondents generally feel that water costs are similar to the ones in their previous accommodations, with the score sitting in the upper part of the benchmark (Figure 84).

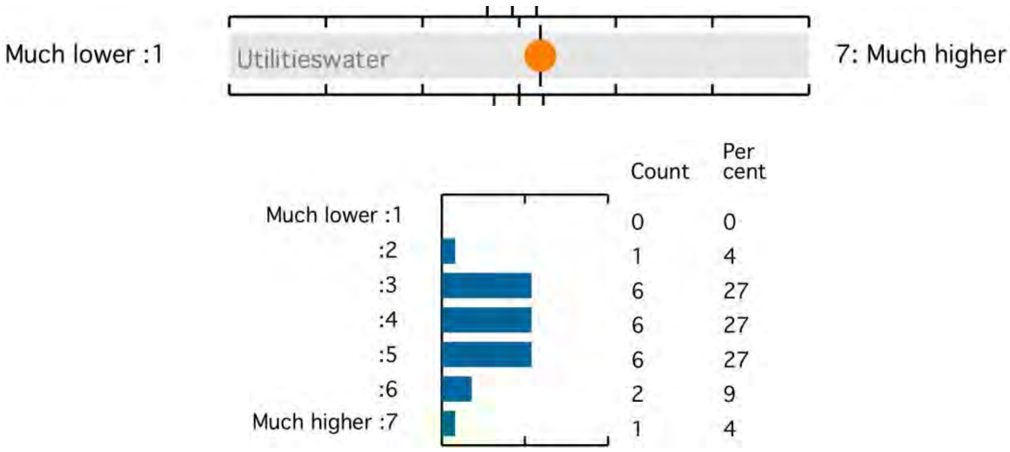


Figure 84 Water costs, slider and histogram

Heating cost examples
• *'Only put on the heating at night as it costs a lot.' (x2)* • *'Rarely need to turn heating on If turned on in the evening it keeps the house warmer for days if doors are kept closed.'* • *'The heating costs about the same but it is generally warmer.'* • *'The heating system is more complicated but generally very efficient.' (x2)* • *'I do not have to fire the heating; it is very clever and effective.'*

Lighting cost examples
• *'I do not use much artificial lighting.' (x3)* • *'Use lighting a lot a natural light is so poor.' (x2)* • *'Use natural daylight more.'(x2)*

6.1.8 Environmental design features

Most of the occupants in the cottage houses (terraced) that feature rainwater harvesting complained that the system is not working properly and that the toilets are not filling up. This is due to the water tank not being sized properly to cover the needs of the houses. Participants pointed out the solar panels effect on reducing electricity bills, while others commented that their bills are high despite the energy and water-saving design features of the dwellings.

Environmental design features
• *'Rainwater harvesting always goes wrong '(x2).*
• *'Frequent problems with toilets not filling up'(x2).*
• *'Solar panels on roof help save money on electricity '(x3).*
• *'I still get high electricity and water bills'.*
• *'Water bills seem high considering I live alone and toilets use rainwater harvesting.'*

6.1.9 Lifestyle

Half of the occupants feel that living in this home has changed their lifestyle (Figure 85).

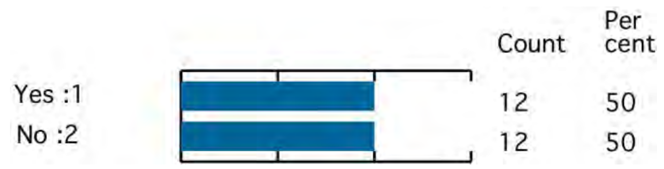


Figure 85 Effect of homes on lifestyle

Lifestyle
• *'Closer to train station and buses.'*
• *'Local buses are excellent and I can get to other areas easily. '(x2)*
• *'Walking distance to town, shopping, night outs'. (x3)*
• *'I go out more as the town is in a walking distance.'*
• *'Walk more, drive less'*
• *'Closer to friends/family.' (x2)*
• *'Better for work opportunities.'*
• *'I walk to work because it is closer.' (x2)*

6.1.10 Aspects that work well or poorly

According to the participants, the main aspects that work poorly are the rain water harvesting system and the bath tap that does not provide hot water. Other comments were received about the location of the parking space that is found to be far from some of the dwellings and the size of the garden that is regarded as small. The key aspects that work well are considered to be the layout, the size of the rooms and the location of the dwellings. Positive comments were also received for the insulation of the envelope and the heating.

Things that work poorly
• *'Rain water harvesting is not reliable. Toilets break down frequently.' (x6)* • *'Toilets are often unusable as rainwater tank is not big enough.'* • *'Parking space'(x4)* • *'Garden is small'. (x3)* • *'No hot water in the bath' (x4)* • *'House too hot.'* • *'Not enough storage. '(x3)*
Things that work well
• *'Good layout, good room size, excellent facilities.'* • *'Good sized rooms'* • *'Size of kitchen and bedrooms.'* • *'Insulation, kitchen, light in the living room.'* • *'Good layout. Warm and easy to heat.'* • *'Two toilets. Big kitchen.'* • *'Location' (x3)* • *'Layout, heating, proximity to shops'*

6.2 Interviews and walkthroughs with occupants

This report summarises the findings of the occupant interviews and walkthroughs in Bryan House on Chapel Street, Bicester.

The occupant interview and walkthrough were conducted on Friday 28th June 2013 in House 1 and on Monday 1st July 2013 in House 2. Both sets of occupants were asked the same questions.

6.2.1 Interviews with occupants

The purpose of the interview is to find out the occupant's level of satisfaction with the handover process and, the appeal of the house, to check how they the occupants feel about the comfort and control of the different systems in their home (heating and hot water, ventilation, daylight and lighting, noise) and what how they perceive the space standards and their flexibility of their home. The walkthroughs involve reviewing specific items in each of the rooms of the house, looking at the best and worst for each space.

Table 10 presents a comparison of the views of the occupants of Houses 1 and 2. The quotes are taken from the formatted and edited transcripts of the semi-structured interviews.

Table 10 Views of the occupants of Houses 1 and 2.

	HOUSE 1	HOUSE 2
SATISFACTION		
Appearance, layout, liveability	• 'We are satisfied with the appearance of the house both internally and externally.' • 'We are happy with the layout of the house.' • 'It is suitable for a family.'	• 'I am very satisfied with the appearance of the house, it looks nice.' • 'We are happy with the layout of the house.' • 'It is very suitable for our family. It is quite a big house.'
Induction	• According to the occupants the induction process was clear.	• 'I was not present during the induction process. My father

	• 'We were shown the MVHR boost in the kitchen and how to operate the room thermostats.' • 'We were told that there would be a follow up visit to show us how the systems worked but this did not happen.'	participated in it and I think he was quite satisfied with it; he had lots to say afterwards.'
Home User Guide	• 'The smaller guide was very clear but the one about the heating was confusing.'	• 'It was not easy to read and some parts of it were confusing.'
Cleaning & Maintenance	• 'It is easy to clean and maintain the house.'	• 'It is not very easy to clean the house because there is no carpet in yet and it collects a lot of dust.'
Understanding of systems and technologies installed in the	• Occupants note that how and when to use the immersion heater has not been fully explained, and various technicians that visited the house had given them conflicting advice that was inaccurate. • 'We do not understand how the solar panels work and how we get any payback from them.' • We do not fully understand how to program the hot water, instead of having it on at all times.' • 'It is confusing having two different water heating systems.'	• Occupants in this house are not at all familiar with the systems installed in the house: • 'I do not understand the Ewgeco meters and their purpose. ' • 'We do not understand how the PVs work.' • 'I do not know what the unit in the garden is.' (Referring to the ASHP).
OPERATION, COMFORT & CONTROL		
Heating performance	• Occupants report that the heating system warms up the house very well but does not always work properly. • 'We have noticed that the heating is always on, even when we turn the thermostats down, resulting in very high temperatures in some of the rooms. We have trouble controlling the heating.' • 'We set the thermostats around 19°C but some of the rooms can reach 23-24°C during winter and the heating is still on.'	• Occupants are not satisfied with the heating system and report that it does not work properly. • 'The heating is impossible to control. We set the thermostats at 17°C and it goes above 23-26°C and it is always really hot in the house. The technicians from Blount who came by turned the heating off in the middle floor but it still feels very hot.' • Occupants report that the unit in the garden is quite noisy (referring to the ASHP).
Heating use & usability	• 'It is easy to use the thermostats but we do not seem able to control the heating system. As I said, sometimes when you turn it on and you want it at a certain heat sometimes it goes higher.' • 'The quality of the heat is good.' • 'System responsiveness could be quicker.'	• Occupants report that they do not have any control on the heating despite the fact that there are thermostats in each room. They believe that the thermostats are not working properly. • 'Temperatures are always higher than we set them to be.' • 'It is always really hot in the house'. • 'It does get quite stuffy in here'.
Renewables performance	• Occupants are aware that PVs show up on the Ewgeco but do not know how to read it. • 'I do not know how the PVs perform'. • '[The performance of the PVs] does not show on the bills we are getting. I do not know how it	• 'We do not know how the PVs perform. We haven't received any payback and it doesn't show on the bills we get, so we don't know.'

	comes off from the electricity bill. I tried to contact the electric company but they weren't very helpful.'	
Heating controls	• Occupants find the room thermostats easy to use but do not know how to operate the masterstat. • In winter occupants kept turning the heat pump off from the main switch, during the day, to save energy. They would only turn it back on during the night to heat the house.	• Occupants note that they understand the controls but cannot get them to work properly. • 'They are not working at all. We cannot control the heating.' • 'It is a bit excessive to have one [thermostat] in each room, having to set temperatures in all of them... It is good in some cases, for example in the baby's room... But, it might have been easier to have one thermostat in each floor instead of each room.'
LIGHTING		
Day lighting	• 'We are absolutely happy with the daylight in the house'.	• According to the occupants most rooms have quite good day lighting apart from the living room. • 'It can get quite dark in [the living room] during the day. There is only one patio door and it is our only source of natural light in here.' • 'Bedrooms have good daylight'. • 'The staircase has a roof light and gets plenty of light.'
Electrical lighting	• 'It is effective'.	• 'It is quite good'.
Lighting controls	• 'The lighting controls are easy to use'.	• 'The lighting controls are easy'.
WATER		
Water system performance	• Occupants report that the water system performs very well apart from the tap in the bath. 'The tap in the bath does not provide warm enough water'. Technicians who inspected it reported that the mixing valve is not working properly and needs to be fixed. • Occupants state that it is easy to heat the water, as the system is automatic. • 'We used to use the immersion heater whenever we wanted to take a bath as the water in the bath was not warm enough and we had turned off the heat pump. We do not use the immersion heater anymore; that comes on once a week now to prevent legionella'. • 'We had turned off all the systems to save electricity as our bills are very high, but Blount told us that we should not do that and turned the systems back on. We are now waiting to see what happens with the bills'.	• Occupants are generally satisfied with the hot water temperature, apart from the bath tap. 'We cannot get hot water in the bath at all'. • 'The showers are really good, they heat up fast'. • 'We do not have to do anything to heat up the water, it is automatic'. • 'We never run out of hot water'.
ACOUSTICS		
Noise	• Occupants do not report any internal acoustic issues.	• 'There is some noise from between floors, you can hear

	• 'We occasionally hear the neighbours going up and down the stairs'. • 'When the windows are closed there is no external noise'.	someone...even from the ground floor to the second floor.' • 'Sometimes you can hear people next doors as well, from both sides.' • 'We do not have any trouble with noise from the outside. It is a quiet neighbourhood and once the windows are closed you can't hear anything.'
VENTILATION		
Ventilation systems used and responsiveness	• 'We open windows and doors, especially when cooking. Not so much during winter though.' 'We are satisfied with the air quality in the house.' 'We can ventilate the house quickly and use the boost if we feel the need for it.'	• 'We open windows and doors to ventilate the house. We rarely do that during the winter.' • Occupants seem to be completely unfamiliar with the MVHR system: 'We don't know what these vents on the ceiling are for.' • 'The air in the house can be stuffy at times.' • 'It is easy to ventilate the living room [using windows and doors], the bedrooms are a bit harder because they are not fully openable, only half of the window opens and the other bit opens only a bit.'
Ease of use and control of MVHR	• Occupants find the MVHR easy to use. • They report that they often use the boost in the kitchen, but do not do so in the bathrooms. • 'We understand how to use the ventilation system.'	• Occupants have never used the MVHR system. • 'We have never used the MVHR system and do not know how to use it.' •
MVHR performance	• 'The system works really well. It is very quick.'	• The MVHR in this house has been broken for several months but occupants were not aware of this and are unaware of a time it did work. •
MVHR guidance and training	• Occupants feel that they received sufficient training and guidance on how to use the MVHR system. • 'During the induction we were shown the boost buttons of the MVHR.'	• The interviewees were not present during the induction. Another member of the house received training on how to use the MVHR.
MVHR control panel (accessibility and understanding)	• 'The boost controls located in the kitchen and bathrooms are easily accessible.' • The unit is in the loft and is very difficult to access.' 'There is no control to turn it off.'	• 'We do not know where it is'.
Operational issues	• Occupants have not reported any breakdowns of the MVHR. • 'Sometimes you feel really cold draughts coming from the vents. It is right above the beds in the bedrooms and it is uncomfortable.' • Occupants do not like the fact that the MVHR is on at all times and believe there should be a	• The MVHR has been broken for several months. • 'I do not think it ever worked.'

	switch so they could turn it off completely, due to both cost and noise issues. • 'The MVHR makes noise and you can hear it at night.' • Occupants would prefer to be able to turn the system off at times, and feel they do not have full control over it because they cannot shut it off, and some of the controls are inaccessible. • 'I really don't think it needs to be on 24/7. It would be nice to be able to turn them up or down individually in each room depending on our needs. We can turn the vents on and off, so we keep them shut, unless it is really stuffy or hot.' • 'We know there is a switch in the loft but it is not easily accessible and we cannot climb up and down every time we want to turn it off.'	
MAINTENANCE		
Breakdowns	• Occupants report that the heating often broke down during the early occupancy period. Technicians visited the property several times during the first few weeks and installed a part that was missing. • 'The little pistons kept sticking in the bedroom and sometimes the pressure dropped and the house was not heating well. The pistons would stick at shut.'	• The MVHR is broken. • Occupants are aware that the heating is not working properly and are awaiting for it to be fixed.
Help service	• 'We have the line to Sanctuary, that's our first call, but I also actually have the number of Blount now because I have been speaking to them a lot to arrange visits and stuff.'	• Another occupant is responsible for resolving issues within the house. • 'I do not know.'
ENERGY MANAGEMENT		
Energy & water consumption	• Occupants are very unhappy with the electricity consumption. • 'We had to turn the heat pump off during winter to save money as our bills are very high. When we don't have the heating on, energy consumption is fine.' • 'Water bills are reasonable.'	• Occupants seem satisfied with their electricity and water bills. • 'We pay around £50/month on the electricity bills'. • 'Water comes to £120 every three months.'
FLEXIIBLITY & SPACE		
Space flexibility	• 'The space is great. It is good for accommodating our needs.'	• 'It is a big house. It is good for our family.'
Space size	• 'The room sizes are good.'	• 'The living room is all right, I just don't like the layout so much.' • 'The single bedroom is quite small.' • 'The kitchen size is good.'

Storage	• 'We would like to have some extra storage space.' • 'We use the shed, the cupboard in the living room and the loft for storage.'	• 'We do not have enough storage space, for such a big house.'
Room function	• 'All rooms are appropriate for their function except the single bedroom that is small.' • 'The bedroom in the front didn't need to be quite that big, and they could have made the smaller room slightly bigger.'	• 'All rooms are appropriate for their function except the small single bedroom on the first floor.'
Future needs	• 'The house is quite flexible.' • 'We could use the small bedroom as an office in the future.'	• 'I don't think it would be good for a growing family. It is already full.'
GENERAL		
Best aspects	• 'The location is good. We can get to town easily, the bus stop is close, all the shops are very close.' • 'We are happy to have a garden.'	• 'The location is very good; even though it is so close to town it is very quiet here.' • 'The size of the house is good.'
Worst aspects	• 'I do not like the stream outside our front door, because it is dangerous for our young daughter.' • 'I don't like the location of the residents parking. I would like to be able to see the car from the house.' • 'We would like to have a slightly bigger garden and a slightly smaller shed. The shed takes up a lot of space and its position is bad.' • 'The high electricity bills during winter are one of the worst aspects of this house'.	• 'The heating is quite a big problem.' • 'The garden is small for a family house.' •

6.2.2 Walkthrough with occupants

The walkthrough for each house took approximately 15 minutes and involved a walk around and through the house, with the researcher asking questions relating to the appearance, liveability, size, acoustics, storage, comfort and maintenance of individual spaces. The following is a summation of the topic areas covered.

6.2.2.1 House 1

Front space
Occupants are satisfied with the appearance of the house and the door and entrance area. However, they dislike having the open stream in front of the house (Figure 86) as they consider it dangerous for young children. Railings could be added to prevent children from falling in the stream.

Figure 86 Front space. Right hand image shows the open stream in front of the houses.

Back garden

Occupants are not satisfied with the size of the garden and believe that the shed is too big and that it takes up vital space. Also, occupants are not satisfied with the privacy of the gardens and would have preferred the fences to be higher (Figure 87).

Figure 87 Back garden. The shed takes up a lot of space. Occupants do not like the position of the ASHP.

Living room

Occupants are satisfied with the size, daylight and thermal conditions in the living room. They reported that it is easy to clean and maintain. They are satisfied with the layout but would like to have the wiring of the television at a different location (Figure 88).

Figure 88 Living room area. Patio door (left) and dining area (right)

Kitchen

Occupants are satisfied with the size and layout of the kitchen and feel that the amount of storage is the best aspect of this space. They also feel that the space has good daylight levels and the floor is easy to clean. Occupants reported that the fire alarm gets set off really easily and that the MVHR is not as effective as a cooker hood and they would like to have a hood above the hob. The occupants use the MVHR boost while cooking but feel that the system disperses cooking smells to other rooms in the house (Figure 89).

Figure 89 Kitchen

Parent's bedroom

Occupants are satisfied with the temperatures, daylight levels and air quality of the space. They are satisfied with the size of the room but complain that there was no built-in storage space. They appreciate the fact that the windows are well designed and easy to clean. The worst aspect of this space is the MVHR vent that is positioned directly above the bed thus creating annoying draughts (Figure 90). The occupants have shut the vent to avoid the draughts and the noise coming from the system. This is common in other bedrooms in the house and has led to the unbalancing of the MVHR system.

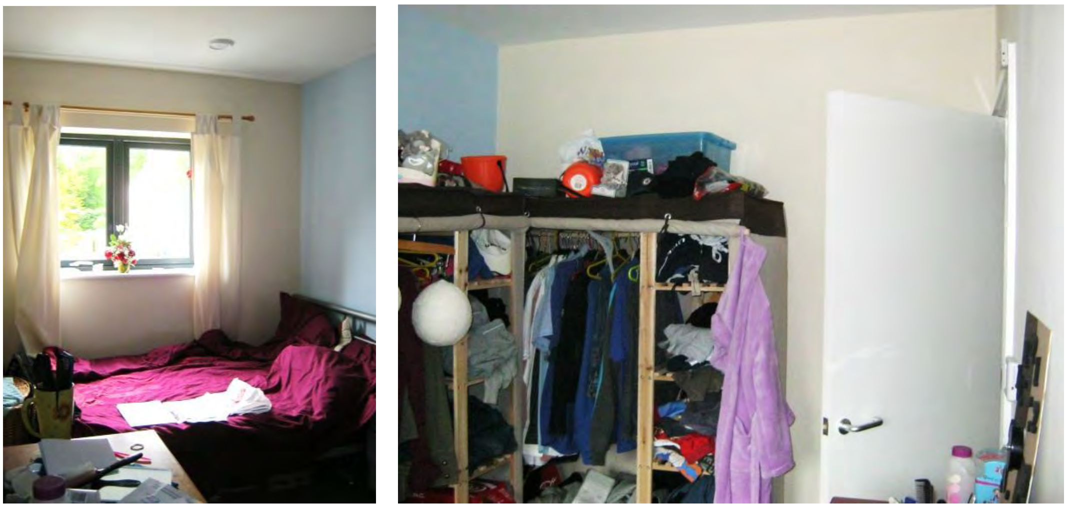


Figure 90 Parent's bedroom. The MVHR vent is located directly above the bed leading to annoying draughts.

Children's' bedroom

The occupants find this room slightly small but are satisfied with daylight levels (Figure 91). They consider the flexibility of this space to be its best aspect and are considering of using it as an office in the future.

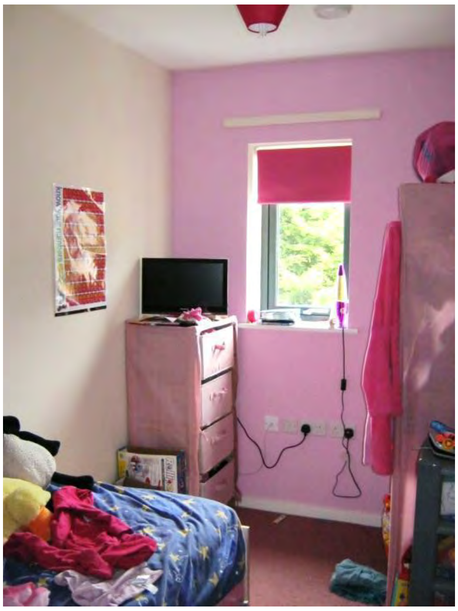


Figure 91 Single bedroom.

Front bedroom

Occupants find this room unnecessarily big and would have preferred a better space distribution among the rooms. Good daylight levels are considered to be the best aspect of this space. The worst aspect of the space is considered to be the MVHR system (Figure 92). The MVHR vent is located directly above the bed leading to annoying draughts. As a result the occupants have shut the vent closed.

Figure 92 Front bedroom. The MVHR vent is located directly above the bed.

6.3.1.2 House 2

Front space

Occupants are satisfied with the appearance of the house but do not like having an open stream in front of their entrances as they consider it to be dangerous for young children (Figure 93). They would also have preferred to have their own separate bins instead of having to use the communal bin shelter.

Figure 93 Front space.

Back garden

The occupants are not satisfied with the size and design of the back garden. Also, they do not like having the ASHP unit in within reach of children (Figure 94).

Figure 94 Back garden.

Kitchen

Occupants find the kitchen easy to clean and maintain and are satisfied with the size, storage space, daylight, ventilation and temperatures in the space (Figure 95). There are enough cupboards for storage. They find the smoke alarm to be the worst aspect of the space as it goes off very easily and they do not have a hood above the hob.

Figure 95 Kitchen

Living room

The occupants reported that the living room can get hot and that daylight is poor because of the depth of the room. They are satisfied with the size of the room but not with the layout (Figure 96).

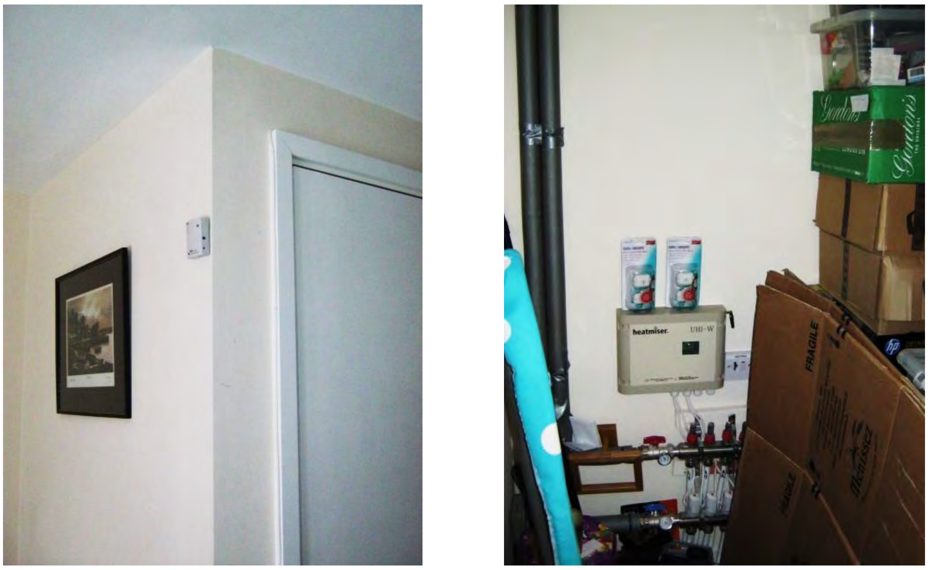


Figure 96 Living room. The living room cupboard serves as storage space (right).

Double bedroom

The temperatures in this room are high as the heating system is not working properly and the room is south-facing (Figure 97). The air quality is not good because the MVHR system is not working and occupants open the windows to ventilate and get rid of excess heat.

Figure 97 Double bedroom.

Single bedroom

Occupants find the single room quite small for its purpose but are satisfied with daylight levels. They reported that temperatures in this room can go high but they open the windows to ventilate it. The room feels stuffy if the occupants do not open the window as the MVHR system is not working. As in House 1 the MVHR vent is located directly above the position of the bed, but the occupants do not complain of draughts since the system is not working (Figure 98).

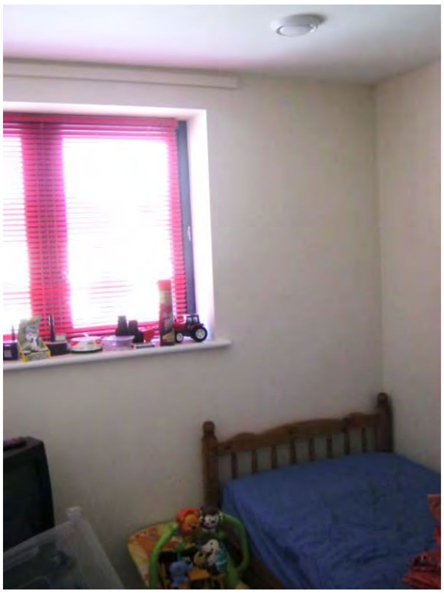


Figure 98 Single bedroom. The MVHR vent is located directly above the bed.

6.3 Conclusions and key findings

6.3.1 Key findings from BUS survey

- The overall picture of the survey revealed a positive opinion towards the dwellings, with the air quality in winter and the quality of light being the most appreciated elements.

- Participants generally feel that the facilities provided meet their needs well and that the dwellings are quite comfortable overall.

- The design of the dwellings was rated positively, with the score sitting at the higher end of the benchmark.

- Temperatures overall during winter are generally regarded as quite comfortable but less so in summer. During both periods, the building scores sit within the benchmark. Only 26% of the respondents in winter and 20% in summer are fully comfortable.

- Respondents rated the building’s appearance favourably with 20% being fully satisfied.

- The layout was rated as quite good on average with only 20% of the occupants being fully satisfied.

- The location was one of the most appreciated aspects of the development with the majority (58%) of the respondents being fully satisfied with it. The building location scored higher than the benchmark.

- Respondents rated the space of the dwellings as satisfactory with almost 30% finding it enough overall.

- The building storage score is the same as the scale midpoint. Contradictory answers were received regarding the amount of storage space with 16% of the respondents finding it more than enough and another 16% not finding it enough. In general, the occupants of the flats feel there is not enough storage space, whereas the occupants of the terraced houses are more satisfied with the amount of dedicated storage space.

- Winter temperatures are perceived as comfortable, scoring above the benchmark. This is mostly due to the high insulation standards of the building fabric and low heat loss coefficient.

- Many comments were received about heating, as occupants feel they cannot control temperatures effectively. Some occupants complain that it gets very hot in the dwellings and that the heating system continues to operate even when the thermostats are turned down.

- In winter, air is perceived as quite satisfactory by the majority of the respondents with 34% being fully satisfied. Air quality in winter scored higher than the benchmark. This indicates that the MVHR system is performing well in providing the dwellings with fresh air.

- Air quality in summer was rated favourably on average but only 17% of the respondents are fully satisfied

- Lighting levels were rated as satisfactory overall. The quality of light is one of the most appreciated elements of the building and scored at the higher end of the benchmark.

- Natural light falls below the benchmark, with 45% of the people being fully satisfied and 25% finding it ‘little’.

- Artificial lighting was regarded as satisfactory by the majority of the respondents.

- Noise from outside is not a problem for the majority of the respondents and was rated above the benchmark. Noise from neighbours is generally regarded as quite high, scoring at the upper end of the benchmark. Noise from other people is generally regarded as slightly high and scored towards the middle of the benchmark.

- Control over cooling was rated negatively on average, with 22% feeling that they do not have any control over it.

- Control over heating and ventilation both scored close to the scale midpoint. Only 17% feel they have full control over heating and 21% feel they have very little control. As regards to ventilation results vary greatly, with 26%of the respondents feeling in full control.

- Respondents generally feel that electricity costs are similar to those in their previous accommodations, with the score sitting close to the scale midpoint. 18% feels that electricity costs in the new homes are much higher than their previous ones. It should be noted that the heating system in some of the dwellings runs on electricity (ASHP) while some dwellings have gas.

- Respondents generally feel that heating costs are similar those in their previous accommodations, with the score sitting close to the scale midpoint. 18% feels that heating bills in the new homes are much higher than their previous ones.

- Respondents generally feel that water costs are similar to the ones in their previous accommodations, with the score sitting in the upper part of the benchmark.

- Most of the occupants in the cottage houses (terraced) that feature rainwater harvesting complained that the system is not working properly and that the toilets are not filling up. This is due to the water tank not being sized properly to cover the needs of the houses.

- Half of the occupants feel that living in the homes has changed their lifestyle. Comments point out that the homes are within walking distance from the town centre and local amenities.

- The main aspects that work poorly are the rain water harvesting system and the bath taps that do not provide hot water.

- The key aspects that work well are considered to be the layout, the size of the rooms and the location of the homes. Positive comments were also received for the insulation of the envelope and the heating.

6.3.2 Key findings from interviews and walkthroughs with occupants

Occupants in House 1 are generally much more engaged with the house and have a deeper understanding of the systems and the technologies in it compared with the occupants in House 2.

6.3.2.1 Energy and water consumption

- Occupants in House 1 are very unhappy with the electricity bills and the performance of the heat pump. Their bill from October 2012 to January 2013 was £552. It should be noted that after receiving this bill, the occupants in this house had to turn off the heating during the day in winter in order to save money.

- In House 2 occupants report that they are satisfied with their electricity bills. They mention that they pay £60/month on electricity but did not produce any bills. However, it seems strange that this house appears to be paying less than House 1 given the fact that the heating in House 2 is always on and that energy use is higher (Section 8.1)

- Occupants in both houses are satisfied with the water bills.

6.3.2.2 Occupant satisfaction

- Occupants in both houses are pleased with the design, layout and overall appearance of the houses and state that they are suitable for their needs. Occupants in both houses agree that most room spaces are satisfactory.

- Occupants in House 1 find it easy to clean and maintain the house, whereas occupants in House 2 have trouble cleaning the house as they have not yet had carpets installed.

- Occupants in both houses are very satisfied with the location of the houses and believe it to be one of the best aspects of their house.

6.3.2.3 Home User Guide & Induction process

- Occupants in House 1 were satisfied with the induction process where they were shown how to operate the thermostats and the MVHR boost. They pointed out that they were expecting a follow up visit that has not occurred. On the other hand, the interviewees in House 2 were not present during the induction process and appear unfamiliar with the systems installed in the house.

- Occupants in both houses find some parts of the Home User Guide to be rather confusing. The occupant in House 2 felt it was not easy to read and the occupants in House 1 believe that the chapter relating to heating is not very clear.

6.3.2.4 Occupant understanding of systems

- It should be noted that occupants in House 2 are not at all familiar with the systems installed in the house.

- Occupants in House 1 report that they are not sure how to benefit most from the PV panels as they do not know how they work or if they have received any payback from them.

- Additionally, occupants in House 1 are confused about the use of the immersion heater due to conflicting advice from different technicians.

6.3.2.5 Heating system: operation, comfort and control

- Occupants in both houses report that the heating system does not work properly and that they have trouble controlling it. They both have noticed that when they set the thermostats at a certain temperature, or even when they turn them down completely, temperatures in the rooms continue to rise and heating remains on. This problem has been reported to Sanctuary Housing. Blount have inspected the properties and have verified that the thermostats are not communicating properly with the heating system. The same problem was reported during the BUS survey by occupants of other houses in the development. Sanctuary Housing has been notified and the problem is being addressed.

- Occupants in House 2 are not satisfied with the room temperatures and complained that it is always very hot in their house as a result of not being able to control the heating through the thermostats.

6.3.2.6 Renewable energy systems

- Occupants in both houses report that they do not know how the PV panels perform and do not understand how they work. They both mention the fact that PV performance is not included in their electricity bills and as such they do not know if they are receiving any payback.

6.3.2.7 Lighting

- Occupants in both houses are generally satisfied with the daylight and the electrical light in the house.

- Occupants in House 2 mentioned that the daylight in the living room is poor.

- Occupants in both houses find the lighting controls easy to use.

6.3.2.8 Hot water

- Occupants in House 2 report that there is always hot water when needed and that it is sufficient for their daily needs.

- Occupants in House 1 state that how and when to use the immersion heater has not been adequately and fully explained to them. It is noted that having two different water heating systems appears confusing to the occupants. The actions they describe in relation to the immersion heater indicate that they do not understand the purpose of the immersion heater, which they had switched off and were only using when required (for example, when a bath was required). After a site visit from Sanctuary Housing and Blount the immersion heater was turned back on and was reprogrammed to come on once a week to prevent legionella.

- Occupants in both houses report that the bath tap does not provide warm water. After inspection it was discovered by Blount that the mixing valve is not working properly. The issue has been reported to Sanctuary and the problem will be resolved.

6.3.2.9 Acoustics

- In House 2 occupants report that there is often noise transfer between floors.

- Both sets of occupants report some noise coming from the neighbouring houses.

- Occupants in both houses agree that when the windows are closed they cannot hear any noise from the outside.

6.3.2.10 Ventilation system

- In both houses occupants mainly ventilate the house by opening windows and doors.

- Occupants in House 2 are completely unfamiliar with the MVHR system. They were unaware of the fact that the MVHR has been broken for several months and report that they do not know how to use it, how it works and where the unit is located. The house can get very stuffy at times as a result of the MVHR not working, and the high temperatures in the house. Brookes researches had identified that the MVHR system was not working and Sanctuary Housing was notified. Blount was called to inspect the unit which needs to be replaced immediately.

- Occupants in House 1 are familiar with the MVHR and its controls and feel that the system works well and is very responsive but are not fully satisfied with it. They have reported problems of draughts and noise, particularly during the night. The position of the supply grills directly above the beds in the bedrooms results in discomfort for the occupants. As a result the occupants have closed the grills thus causing an unbalance within the system, which will have to be re-commissioned immediately.

- Occupants in House 1, even though they feel they know how to use the MVHR and believe they have received sufficient training, demonstrate a lack of understanding and proper guidance. They are actively trying to disable the system and mention that they would prefer to be able to shut it off completely in order to save electricity. Occupants are able to see the electricity consumption of the MVHR unit on the Ewgeco meter and want to minimize it.

6.3.2.11 Maintenance, reliability and breakdowns

- Occupants in House 1 report that they have experienced several problems and breakdown of the heating system. As mentioned above, both houses state that the heating is still not working properly and the occupants are unable to control temperatures through the thermostats. According to the BUS survey conducted in all properties in the development, this issue seems to be common in many of them. The problem has been reported to Sanctuary Housing and needs to be addressed immediately.

- It should be noted that occupants in House 2 were not aware of the fact that the MVHR system was broken for several months. This indicates that they have not received sufficient training and also that the MVHR unit is not accessible to the occupants and that it does not give any malfunction or maintenance warnings. This is a serious problem that Sanctuary Housing needs to address in all properties as it may result in the units not being used efficiently and potentially leading to maintenance issues in the future.

6.3.2.12 Flexibility and space standards

- Occupants in both houses are satisfied with the spaces in the house and believe their needs are well accommodated.

- Occupants in both houses are generally satisfied with the room sizes, apart from the single bedrooms which they find quite small.

- Occupants in both houses complain that there is not enough storage space.

6.3.2.13 Outdoors

- Occupants in both houses are concerned about the open stream in front of the houses and feel it is dangerous for young children. They suggest that some railing, to prevent children from falling in, is necessary.

- Occupants in both houses feel that their garden is quite small and that the shed takes up a lot of the space.

6.4 Recommendations

- Maintain good standard of design and layout.
- Maintain the flexibility and generous space standards.
- Revise window sizes and positions to provide more daylight in future developments. Window design should take into account the effect on heating energy and overheating by following environmental design principles on window-to-floor ratio (<20%).
- Collate all lessons learnt on the project from issues raised (heat pump breakdowns, leaks, renewables installation) and use them as feedback to future projects. Communicate lessons to the council, maintenance and design team.
- Review the location of the MVHR for future projects to allow for more accessibility.
- Review the design of heating and MVHR controls to allow for a more straight-forward, simple and user-friendly approach.
- Review induction process to provide more detailed and hands-on experience.
- Improve customer care and help service.
- Provide training to the maintenance personnel on renewables and low carbon technologies to reduce contradictory advice given to occupants and increase understanding of the systems, maintenance requirements, suitable use and benefits.
- Review air tightness specifications and inspection of construction quality and detailing for future project, to ensure that design airtightness is achieved in reality.
- Take measures to improve the performance of the ASHP by training the occupants, re-balancing the system, improving air tightness in dwellings and addressing breakdowns quickly.
- Review the Home User Guide to provide more accurate and useful information to occupants on how and when to change the settings of the heating system seasonally, in a simple and user-friendly manner.
- Consider re-training of existing occupants on the systems within the homes to include hands-on experience of heating settings, boost button, and filter change, in order to help enhance familiarity of the symbols and processes.
- Consider adding railings to the open stream in front of the dwellings to reduce health and safety issues in the area.
- Review the garden sizes and design for future projects.
- Review noise specification standards for partition walls between dwellings, as well as within the dwellings themselves (floors and walls).
- Reconsider the amount of dedicated storage space in the larger properties and design dedicated storage spaces in flats particularly, and also houses. Reconsider the storage space in the smaller properties. Dedicated storage space needs to be ‘designed’ properly in line with occupants’ expectations.

7 Installation and commissioning checks of services and systems, services performance checks and evaluation

A review of installation and commissioning of services and systems was carried out on 13th March 2013 for Houses 1 and 2. The review looked at ventilation systems, heating and hot water systems, and lighting.

Several issues were discovered during the commissioning review and were reported to the building owners. Most of the problems were common in both houses, suggesting that the same could be encountered in more houses across the development, if not all.

7.1 House 1

7.1.1 Ventilation systems

- The MVHR unit is located in the loft space that is accessible through the loft hatch. The unit is not easily accessible by the occupants. This suggests that there is not sufficient access for routine maintenance repair and replacement of components.
- The commissioning review revealed that the system has not been installed in accordance with the manufacturer's requirements. The ductwork is not properly insulated and the de-condensation pipe was not properly connected to the unit and did not drain properly resulting in water being concentrated in the unit (Figure 99).
- The review showed that the correct number of grills had been installed, however, none of the extract and supply grills were locked in a fixed position, thus allowing the occupants to open or close them at will, resulting in unbalancing the system.
- The location of the supply grills in the bedrooms, directly above the beds, was not found to be appropriate. The occupants reported that the draughts coming from the grills led them to shut the grills closed.
- All internal doors have sufficient undercut to allow air transfer between rooms.
- All protection/packaging had been removed and the system was fully functional.
- During the commissioning test, air flow measurements were taken from both the extract and supply grills:
    - The extract air flow rates in the kitchen, bathroom and WC were measured to be slightly higher than the design specifications (Table 11) ranging from 8.7-15.8 l/s (high rate) and 6.2-12.1 (low rate).

Table 11 Air flow measurements (extract) taken during commissioning review (13th March 2013)

Location of terminals	Measured air flow high rate (l/s)	Design air flow high rate (l/s)	Measured air flow high rate (l/s)	Design air flow high rate (l/s)
Bathroom	8.7	8	6.2	N/A
Kitchen	15.8	13	12.1	N/A
WC	9.5	6	7.4	N/A

- The supply air flow rates in the living room and bedrooms were measured to be either zero or much lower than the design specifications (Table 12). The low flow rates in the bedrooms are a result of the occupants shutting the grills in order to avoid the cold draughts blowing onto their beds. In the living room the air flow rate measured was half than the one specified in the design. This might result from occupant intervention or poor initial commissioning (Figure 100).

Table 12 Air flow measurements (supply) taken during commissioning review (13th March 2013)

Location of terminals	Measured air flow high rate (l/s)	Design air flow high rate (l/s)	Measured air flow high rate (l/s)	Design air flow high rate (l/s)
Living room	6.5	13	4.2	N/A
Bedroom 1	0 (valve closed)	13	0 (valve closed)	N/A
Bedroom 2	2.1 (valve closed)	6	1.3 (valve closed)	N/A
Bedroom 3	0 (valve closed)	5	0 (valve closed)	N/A

A separate MVHR test was performed at a later stage. During the follow up test the grills in the bedrooms had been re-opened which resulted in different extract and supply air flow rates from the test carried out during the commissioning review (Tables 13, 14). Measurements show that the system is unbalanced as the total supply rate is higher than the extract rate and also because the flow rate in Bedrooms 2 and 3 is much higher than the design specification, whereas in the living room the air flow is not sufficient.

Table 13 Air flow measurements (extract) (17th July 2013)

Room	Filters: Clean		Filters: 50% Blockage	
	Low rate (l/s)	High rate (l/s)	Low rate (l/s)	High rate (l/s)
Kitchen	4.4	7.1	5	7.2
Bathroom	4.3	6.1	4.4	6
WC	4.7	6.5	4.5	6.6
TOTAL	**13.4**	**19.7**	**13.9**	**19.8**

Table 14 Air flow measurements (supply) (17th July 2013)

Room	Filters: Clean		Filters: 50% Blockage	
	Low rate (l/s)	High rate (l/s)	Low rate (l/s)	High rate (l/s)
Living room	2.1	2.5	2.2	2.6
Bedroom 1	2.4	3.1	2.5	3.9
Bedroom 2	7.5	11	7.4	9.5
Bedroom 3	6.6	6.4	5.7	6
TOTAL	**18.6**	**23**	**17.8**	**22**

Figure 99 MVHR unit in loft space

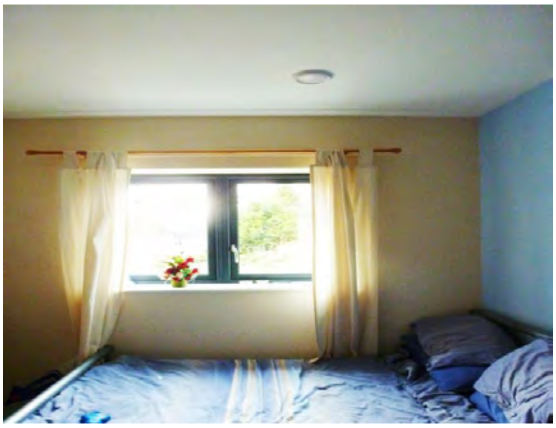


Figure 100 MVHR grill directly above bed

7.1.2 Heating and hot water systems

- The heating and hot water system has been installed in accordance with the manufacturer's requirements.
- The benchmark commissioning sheet was not left with the end user along with the user guide.
- Inspection revealed that the heating and hot water circuits have fully pumped circulation but the primary hot water circuits and all pipework emanating from the cylinder are not properly insulated.
- Occupants were complaining that the heating is on even when the thermostats are set at low temperatures and are not calling for heat. The commissioning review revealed that the wireless thermostats are not properly connected to the heating system making it difficult for occupants to control the heating and temperatures in the house. This was reported to the developers (Sanctuary) and the installer of the heating system (Blount) who inspected the heating systems in all houses across the development and found that this fault was common among most houses. The installer had to re-commission the thermostats and make them communicate with the heating system.

7.1.3 Lighting

- All the lighting used in the house is low energy.
- Low energy lighting includes CFL and linear fluorescent.

7.2 House 2

7.2.1 Ventilation systems

- The MVHR unit is located in the very narrow loft space that is accessible through the loft hatch. The unit is not easily accessible. There is not sufficient access for routine maintenance repair and replacement of components and not enough space for the ductwork (Figure 102).
- The commissioning review revealed that the system has not been installed in accordance with the manufacturer's requirements. The ductwork is not properly insulated and the de-condensation pipe was not draining resulting in water being concentrated on the loft and running through the floor to the ceiling below (Figure 101).
- The review showed that the correct number of grills had been installed, however none of the extract and supply grills were locked in a fixed position.
- All internal doors have sufficient undercut to allow air transfer between rooms.
- All protection/packaging had been removed and the system was fully functional.
- During the commissioning review it was discovered that the MVHR unit was not working. The occupants had not realised that the system was not functioning and had not reported the breakdown to the building owners who were notified by the research team. The installer was called to inspect the unit and reported that the breakdown was due to a manufacturing flaw. Further investigation carried out by the installer in all houses across the development revealed

that this issue was common in many houses and the manufacturer was called to repair the units. The MVHR breakdown in House 2 has still not been resolved and air flow measurements could not be taken.

Figure 101 Condensation pipe not draining

Figure 102 MVHR located in narrow loft space

7.2.2 Heating and hot water

- The heating and hot water system has not been installed in accordance with the manufacturer's requirements. The masterstat is not commissioned according to the specifications.
- The benchmark commissioning sheet was not left with the end user along with the user guide.
- Inspection revealed that the heating and hot water circuits have fully pumped circulation but the primary hot water circuits and all pipework emanating from the cylinder are not properly insulated.
- Occupants were complaining that the heating is on at all times even when the thermostats are set at low temperatures and are not calling for heat. As in House 1, the commissioning review revealed that the wireless thermostats are not properly connected to the heating system making it difficult for occupants to control the heating and temperatures in the house. The installer had to re-commission the thermostats and make them communicate with the heating system.

7.2.3 Lighting

- All the lighting used in the house is low energy.
- Low energy lighting includes CFL and linear fluorescent.

7.3 Conclusions and key findings

- The MVHR units are located in narrow loft spaces that are not easily accessible. There is not sufficient access for routine maintenance repair and replacement of components and not enough space for the ductwork.
- The MVHR ductwork is not insulated and the de-condensation pipe in both properties was not draining properly.
- The extract and supply grills in the houses were not locked in a fixed position, allowing the occupants to open or close them at will and unbalancing the system.
- The location of the supply grills in the bedrooms, directly above the beds, is problematic as it creates unpleasant draughts.
- The low flow rates in the bedrooms of House 1 are a result of the occupants shutting the grills in order to avoid the cold draughts blowing onto their beds. In the living room the air flow rate measured was half than the one specified in the design. This might result from occupant intervention or poor initial commissioning.
- Follow up air flow measurements in House 1 showed that the system is unbalanced as the total supply rate is higher than the extract rate.
- In House 2 it was discovered that the MVHR unit was not working. The occupants had not realised that the system was not functioning and had not reported the breakdown to the building owners who were notified by the research team. The installer reported that the breakdown was due to a manufacturing flaw. Further investigation carried out by the installer in all houses across the development revealed that this issue was common in many houses and the manufacturer was called to repair the units.
- Primary hot water circuits and pipework are not properly insulated.
- Occupants in both houses were complaining that the heating is on even when the thermostats are set at low temperatures and are not calling for heat. The commissioning review revealed that the wireless thermostats are not properly connected to the heating system. The installer (Blount) inspected the systems in all houses across the development and found that this fault was common among most houses. The installer had to re-commission the thermostats and make them communicate with the heating system.
- All the lighting used in the houses is low energy.
- It is important to note that the manufacturing problems of the MVHR units and the poor commissioning of the room thermostats installed in Bryan House scheme were revealed and repaired thanks to the BPE study.
- It should be noted that repair of the heating and thermostat connection was slow and that the MVHR unit breakdown in House 2 has not yet been addressed.

7.4 Recommendations

- Provide adequate space for mechanical equipment and extra dedicated storage space from the initial design stage.
- Place the MVHR unit in a more easily accessible space and allow enough space for maintenance and filter change.
- Careful commissioning of all systems and controls after construction. Take extra care in connecting wireless thermostats with the heating system.
- Installation and commissioning procedures need to be robust, including appropriate certification by knowledgeable engineers. Documentation of the commissioning reports is vital for seasons commissioning.
- Before specifying suppliers, the design and construction team should ensure that there is a sufficient post-installation support and maintenance guarantee possibly through service contracts.
- Improve customer care by providing a more rapid response and repair service to the tenants. This may avoid frustration amongst tenants and increase the forgiveness factor.

8 Other technical issues

8.1 Energy monitoring

The houses are equipped with Ewgeco meters so that the occupants can monitor their electricity consumption and PV generation. Electricity use in the house from PV generated electricity was not being monitored in this Phase 1 study.

During the monitoring period (December 2012-September 2013) House 2 total grid electricity consumption is higher than House 1's by 1600kWh (Figure 103).

It should be noted that due to a commissioning error the room thermostats were not properly connected to the heating system. As a result of this, the heating system was constantly on even when the temperatures in the rooms were high and the thermostats were not calling for heat. This was discovered by the BPE team, several months after the move in following occupants complains of not being able to control heating and of spaces being too hot. In order to overcome this issue, control heating and reduce energy consumption, occupants in House 1 had decided to turn off the ASHP from the main switch on a daily basis, only turning it on during the night to heat the spaces. In order to heat water for baths and showers they turned on the immersion heater which they also kept switched off, from the main switch, during the rest of the day, thus de-programming the legionella control. Detailed inspection revealed that in House 2 the ground and second floor heating system was working well but on the first floor the heating coils were not connected to the room thermostats and the heating was constantly on. Despite this, occupants in House 2 did not take any action to control the heating. It should be noted that these issues had not been reported to the housing authority as occupants in both houses had not realised the source of the problem due to lack of understanding of the ASHP and underfloor heating system. Especially, in House 2, where the occupants knew there was '*something wrong',* they thought this was a characteristic of the underfloor heating as they had no previous experience with such a system. As a result of these commissioning errors occupants became sceptical towards the technologies used in the house and consider them responsible for their high electricity bills. The commissioning fault has in deed increased electricity use in the houses undermining fine-control and leading to inefficient practices.

Monitoring data on electricity use shows that the actions taken by occupants in House 1 did not lead to the energy reduction results the occupants were hoping for. As a result of the reduced efficiency of the ASHP and the use of immersion heater for domestic hot water, occupants in House 1 consumed 7.5kWh/m2/year more electricity than their neighbours in House 2, despite the fact that House 2 is occupied continuously. In addition, average internal temperatures in the houses differ significantly, with temperatures in House 1 falling below the comfort band throughout winter.

- House 1: Grid electricity consumption is nearly 6300kWh. PV generation is 520kWh.
- House 2: Grid electricity consumption is almost 7900kWh. PV generation is 800kWh.

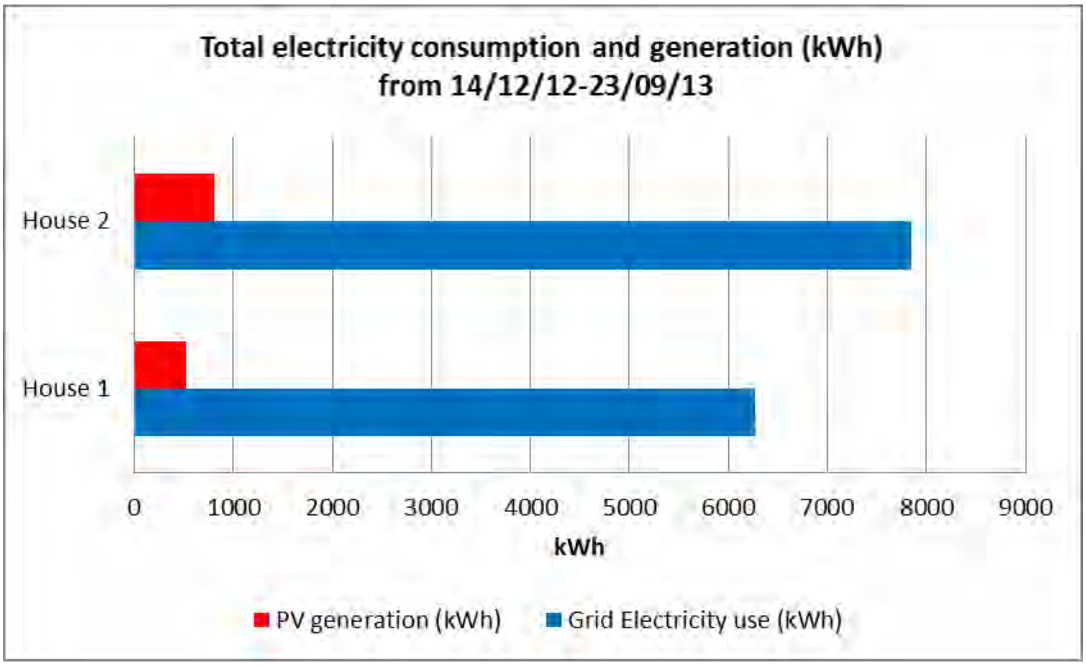


Figure 103 Total grid electricity consumption and PV generation (kWh) (December 2012-September 2013).

Figure 104 shows the total grid electricity consumption in kWh/m^2.

- House 1: Grid electricity consumption is 71kWh/m^2. PV generation is 6kWh/m^2.
- House 2: Grid electricity consumption is almost 63kWh/m^2. PV generation is 6.5kWh/m^2.

This indicates that the PV generation per m^2 is similar in the two houses and that the PV array electricity generation has been distributed equally among the houses taking their area into account.

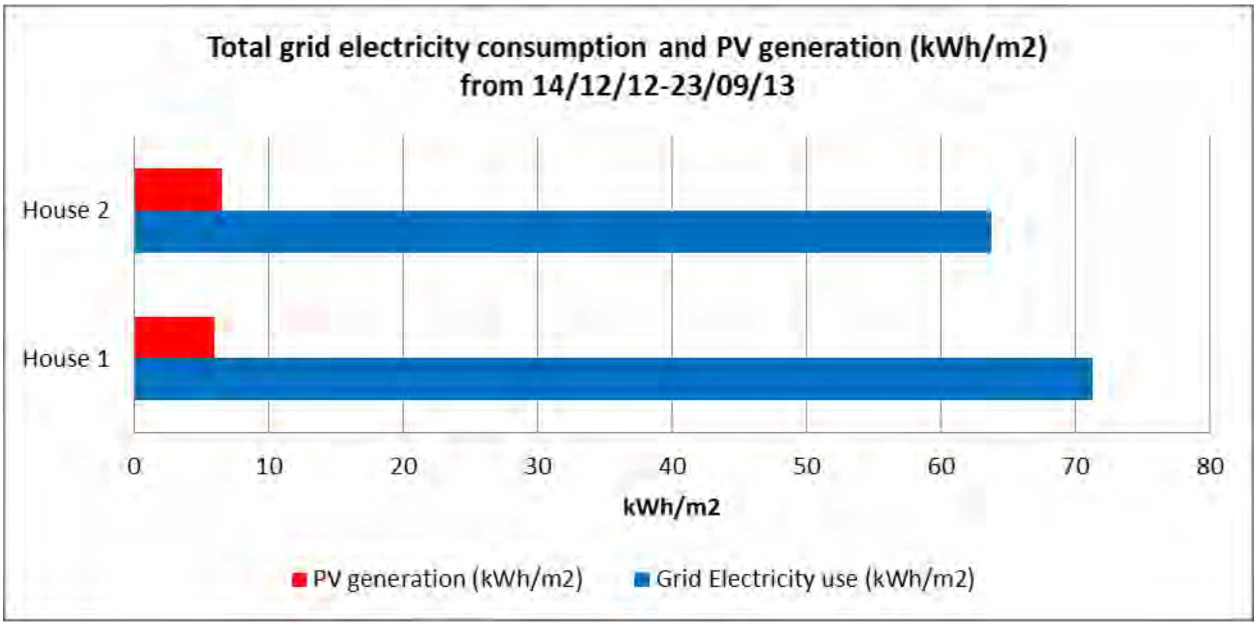


Figure 104 Total grid electricity consumption and PV generation (kWh/m^2) (December 2012-September 2013).

Carbon emissions from grid electricity import from December 2012 – September 2013 are 39kgCO_2/m^2 for house 1 and 35kgCO_2/m^2 in House 2 (Figure 105, Table 15) (Carbon factor= 0.55).

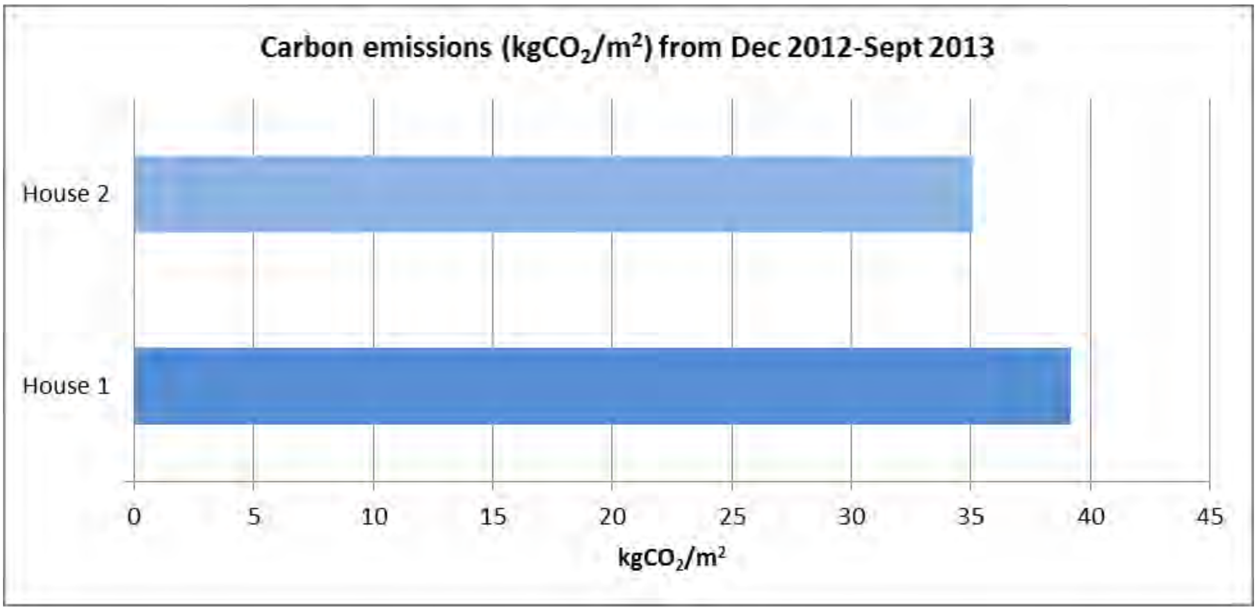


Figure 105 Carbon emissions (kgCO_2/m^2) from December 2012 to September 2013. (Carbon factor= 0.55).

Table 15 Grid electricity import and carbon emissions from December 2012 to September 2013.

	Electricity import (kWh/m^2)	**Carbon emissions from grid electricity import (kgCO_2/m^2)**
House 1	71	39

House 2	63	35

House 2 monthly grid electricity consumption is higher than House 1's by 0-400kWh (Figure 106).

- House 1: monthly consumption ranges from 340-1150kWh.
- House 2: monthly consumption ranges from 350-1400kWh.

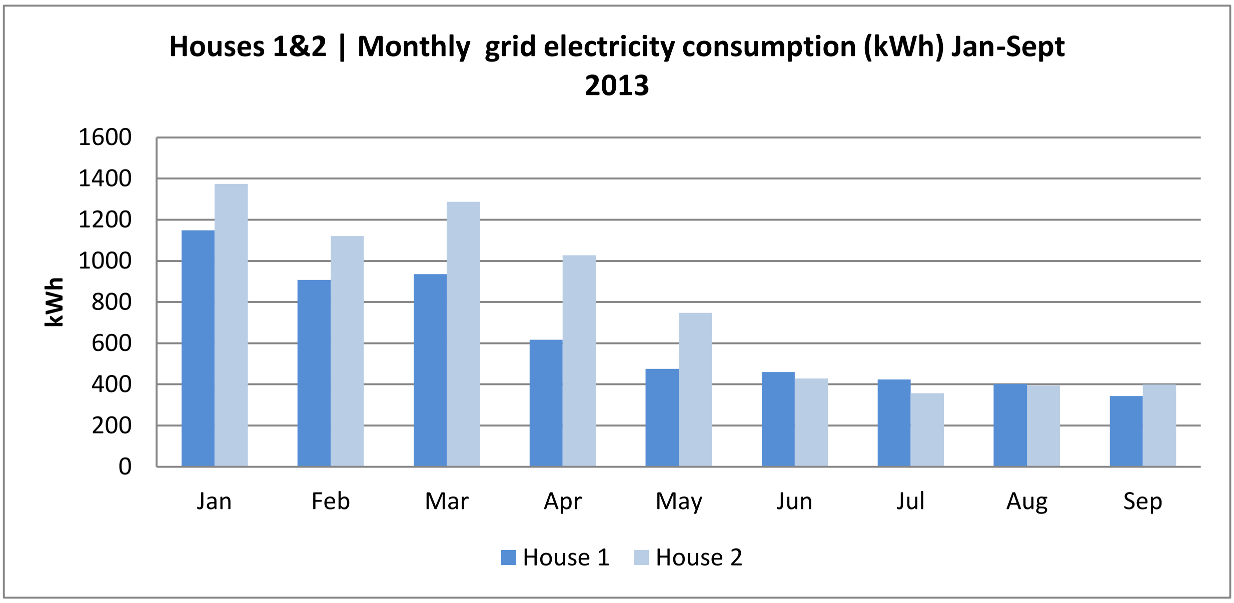


Figure 106 Monthly grid electricity consumption from January to September 2013.

8.1.1 House 1

Figure 107 shows the monthly grid electricity consumption and PV generation of House 1 from January to September 2013. The amount of PV generated electricity that is either used in the house or exported to the national grid is not measured.

- Monthly grid electricity use ranges from 340-1150 kWh.
- Monthly PV generation ranges from 6-107 kWh.
- MVHR electricity consumption ranges between 10-14kWh

Monthly electricity use pattern shows that grid electricity use closely follows the changes in external temperature, with grid electricity use rising and PV generation dropping in the winter months. Grid electricity consumption appears to be lower in February than March, although monthly mean external temperatures are the same, due to the smaller number of days in February. This was checked by comparing the grid electricity consumption in the first 28 days of March (885kWh) and February (906kWh).

Grid electricity use ranges between 340-450kWh/month from June to September (PV electricity use not included), indicating that this amount of electricity is used for lighting, appliances and domestic hot water and that the residual amount in winter months (~500-800kWh/month) is used for heating.

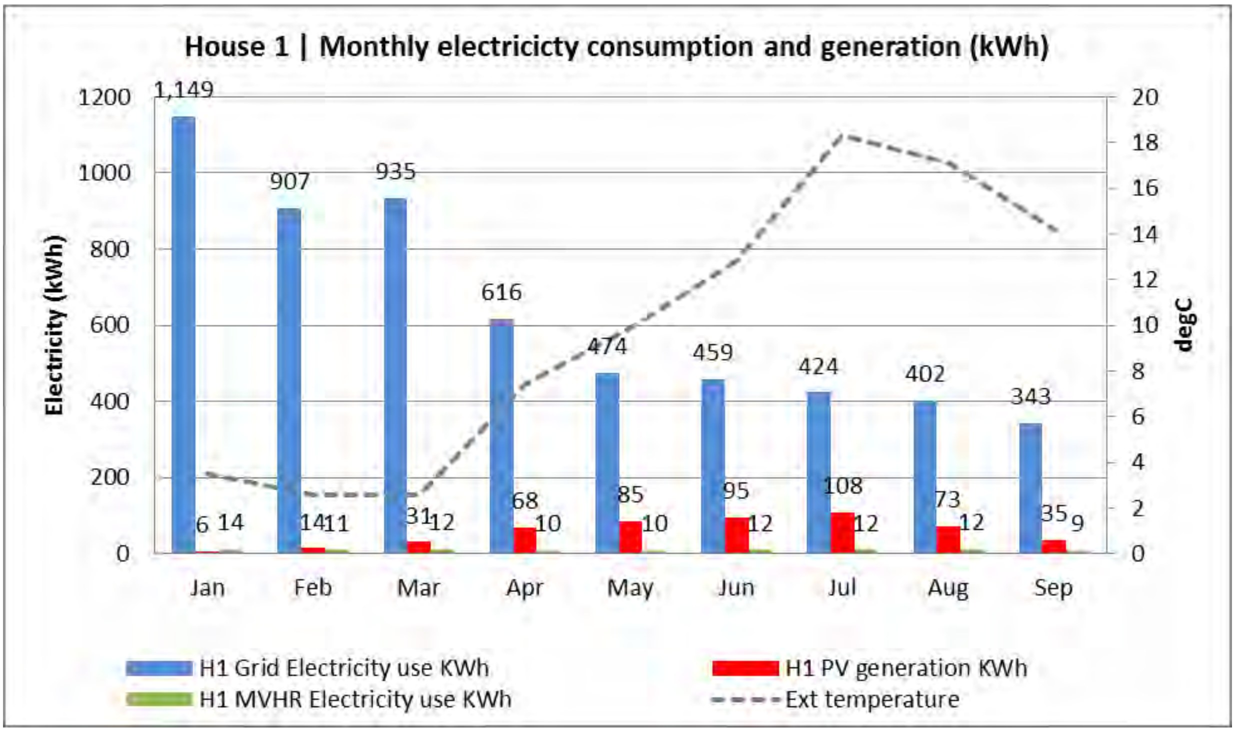


Figure 107 House 1 monthly electricity consumption and PV generation (January-September 2013).

Figure 108 shows the grid electricity consumption across the week.

- Average hourly grid electricity consumption rises between 05:00-07:00 and then again at 12:00 and peaks in the afternoon, between 15:00-18:00.
- It should be noted that the occupants turned on the heating only during the night. During sunshine hours grid electricity consumption is also lower as the house is using PV generated electricity.

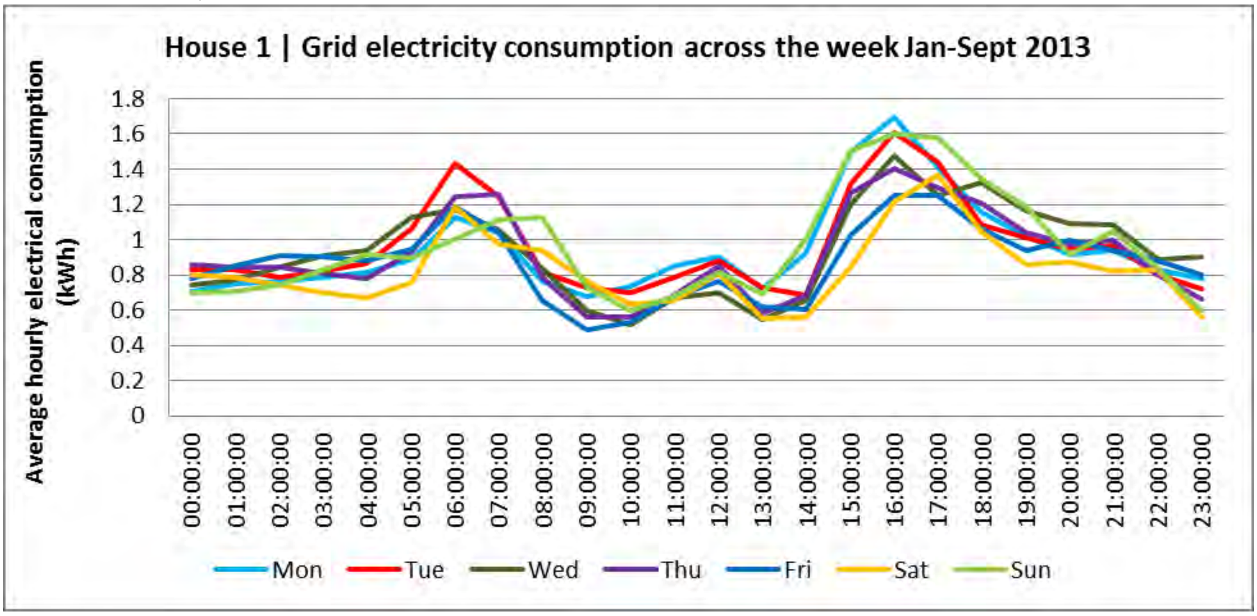


Figure 108 House 1 grid electricity consumption across the week (January-September 2013).

Figure 109 shows the average hourly grid electricity consumption of House 1 across seasons. The higher electricity consumption is recorded during winter (December-February) and peak during the afternoon when the family gathers in the house and more appliances are likely to be used.

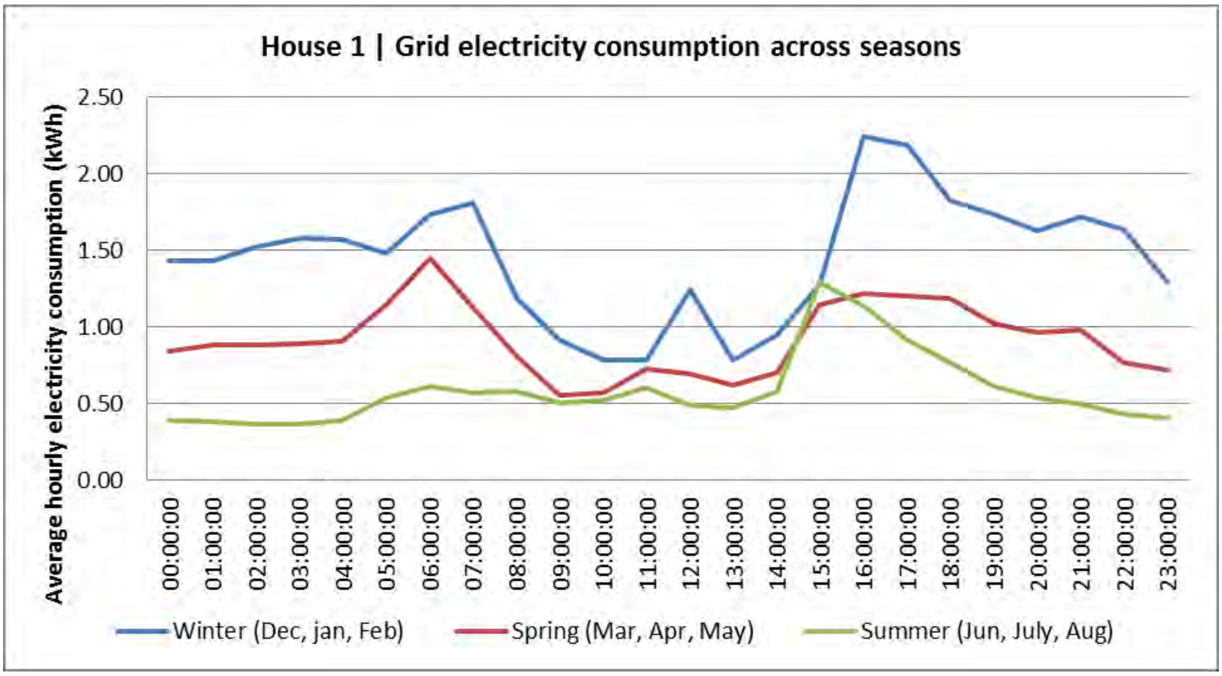


Figure 109 House 1 grid electricity consumption across seasons (December 2012-August 2013)

8.1.2 House 2

Figure 110 shows the monthly grid electricity consumption and PV generation of House 2 from January to September 2013. Electricity use of PV generated electricity is not captured.

- Monthly grid electricity consumption ranges between 350-1370 kWh.
- Monthly PV generation ranges from 11-146 kWh.
- MVHR electricity consumption ranges between 14-23 kWh. It should be noted that the MVHR unit has been out of order from the past 4 months, however, the system seems to be consuming electricity.

As in House 1, monthly electricity use pattern shows that grid electricity use closely follows the changes in external temperature, with grid electricity use rising and PV generation dropping in the winter months. Grid electricity consumption appears to be lower in February than March, although monthly mean external temperatures are the same, due to the smaller number of days in February. This was checked by comparing the grid electricity consumption in the first 28 days of March (1128kWh) and February (1121kWh).

Grid electricity use ranges between 350-430kWh/month from June to September (PV electricity use not included), indicating that this amount of electricity is used for lighting, appliances and domestic hot water and that the residual amount in winter months (~600-1000kWh/month) is used for heating.

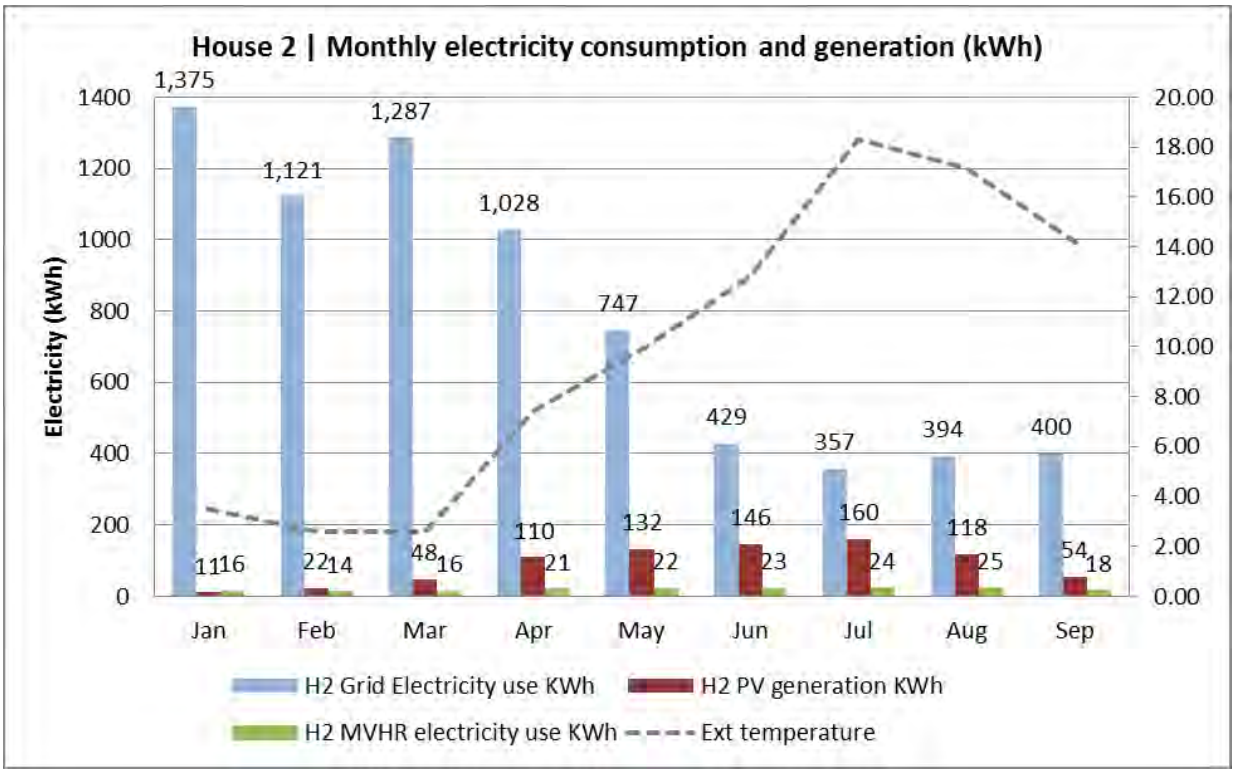


Figure 110 House 2 monthly grid electricity consumption and PV generation (January-September 2013).

Figure 111 shows the average hourly grid electricity consumption across the week.

- Average hourly electricity remains constant throughout the week and during the day. A peak on Sunday at 01:00 is linked to the Immersion heater and the safety settings to prevent legionella. This does not appear in House 1 as the occupants had de-programmed the legionella timer in order to reduce their electricity consumption.
- During sunshine hours electricity consumption is slightly lower as the house is using PV generated electricity.

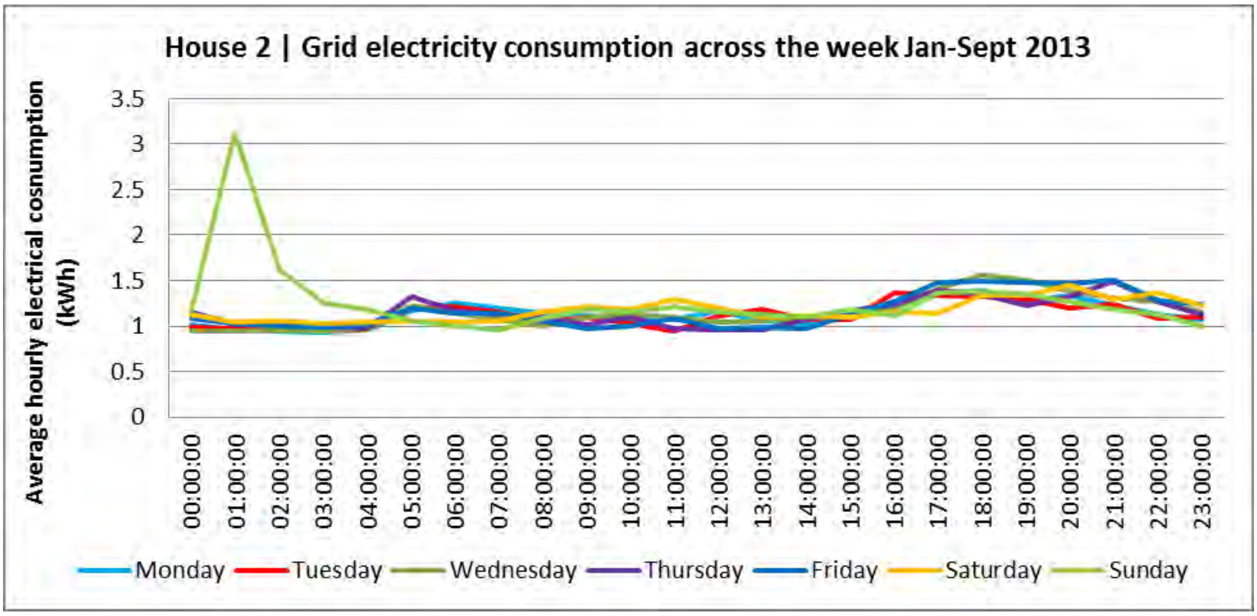


Figure 111 House 2 Average hourly grid electricity consumption across the week (January-September 2013).

Figure 112 shows the average hourly grid electricity consumption across seasons. The higher electricity consumption is recorded during winter (December-February) and is kept quite steady throughout the day ranging between 1.5-2 kWh per hour. During summer (June- August), grid electricity consumption ranges between 0.4-0.8 during the day, indicating that the residual amount in winter months (1-1.6 kWh) is used for heating. Winter and spring daily profiles are quite similar as heating was on during most spring months.

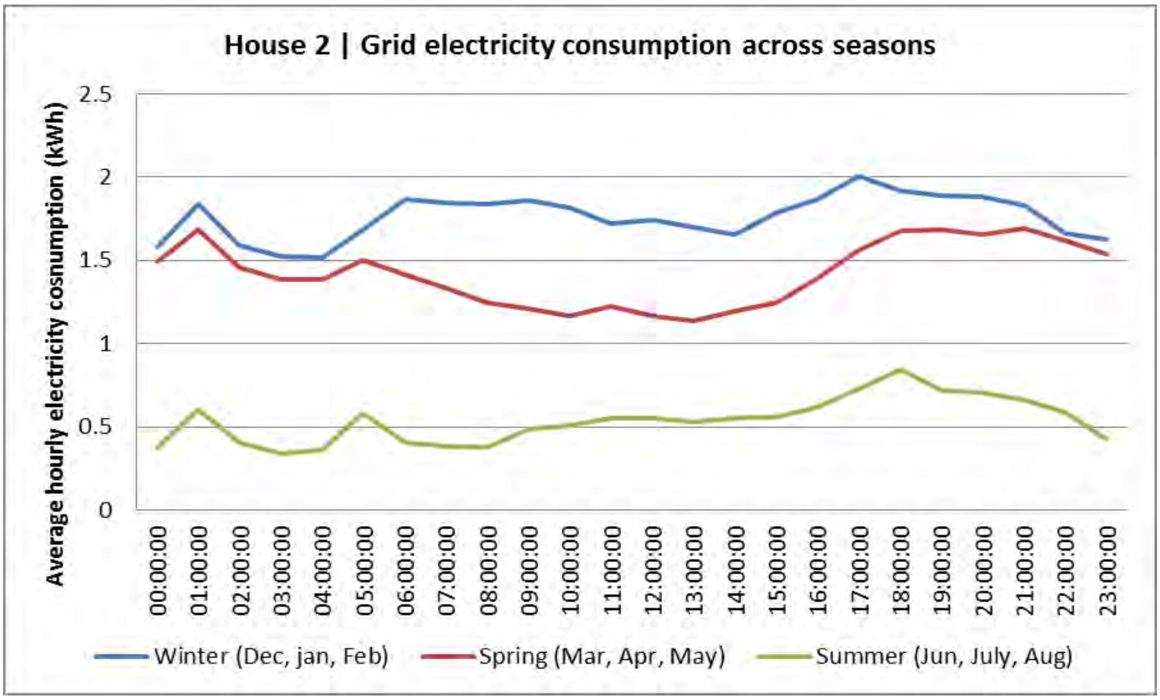


Figure 112 House 2 average hourly grid electricity consumption across seasons (December 2012-August 2013).

8.2 Environmental monitoring

8.2.1 Indoor Temperatures

Figure 113 shows the average daily indoor temperatures in Houses 1 and 2 from December 2012 to September 2013.

- House 1: temperatures range between 18°C-25°C. Bedroom 1-2°C cooler than living room during winter and 1-2°C warmer in summer.

- House 2: living room temperatures range between 19°C-26°C. Bedroom 1-2°C hotter than living room during winter and 2-3°C hotter during summer.

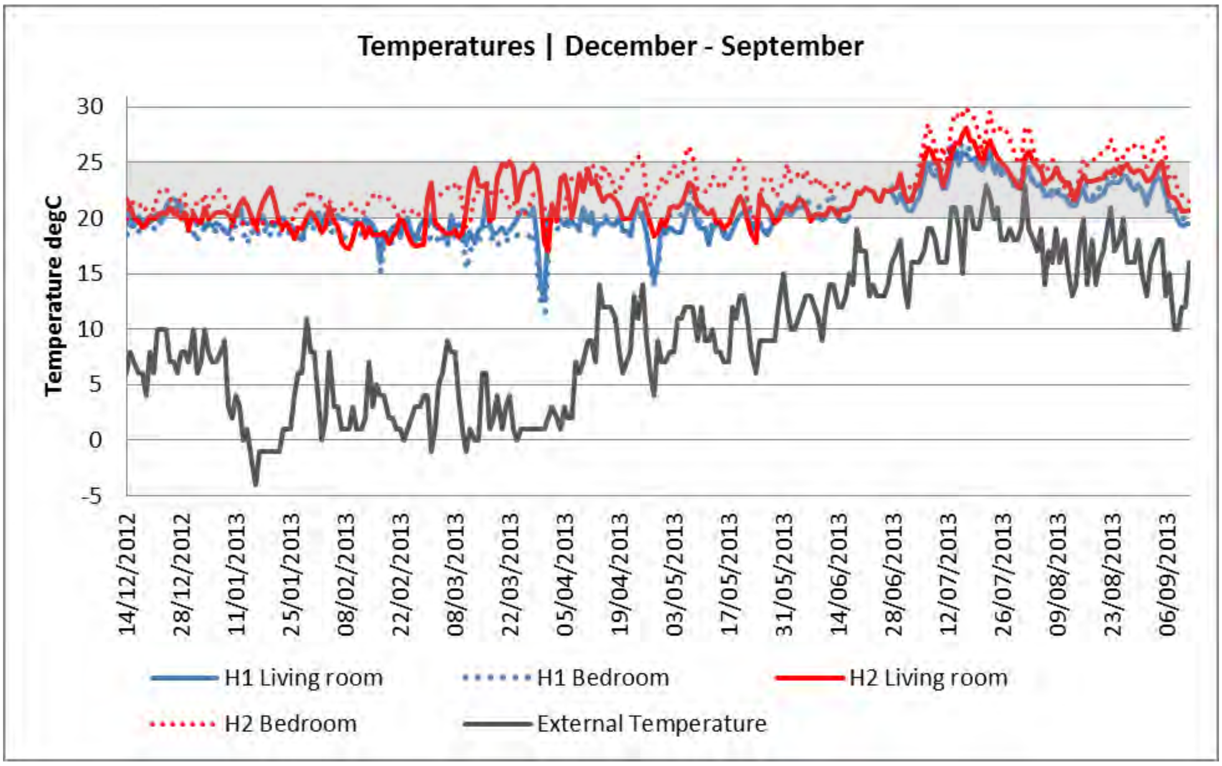


Figure 113 Average daily internal temperature in Houses 1 and 2 from December 2012 to September 2013.

Figure 114 shows the average hourly temperatures in House 1 and 2 living rooms and bedrooms throughout the day.

- House 1: Living room temperatures range between 19°C-21.5°C. Bedroom temperatures range between 19°C-21°C, decreasing during the day. It should be noted that occupants kept the heating off during the day to save electricity. As a result temperatures in the living room and bedroom fall below the comfort band during winter.

- House 2: Living room temperatures range between 20.5°C-22.5°C. Bedroom temperatures range between 23-24.5°C. Occupants complain that the bedroom is always very hot and that they could not turn off the heating. As discussed in Section 7 investigation revealed that the thermostats were not connected to the heating system which was constantly on in the bedroom. Occupants in House 2 are not satisfied with the room temperatures and complained that it is always very hot in their house as a result of not being able to control the heating through the thermostats.

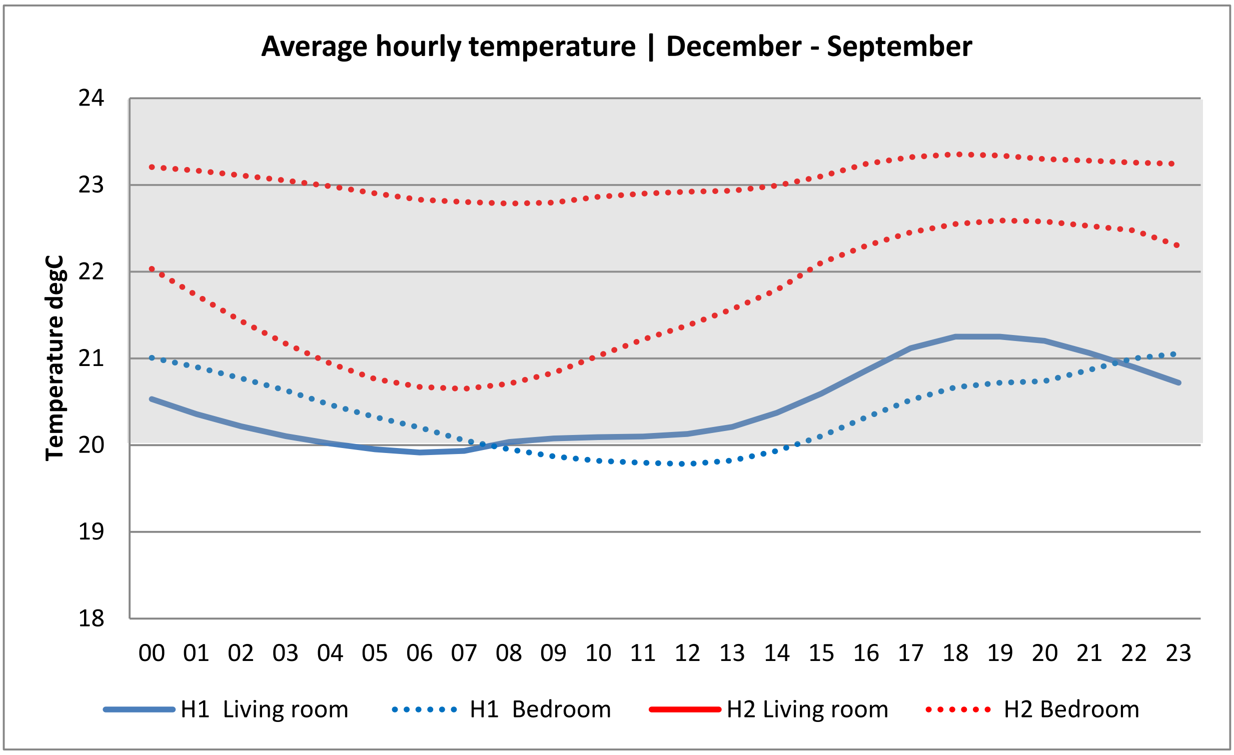


Figure 114 Average hourly temperatures in Houses 1 and 2 (December 2012-September 2013)

Figure 115 shows the internal temperature distribution in Houses 1 and 2.

- House 1 temperatures remain above 28°C for 1.6-1.8% of the time.
- House 2 temperatures remain above 28°C for 3.3% of the time in the Living room and 4.6% of the time in the bedroom, indicating overheating. It should be noted that the heating was on even when the rooms where above 26°C, because the thermostats were not connected to the heating system.

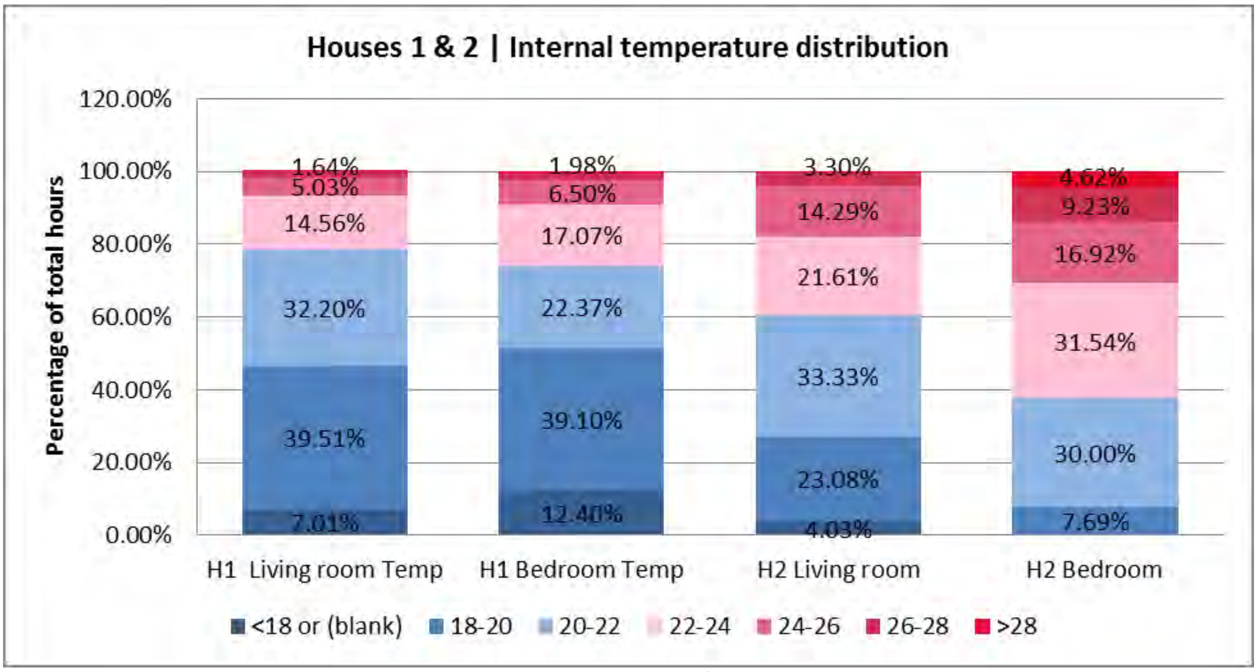


Figure 115 Internal temperature distribution (December 2012-September 2013).

In House 1 average monthly temperatures are below the comfort band from January to May falling as low as 13^{o}C in March due to the fact that the occupants switched off the heating systems during the day in winter in order to save on electricity (Figure 116).

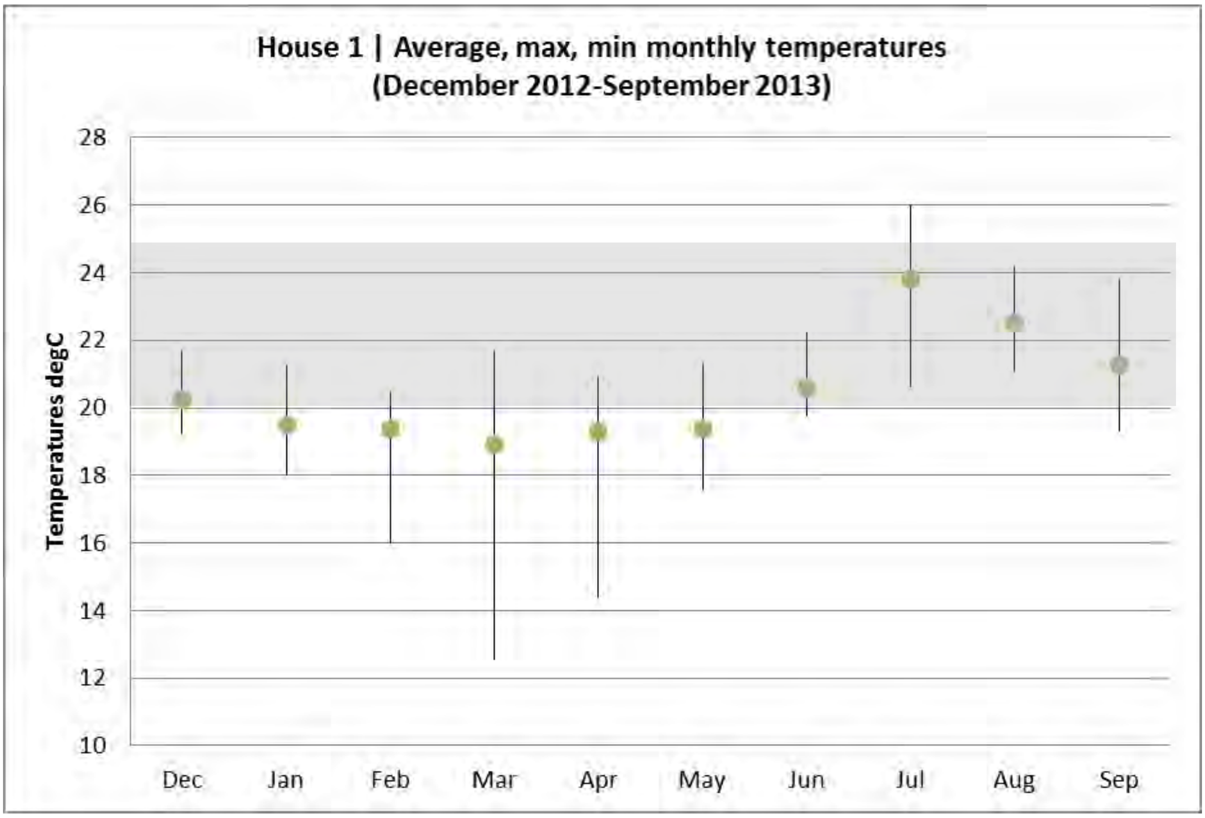


Figure 116 House 1 average, minimum and maximum monthly temperatures from December 2012 to September 2013.

Average monthly temperatures in House 2 living room are well within the comfort band with the exception of January (19^{o}C). Temperatures in July went high above the comfort band reaching 28^{o}C (Figure 117).

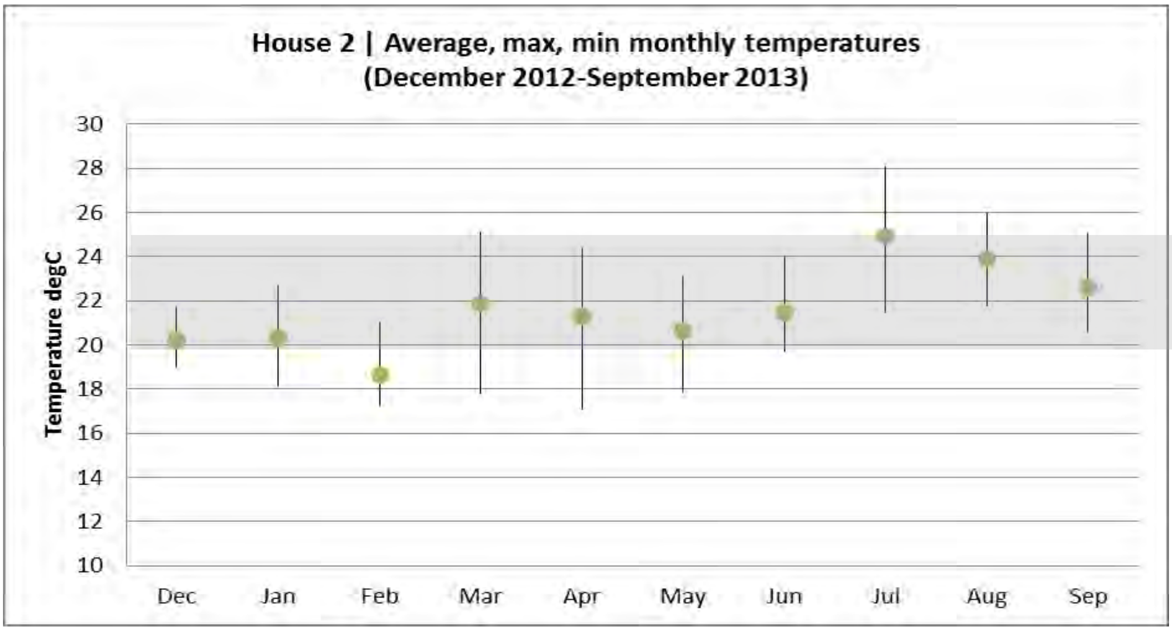


Figure 117 House 2 average, minimum and maximum monthly temperatures from December 2012 to September 2013.

8.2.2 Relative humidity

Figure 118 shows the external and internal relative humidity in Houses 1 and 2 living rooms and bedrooms from December 2012 to September 2013. Relative humidity levels range between 40-65% in House 1 living room and 30-60% in House 2 living room, remaining within CIBSE recommended levels of 40-70% for most of the monitoring period. During winter the highest RH levels are recorded in House 1 bedroom and the lowest in House 2 living room.

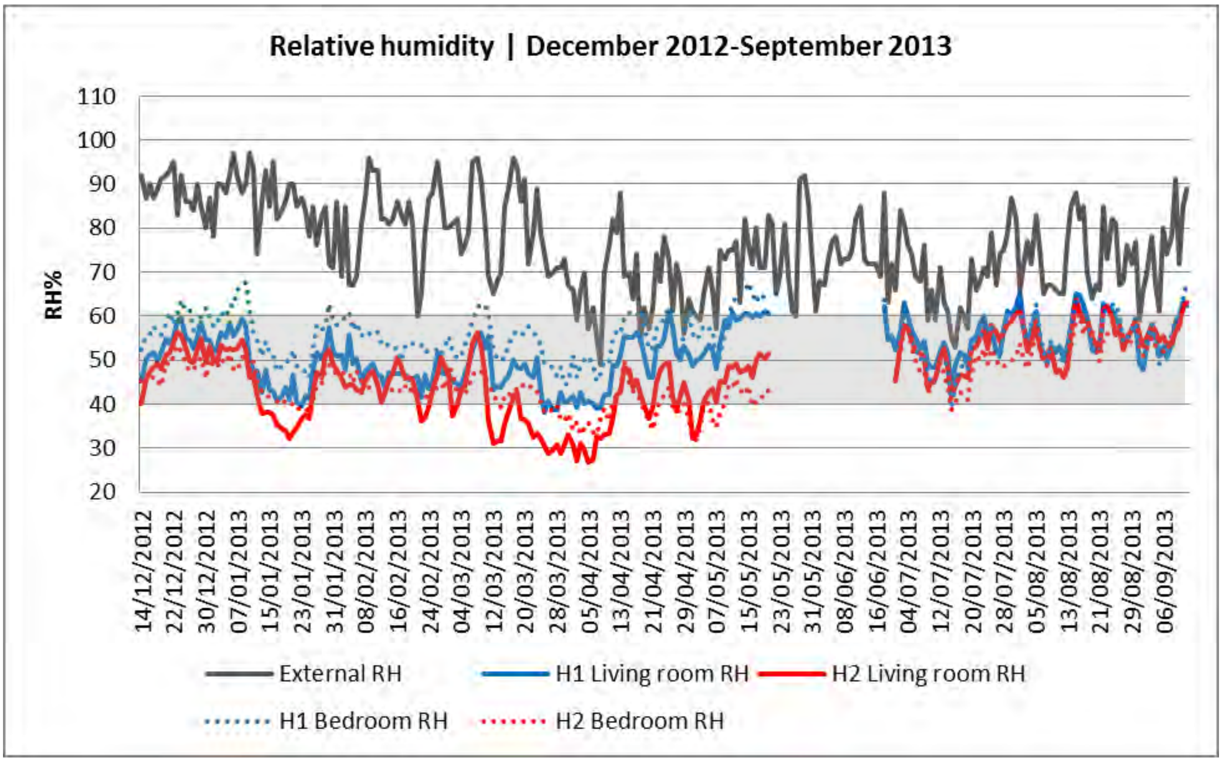


Figure 118 External and internal relative humidity in Houses 1 and 2 (December 2012 -September 2013). (Gap in monitoring data from 20/5/13 to 16/06/13).

Figures 119 and 120 shows the average, minimum and maximum monthly relative humidity in House 1 and House 2 living room. Relative humidity levels in House 1 living room remain well within the CIBSE recommended levels throughout the whole monitoring period. Relative humidity levels in House 1 living room fall below the CIBSE recommended levels during winter months, possibly due to the low air change rates in the house as a result of the MVHR breakdown and the high temperatures recorded in the spaces.

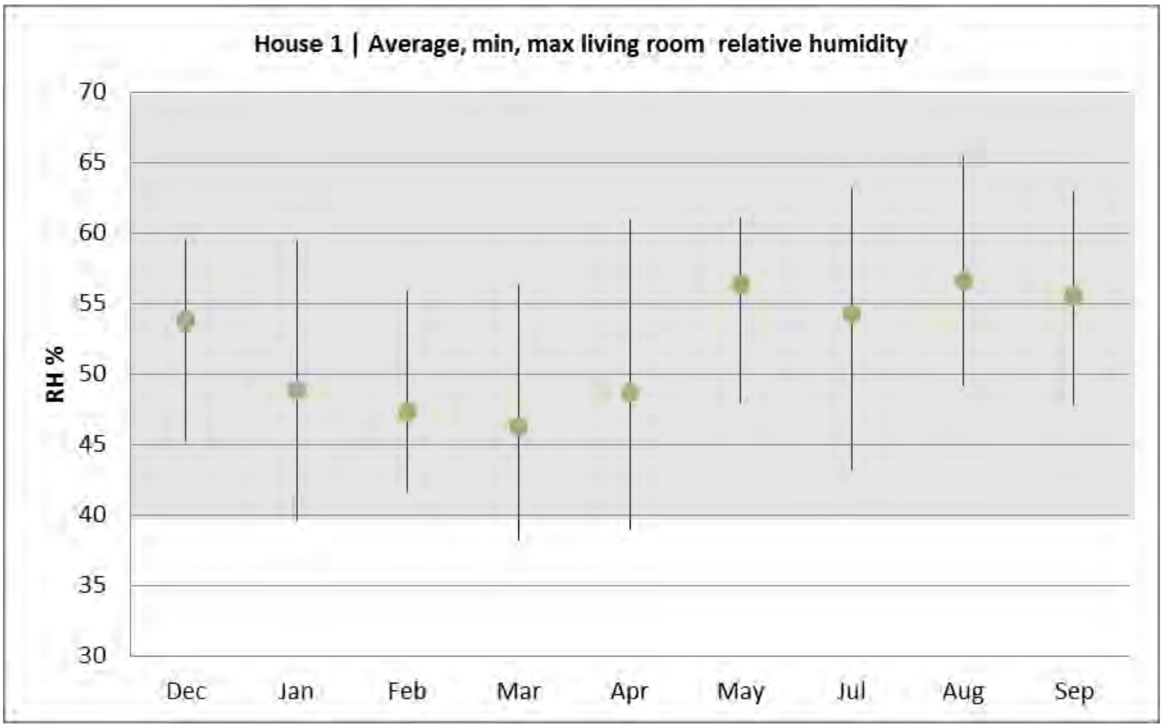


Figure 119 House 1 living room average, minimum and maximum monthly relative humidity. (June has been omitted due to lack of monitoring data).

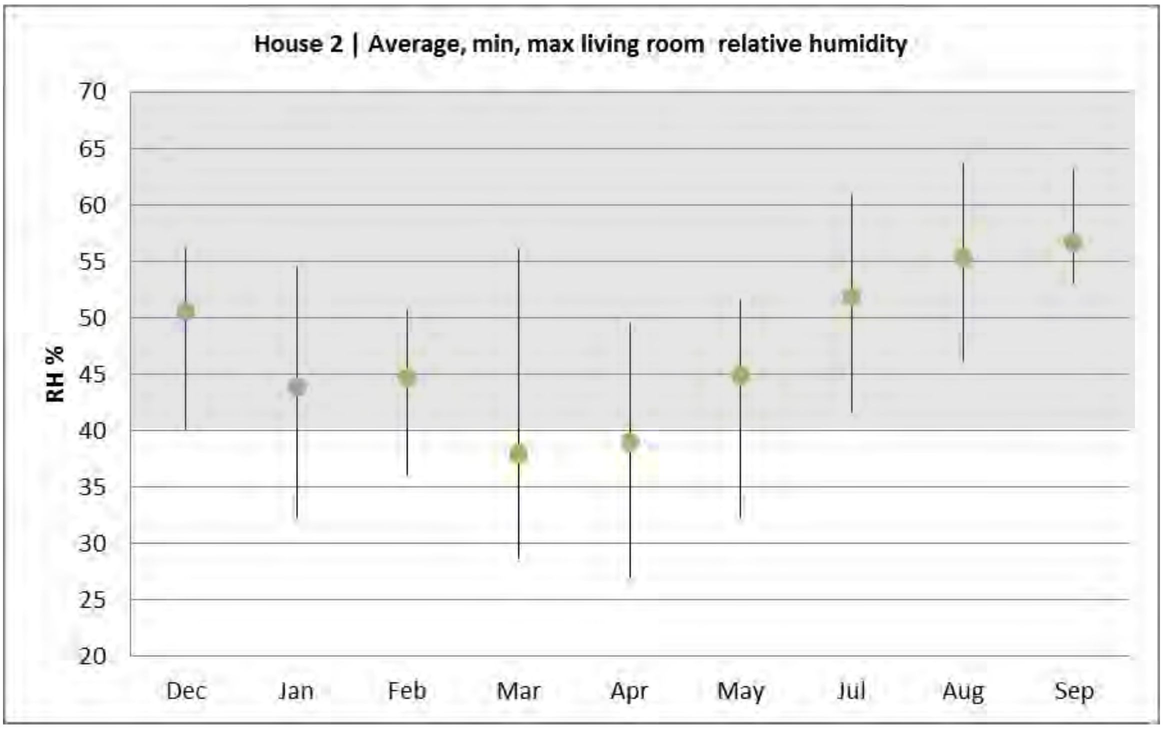


Figure 120 House 2 living room average, minimum and maximum monthly relative humidity. (June has been omitted due to lack of monitoring data).

8.2.3 Indoor air quality

Spot measurements were taken on 14th February 2013 (Figure 121).

- VOCs were zero in both properties.
- CO_2 levels in both houses do not exceed ASHRAE benchmark (400-1000 ppm)
- The highest value (950 ppm) was recorded in the hallway of House 2.
- CO_2 levels in House 2 were generally higher than those in House 1 possibly due to the fact that the MVHR system in the house was not working.

These results, coupled with the fact that the measured air permeability of the houses (6 m3/m2.h) is double than the design target (3 m3/m2.h), and taking into account that the MVHR system in House 2 was not working, indicate that the MVHR system might not be necessary. However, safe conclusions cannot be drawn unless the air quality in the spaces is monitored for a long period of time with the use of dataloggers.

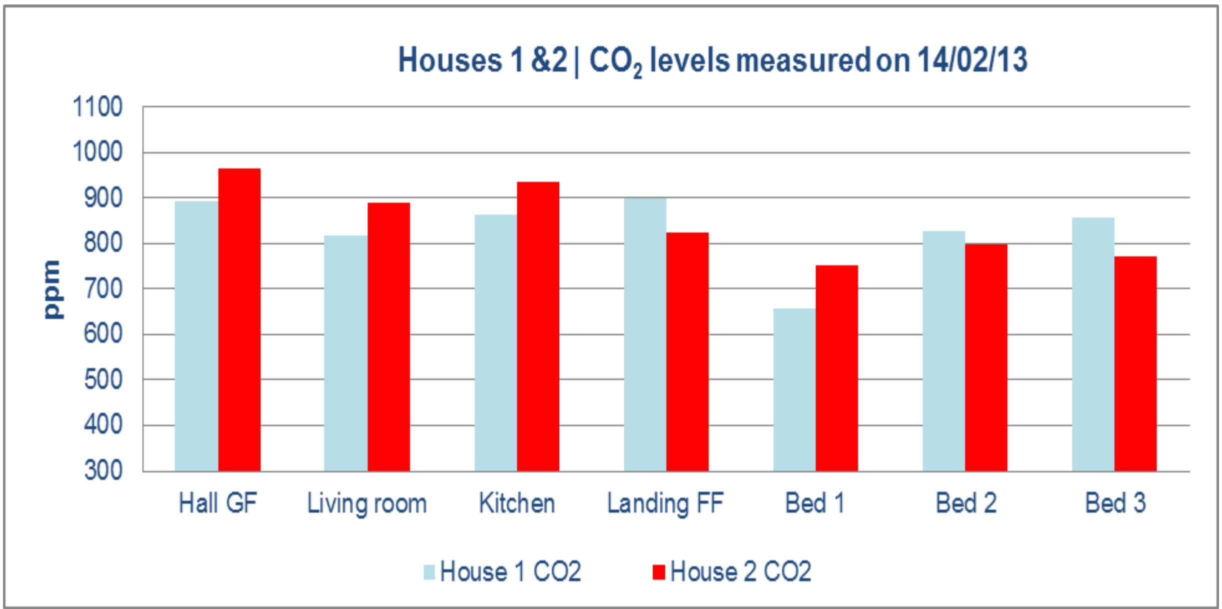


Figure 121 CO_2 levels in Houses 1 and 2. Spot measurements taken on 14th February 2013.

8.3 Conclusions and key findings

- Improper commissioning of the room thermostats that were not connected to the heating system led to increased electricity consumption and made occupants feel they lack control over heating and temperatures. In addition, this problem made occupants sceptical towards the heat pump and the technologies used in the houses.

- Lack of understanding of the heating and hot water system and poor control resulting from improper commissioning, made occupants in House 1 turn off the heating system from the main switch on a daily basis, only heating the house during the night, in an attempt to save energy. As a result, the efficiency of the ASHP was reduced and House 1 electricity consumption is not much lower than that of House 2 where the heating was constantly on. In fact, occupants in House 1 consumed 7.5kWh/m2/year more electricity than their neighbours in House 2, despite the fact that House 2 is occupied continuously. Also, as a result of occupant activities, the immersion heater settings to prevent legionella were de-programmed increasing the risk of legionella infection and temperatures in the House 1 fell below the comfort band during winter.

- Differences in the energy and environmental performance of the two houses are a result of occupant behaviour and action towards the commissioning problem of the room thermostats. In House 1 occupants took measures to actively control heating by switching off the ASHP, whereas in House 2 occupants did not take any action and had accepted the fact that the heating was constantly on in some spaces.

- Lack of control over heating and room temperatures, due to poor commissioning, undermines occupant satisfaction and comfort.

- Grid electricity consumption from December 2012-September 2013 is nearly 6300kWh in House 1 and 7900kWh in House 2.

- Carbon emissions from December 2012-September 2013 are 39kgCO_2/m^2 for House 1 and 35 kgCO_2/m^2 in House 2.

- During winter months House 2 grid electricity consumption is around 400kWh higher than that of house 1, whereas during summer months the amounts of electricity consumed by the two houses are similar ranging between 350-400kWh per month.

- Total PV generation from December 2012 to January 2013 is 520kWh in House 1 and 800kWh in House 2. However, the PV generated electricity per square metre is similar in the two houses (House 1: 6kWh/m^2, House 2: 6.5 kWh/m^2). This indicates that the PV array electricity generation has been distributed equally among the houses taking their area into account.

- In House 1 average monthly temperatures are below the comfort band from January to May falling as low as 13^{o}C in March due to the fact that the occupants switched off the heating systems during the day in winter in order to save on electricity. During the monitoring period, living room temperatures range between 18^{o}C-25^{o}C.

- Overheating was observed in House 2. This might be related to the fact that the MVHR system is not working and also to the fact that the occupants could not turn off the heating through the thermostats.

- Relative humidity levels in House 1 living room fall below the CIBSE recommended levels during winter months, possibly due to the low air change rates in the house as a result of the MVHR breakdown and the high temperatures recorded in the spaces.

- Spot measurements showed that CO_2 levels in House 2 were generally higher than those in House 1, possibly due to the fact that the MVHR system in the house was not working.

- CO2 levels were found to be below the ASHRAE recommended limit of 1000ppm. These results, coupled with the fact that the measured air permeability of the houses (6 m3/m2.h) is double than the design target (3 m3/m2.h), and taking into account that the MVHR system in House 2 was not working, indicate that the MVHR system might not be necessary. However, safe conclusions cannot be drawn unless the air quality in the spaces is monitored for a long period of time with the use of dataloggers.

8.4 Recommendations

- Careful commissioning of all systems and controls after construction especially when connecting wireless thermostats with the heating system. Provide seasonal commissioning to ensure that all systems are performing according to their specifications.
- The design and construction team should ensure that there is a sufficient post-installation support (through service contract) and maintenance guarantee.
- Encourage hands on training of residents as part of handover process to enable them to familiarize themselves with the low carbon technologies installed in the house.
- Occupants need to have sufficient guidance and training. The Home User Guide should include simple and clear guidance on the daily operation of the heating system and on the purpose of the ventilation along with recommendations on summer and winter modes of operation of MVHR systems.

9 Key messages for the client, owner and occupier

9.1 Key messages

Table 16 presents a summary of the key initial findings associated with the BPE study elements.

Table 16 key findings across BPE Phase 1 study elements

BPE Study Elements	Findings	Key messages
'As designed' and 'as built' comparison	• The houses did not present any apparent differences from the architectural drawings. • Small deviations from the architectural designs probably related to construction flaws. • Some discrepancies can be noticed between the design intent and the actual construction detailing.	Lack of proper commissioning of thermostats and heating system led to occupant's difficulty of controlling the heating system and temperatures in the houses and increased electricity consumption.
SAP calculations review	• In the 4-bed end-terraced house a four point difference was observed between the existing SAP rating and the revised STROMA rating. • In the 3-bed mid-terrace house a five point difference was observed between the existing SAP rating and the revised STROMA rating. • Deviation is related to the effect of the higher air permeability rates that were measured in the dwellings (average 5.5 $m^3/h*m^2$) instead of the as designed value of 3 $m^3/h*m^2$.	
Review of control interfaces	• The usability of heating and hot water controls is not intuitive and needs instructions to use it properly. • The thermostats were not properly connected to the heating system. • The MVHR unit is located in the loft in a very	

	narrow and inaccessible space making its operation and maintenance very difficult. • Light switches and control panel are intuitive to use and have good labelling and annotation.	Lack of adequate and accessible services space led to maintenance and poor installation issues of the MVHR.
Thermographic survey	• No thermal anomalies are evident in the walls with the exception of the party walls between the properties of different height where some heat loss was observed. • Thermal bridging across threshold was observed in both properties. • A cold bridge from a beam in the ceiling of the kitchen was identified in both houses. This is due to the detailing of the kitchen roof. • Cold spots identified on House 1 ceilings indicate that roof insulation is missing. Investigation revealed that the loft insulation has been misplaced. • Square sold area in House 1 kitchen wall indicates that an insulation panel is missing. This is possibly due to a mistake during construction.	Fabric first approach is proven to work effectively.
U-value measurement	• The U-values measured on site indicate that the envelope is well insulated. • Actual wall U-values are very close to those specified at the design stage.	
Air permeability testing	• Both houses failed to meet the design air permeability of 3 m^3/hm^2 and were measured to have between 5.27-5.91 m2/hm^2. • However, they were both significantly less than the national building standard of 10 m^3/hm^2 • The smoke pencil test revealed several air leakage paths through skirting boards, electrical outlets, plasterboards, light fittings loft hatch.	The use of MVHR systems needs to be re-viewed in buildings that are not as air tight as specified.
Design and delivery team walkthrough	• Design intention was to achieve a Code Level 4 and 5 scheme with a traditional appearance that would fit well within its surroundings. • The design team members were not familiar with MVHR and ASHP systems and these had to be included in order to achieve the higher levels of the Code. • Both the developer and the architect agreed that controls especially the individual room thermostats and master stat, have been over-engineered and interfaces are not very usable. • The design team agree that the best aspects of the houses are the fabric, their physical position and their planning. • The worst aspects of the houses are related to the performance and usability of controls and the performance of the MHVR system.	Lack of clear controls strategy led to overdesign and complicated controls. A defined strategy regarding systems and services early in the design process would allow for better sizing and provision of services space.
Evaluation of home user guide and handover	• Not necessary to provide air testing, installation manuals and electrical certificates	

	• A well formatted, colour, booklet version of this information is more likely to be read. The home user guide should not be long in size but should provide basic information on how to operate the systems in the house in a straight forward and graphically clear way. • Errors such as information on gas heating needs to be checked and changed according to property, instead of using the same user guide for the whole development.	Complicated and not user friendly Home User Guidehad a negative effect on occupant understanding of systems and services installed in the houses.
Occupant satisfaction survey, interviews and walkthroughs	• The overall picture of the survey revealed a positive opinion towards the houses, with the air quality in winter and the quality of light being the most appreciated elements. • Participants generally feel that the facilities provided meet their needs well and that the houses are quite comfortable overall. • The location was one of the most appreciated aspects of the development. • Many comments were received about heating, as occupants feel they cannot control temperatures effectively. Some occupants complain that it gets very hot in the houses and that the heating system continues to operate even when the thermostats are turned down. • Lighting levels were rated as satisfactory overall. The quality of light is one of the most appreciated elements of the building and scored at the higher end of the benchmark. • The key aspects that work well are considered to be the layout, the size of the rooms and the location of the houses. Positive comments were also received for the insulation of the envelope and the heating.	Lack of understanding of the heating and hot water system led the occupants in House 1 to turn off the heating and hot water system during the day in winter in order to save electricity.
Commissioning review	• Heating system not connected to room thermostats. • MVHR in House 2 not working. Manufacturing faults in all MVHR systems installed in development. • MVHR in House 1 unbalanced. Occupants had shut the valves closed.	The manufacturing problems of the MVHR units and the poor commissioning of the room thermostats installed in Bryan House scheme were revealed and repaired thanks to the BPE study.
Spot checks and recording measurements	• Grid electricity consumption from December 2012-September 2013 is nearly 6300kWh in House 1 and 7900kWh in House 2. • Carbon emissions from December 2012-September 2013 are 39kgCO_2/m^2 for House 1 and 35 kgCO_2/m^2 in House 2. • Overheating was observed in House 2. This might be related to the fact that the MVHR system is not working and also to the fact that the occupants could not turn off the heating through the thermsotats. • Overheating was observed in House 2. This may be because the MVHR system is not working and the fact that occupants could not turn off the heating through the thermsotats.	

9.2 Recommendations

9.2.1 Recommendations to owner/developer

- Careful commissioning of all systems and controls after construction is essential. Take extra care in connecting wireless thermostats with the heating system.
- Opt for rapid diagnostics to quickly identify mistakes and omissions during the construction phase.
- Perform accurate and reliable air permeability tests in all properties right after construction and quickly take measures to address deficiencies.
- Carefully distribute layers of insulation in roof space and make sure to select the appropriate type of insulation for this space.
- Consider using a front door of higher specifications and insulation levels in future projects.
- Maintain the good levels of insulation in walls and follow this construction process in future projects as it was proven to work relatively well.
- Review induction process to provide more detailed and hands-on experience.
- Improve customer care and a troubleshooting service using trained technicians. Servce contracts can help.
- Collate all lessons learnt on the project from issues raised (heat pump breakdowns, leaks, renewables installation) and use them as feedback to future projects. Communicate lessons to the council, maintenance and design team.
- Installation and commissioning procedures need to be robust, including appropriate certification by qualified technicians and documentation of commissioning reports.
- Before specifying suppliers, the design and construction team should ensure that there is a sufficient post-installation support and maintenance guarantee.
- Provide training to the maintenance personnel on renewables and low carbon technologies to reduce contradictory advice given to occupants and increase understanding of the systems, maintenance requirements, suitable use and benefits.
- Review air tightness specifications and inspection of construction quality and detailing for future project, to ensure that design airtightness is achieved in reality.
- Take extra care in detailing and finishes during construction to avoid air leakage paths and construction flaws.
- Take measures to improve the performance of the ASHP by training the occupants, re-balancing the system, improving air tightness in houses and addressing breakdowns quickly.
- Review the Home User Guide to provide more accurate and useful information to occupants on how and when to change the settings of the heating system seasonally, in a simple and user-friendly manner. Provide the occupants with a more compact and easy to ready home user guide according to the systems of each property.
- Consider re-training of existing occupants on the systems within the homes to include hands-on experience of heating settings, boost button, and filter change, in order to help enhance familiarity of the symbols and processes.
- Consider adding railings to the open stream in front of the houses to reduce health and safety issues in the area.

9.2.2 Recommendations to design team

- Provide adequate space for mechanical equipment and extra dedicated storage space from the initial design stage.
- Have a defined strategy regarding systems and services at an earlier stage in order to provide better spaces for services and allow less room for mistakes. Need for integrating a design strategy and servicing design for heating and ventilation systems. A detailed and coordinated services layout plan showing location of controls will help solve issues of accessibility and efficiency loss.
- It is important to update SAP worksheets in case of changes in construction or design details that could affect the energy performance of the dwelling. Review SAP according to as built air permeability values taken from air permeability tests after construction.
- Use a clear controls strategy that should be defined during the design stage.
- Too many thermostats in a dwelling tends to cause confusion amongst occupants. A simpler approach with less zoning but with a high level of fine control may work better.
- In future projects try to place the MVHR unit in a more easily accessible space and allow enough space for maintenance and filter change.
- Attention to detailing to avoid thermal bridging in roof joints and thresholds.
- Consider using a front door of higher specifications and insulation levels in future projects.
- Carefully design detailing for exposed areas of party walls.
- Follow fabric first approach in future projects. Maintain the good levels of insulation in walls and follow this construction process in future projects as it was proven to work relatively well.
- Reconsider the need for MVHR systems in buildings that are not so air-tight.
- Maintain good standard of design and layout and generous space standards.
- Revise window sizes and positions to provide more daylight in future developments.
- Review the Home User Guide to provide concise but more accurate and useful information to occupants on how and when to change the settings of the heating system seasonally.
- Reconsider the storage space in the flats and smaller properties. Dedicated storage space needs to be ‘designed’ properly in line with occupants’ expectations.
- Review the design of heating and MVHR controls to allow for a more straight-forward, simple and user-friendly approach.
- Review the garden sizes and design for future projects.
- Review noise specification standards for partition walls between houses, as well as within the homes themselves (floors and walls).

10 Wider lessons

The example of Bryan house scheme has provided us with great lessons for the industry, clients, developers, building users and the supply chain. The BPE study has revealed several issues relating to commissioning, handover, design and construction. Wider lessons learnt from the BPE study are presented in the following sections.

10.1 Lessons for building owners

- Avoid complexity. Clarify needs and demands with the design team.
- Ask for adaptability and flexibility.
- Ask for proper handover and easy to understand User Guides
- Follow the construction process closely and ask for rapid diagnostics.
- Set up maintenance (service) contracts for unfamiliar low carbon systems.
- Ask for seasonal commissioning of low carbon technologies and systems.
- Ensure building users are properly trained and have full understanding of all the systems and controls installed.

10.2 Lessons for building designers

- Make the design intent clear to building users. Install user control interfaces clear and easy to use.
- Provide the user with adaptive opportunities where necessary (operable windows, temperature and ventilation controls, adaptable shading).
- Design for space flexibility and adaptability.
- Design for robustness, usability and manageability.
- Provide careful detailing to avoid thermal bridging. During construction ensure that insulation standards and detailing are followed as designed. Opt for rapid diagnostics.
- Promote seasonal commissioning of low carbon technologies and systems installed.
- Provide the owners and users with a simple and visual user guide as part of your services.
- The home user guide should be designed by architects who are more experienced in communicating information visually.

10.3 Lessons for building developers

- Closely follow design and detailing. During construction ensure that insulation standards and detailing are followed as designed. Opt for rapid diagnostics.
- Provide seasonal commissioning of low carbon technologies and systems installed.
- Take the feedback from each building into account.
- Follow a phased approach to handover. It would be useful to ask occupants to demonstrate the use of controls and focus on a more hands-on approach.

10.4 Lessons for building users

- Familiarize yourselves with the systems and low carbon technologies installed in the house. Ask for guidance whenever necessary.
- Read the home user guide and provide feedback to the owners/developers.
- Follow the guidelines provided in order to minimize energy needs.
- Immediately report any maintenance issues and breakdowns.
- Understand the ventilation strategy and the purpose of the MVHR system. Shutting the MVHR grills results in decommissioning the system.
- Make use of the electricity generated by the PVs by adjusting your appliances use to sunshine hours.

Appendix

Appendix A

Review of controls

This section includes the findings from the review of control interfaces of the two houses in Bryan House that were omitted from Section 2.4

1. Heating and hot water controls

1.1 Immersion heater thermostat

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Clear and intuitive switching. Well labelled. No indication of system response. Located at one side of the tank. Hard to access in the cupboard.

2. Electrical equipment controls

2.1 Electric switches kitchen panel

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Well labelled set of fuses and switches located very close to appliances and easy to reach. However, in House 1 the occupants have placed different appliances to each plug than the ones originally indented.

2.2 Smoke & Heat alarm

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Smoke alarm in heating areas and heat alarm and carbon monoxide alarm in the kitchen, located directly above hob. Their location so close to the hob is very poor and it results in the alarm going off very easily. In House 1 occupants said they are not able to switch off the fire alarm. In House 2 occupants did not report any problems with the fire alarm.

2.3 Red switch - Unidentified

Located in both houses. House 1 in GF hallway, House 2 in GF Hallway and SF Bedroom 3. Its use hasn't been identified and the occupants were also unaware of its purpose.

3. Kitchen Appliances

Kitchen appliances labelling seems clear and intuitive. Poor indication of system response in some models.

3.1 Cooker hob

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Switching is intuitive in both houses. Well labelled. In House 1 no direct indication of system response apart from the hob going red.

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Switching is intuitive in both houses. Well labelled. In House 2 Indication of system response through a little red lamp.

3.2 Oven

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

In House 1 switching is not very intuitive and labelling is not very clear. Button to switch between the two different ovens (upper-lower). Good level of fine control.

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

Good level of fine control. In House 2 switching is intuitive and labelling is clear.

4. Water services controls

Hand basin taps are clearly labelled and easy to use but taps are not so clear in the kitchen. Hand basin taps do not have good degree of fine control in contrast to the shower tap.

4.1 Shower/bath tap

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

Comments

One side controls temperature and the other flow. Labelling is not clear. Safety button for kids.

4.2 Kitchen tap

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					
Accessibility					

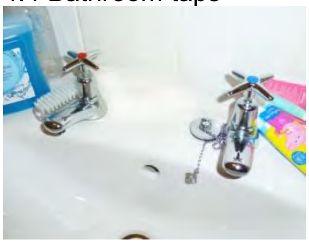
Comments

Not clear hot/cold indication.

4.3 Toilet flush

Criteria	Poor				Excellent
Clarity of purpose					
Intuitive switching					
Usefulness of labelling & annotation					
Ease of use					
Indication of system response					
Degree of fine control					

4.4 Bathroom taps



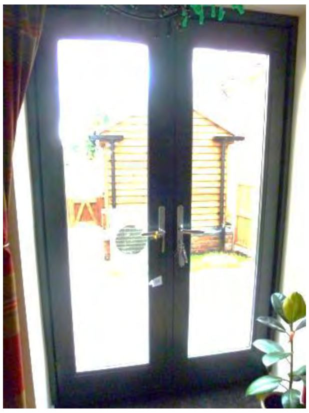
Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching					■
Usefulness of labelling & annotation					■
Ease of use					■
Indication of system response					■
Degree of fine control		■			
Accessibility					■

Comments

Simple labelling hot/cold on tap. Easy to use and intuitive. No mixer tap does not allow control of temperature.

5. Passive controls

5.1 Patio door



Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching					■
Usefulness of labelling & annotation					
Ease of use					■
Indication of system response					■
Degree of fine control	■				
Accessibility					■

Comments

Door easy to open and operate. No degree of fine control.

Appendix B

Design and delivery team walkthrough

1.1 Owner/Developer Interview Bryan House scheme

Date: 9/4/13

Interviewee: Head of Development, Sanctuary Group

Section A: PERFORMANCE ASPECTS

1. What were your main original design intentions for the project?

The design intentions initially was to deliver a scheme that was designed to be energy saving, that would be cheap to live in by those tenants, that could demonstrate a sustainable scheme and because it was a partnership development with Cherwell District Council we set out to work with them to deliver an exemplar Code for Sustainable Homes Levels 4 and 5 scheme so that we could demonstrate the project had reached those levels in terms of its build. The design also had some constrains because we are in a conservation area so we had to work within certain planning constrains. We also had some technical design constrains that we had to work with, such as requirements from the environment agency and certain external materials constrains. So, we weren't completely free. The design intent was to get something that fitted in with the local area and actually one of the things that was quite high on our list was that a lot of the design schemes of Code 4 and 5 residential schemes until now have a very modern appearance whereas we wanted to try and show that you could have a fairly traditional looking scheme which is still sustainable. That was one of the design aims was that it fitted in with its surroundings.

Our role was from inception to delivery. My role was to take the site from initial inception, which was essentially a clean sheet of paper and a car park and a redundant shelter scheme, deliver the planning permission for it, make sure that that planning consent was deliverable and that it was a design that included the requirements of that level of sustainability. Also, procure the contractor and deliver the scheme to completion by project managing it with our construction scheme.

2. What strategies were used to attain each of the above goals?

That would be better directed at Kate Mansfield. We were advised by Kate to start with a clean sheet of paper, so what we didn't do is we didn't have a design of dwellings and then go back and try to figure out how to get them to that level of sustainability. I am glad that we did that; otherwise we would have had a problem. We had an intention to have a fabric first approach. We asked for advice with regards to what would or would not work in terms of reaching certain levels of code and sustainability and CO_2 reduction. We also had advice with regards to what technically would work, for example we knew that we couldn't use PV everywhere because of overshadowing and orientation. Because we were asked to get to the higher level of sustainability we could, initially we did investigate the possibility of district heating system and CHP and we quickly ruled it out because we didn't have the room on the site and we didn't feel it was going to be technically efficient to do so. So we went for individual heating systems.

Regarding controls we went for maximum level of control and flexibility for residents because we believed that was what we needed to do, but now it might seems we might have gone too far with it. We believed the occupants not only should they have the benefit of the systems but they should also have total autonomy on how they get to control them.

3. Did you apply the learning from a past project into the design?

We hadn't done anything Code 4 and 5 before, we had done Code 3 before. We had always used traditional gas central heating systems and some solar hot water before which had always worked very well. We knew that we were entering slightly unchartered territory at Code 4 and 5. As Sanctuary Group we have used ASHP and MVHR before, and what we learned from that was that there were certain MVHR systems that we wouldn't use because we had had some problems with the way tenants had used them. We hadn't had many problems with the MVHR but maybe it is something that is gradually coming to light.

4. Could you relate the design intentions to the following issues?

Sustainability/ Low Energy/Low Carbon

Essentially Level 4 and 5 that was the design intention to achieve. In some of the Level 4 it was to achieve a higher level of CO_2 reduction than was necessary, so we strived to go beyond to what we were required to do. It was also about the tenants' ability to have lower bills and for the m to have as much flexibility as possible, and that was partly because the design intention was to tackle the problem of fuel poverty which was one of the issues for us.

Cost benefits/Life cycle costing

We did a life cycle costing and a Building for life calculation, as required. The scheme was also Life time homes standard as well, which was a planning requirement.

5. How well has the built product matched your original design intentions?

Space planning?

I think it has matched them pretty good in terms of space planning, and also Cherwell thinks the same.

Sustainability?

In terms of sustainability I think it has matched them well but we are still getting the results back from some of the data studying that the BPE TSB programme is doing.

Comfort and Control?

From the data that we got for the moment we have got varying degrees of view about that, because from the houses that the BPE TSB programme is studying it is clear that the User Guide information and the ease of control is not as simple as it could be, whereas in one of the other blocks, the fact that the tenant is very into the kit and the equipment we are getting a different sort of feedback. Overall, we were not completely satisfied with the control mechanisms.

Flexibility?

Again, it is different upon the two you are studying and the other one. The flexibility of the one bedroom flat is very good, but this doesn't seem to be the case in the two you are studying. This seems to be partly because there is too much choice in setting for people.

Q: Would you consider doing a kind of prototype in other developments before doing all dwellings?

In a sense we did do that in this scheme, as we delivered block three first and the first tenant to move there certainly indicated to us that tenant education is the biggest obstacle, but when we overcame that with certain bits of kit it worked very well. So I think the question is not to have a full trial of a unit but to properly educate the tenants before they take up occupancy.

6. Did you have to do any changes from the original design?

I think we stuck with the original design because we felt that it was complying with achieving the Code Levels and the CO_2 reduction. We didn't make any significant changes apart from the Ewgeco monitoring we adapted to record different data to the study houses compared to the other houses.

7. Would you repeat this design?

I think we would adapt this design if we were doing it again based on the information that is coming out of this study. That is because the feedback that we are getting in respect of controls and the MVHR and some of the interactive technology is leading me to believe it doesn't work very well with the user group compared to the non-interactive stuff.

8. What would you do differently, if you had the chance to now?

Typology?

We would go for a design that still follows a fabric first approach but we might have a harder look at whether more conventional heating systems and ventilation systems are appropriate for the type of user group that we have.

Space planning?

There is always going a difficult balance between maximising our built area and site constrains and this particular scheme was very typical of trying to deal with a difficult shaped site and a mix of house types. So, you are always going to have different constraints depending on the site.

Technology?

The MVHR is something that I am questioning its practicality as a piece of engineering. Solar PV is very good as it requires very little input form tenant or us. Building fabric is fine. ASHP is one of the systems we need to think carefully about in terms of how well it works and I think it is more about tenant education.

Comfort and Control?

We would look at different controls because I think that the ones we have are great if you are really very into it, but if the user is only used to tuning the dial on the thermostat then it is too much for people.

Materials?

The light steel construction was ok in terms of the speed of construction and we found that it is flexible enough for our purpose. Steel is rather flexible as a product in the way it could be designed to cope with our bespoke house types, the delivery and the execution of it was very good. Also it was possible to alter the design where we needed to make some very small changes

9. Which was the ventilation strategy followed in the design? Why did you use MVHR?

It was in order to get the Code, as we were required to achieve the highest level of energy reduction and CO_2 reduction possible. We looked at a combination of things which gave us the greatest number of code points.

Section B: COMFORT AND CONTROL

10. How well do you think the building has met your design aspirations in terms of comfort and control?

Heating strategies?

We haven't received a lot of complaints from the tenants which suggests that they are generally happy with what they have. So I think the system is pretty good, but if they find it a bit complex as you are suggesting that suggests that it hasn't worked so well.

Ventilation strategies?

In one of the other properties we don't have an issue with regards to the ventilation, but this might be due to the user and not the system itself.

Lighting strategies?

There were a lot of design related inputs with respect to windows, their location and sizes in order to give the daylight calculations to be able to hit the level of Code. In terms of artificial lighting we are using low energy fittings everywhere. We didn't consider looking at LEDs as they are expensive.

Section C: FLEXIBILITY AND SPACE STANDARDS

11. How well has the building met your design intentions in terms of flexibility and space standards?

It is pretty good in terms of space standards. We had HQIs to work to in terms of space standards. In terms of flexibility I think again it works pretty good.

Section D: OPERATION AND USAGE PATTERNS

12. How are the operational controls performing?

This would include programmers, lights, ventilation controls, temperature settings etc. As installed we thought that they were doing what they should do but now we are seeing that the level of complexity of certain controls are more complicated than we would have wanted them to be.

Section E: MAINTENANCE

13. Have there been any issues related to maintenance, reliability and reporting of breakdowns?

Not really. We haven't noticed any sort of initial barrage of call-outs for various different things in the first period of let, as it usually happens. Nothing really major occurred. The amount of call-outs is about normal, compared to other developments we have. But we cannot yet decipher whether it is because there are no problems or because the tenants do not know whether it is working properly, because of using innovative products

14. Do the occupants have an easy access to a help service?

They have the 24h 7days a week repairs line that they can ring. They also have their tenancy services officer whom they can contact regarding anything which is scheme related. So, in theory they do have an easy access to a help service.

15. Have issues being logged in a record book?

Our call centre would log enquiries for repairs etc. Because we are in our defects period with our main contractor they would normally be passed directly onto them but we would have a call log.

Section F: ENERGY MANAGEMENT

16. Does the energy and water consumption of the dwelling meet the original expectations?

I hope so. We are waiting to have enough data to analyse over a 12 month period

Section G: GENERAL

17. What are the best aspects of the house?

They do set out to achieve the Code Levels that we wanted to achieve.

The building fabric first approach has worked very well.

Their physical and their setting is positive and is a demonstrator to show that you can have a Code Level 4 or 5 house which doesn't need to look like a very contemporary dwelling, but that it can look like a traditional building. Also, some of the feedback that we are getting from the occupants is that it has worked very well.

18. What are the worst aspects of the house?

The MVHR probably. Other things that relate more to the physical programme of build and that it was technically difficult: for example the fact that we had a constrains site and difficult ground conditions, the issues with timing because of the constrains of the site.

We had some massive problems as we needed to do a lot of things, and the mixture of typologies was a major challenge. But we have achieved that.

19. How effective was the communication between the different project team members?

Communication between ourselves and the main contractor could have been better. We have reservations about the execution of the project by our main contractor, in terms of project management on their behalf, the phasing. Delivery was at least three months late.

Other than that, we went out of our way to employ Kate Mansfield as a conduit for making sure we achieved what we wanted and that worked partially, but it felt as though it worked when Mansell didn't know what they were doing. So, I am glad we had an independent consultant to advise us on certain things.

20. What were the lessons to be learned about the design features/ technologies in this building (during construction, commissioning)?

For future design we have to look carefully about control mechanisms and what level of technology we are putting in. We maintain that fabric first approach is the route to go. We need to reconsider whether or not we want to use more conventional heating and ventilation systems. Find ways to educate tenants more effectively, we need to improve on that. We deliberately went through a very rigorous selection of tenants, during an interview we explained them the benefits of this type of housing and then we had two training sessions. But it seems that this is not enough; probably need to do something more interactive after they have moved in. Probably use as Eco Bicester a show home, prototyping, and use it as a good way to educate people before they move-in.

21. Which sustainability features would offer potential learning for the design community?

To be careful about the levels of technology they include. That will depend on whether it is an owner occupied or a tenant. Building fabric first approach is a learning to be kept. Also, the fact that you can have a well-designed traditional looking building in a conservation area which are still very energy efficient in terms of building fabric. Architecturally it works very well and it is energy efficient.

END OF INTERVIEW

1.2 Design team Interview Bryan House scheme

Date: 9/4/13

Interviewee: Design team architect , David J Stewart Associates.

Section A: PERFORMANCE ASPECTS

1. What were your main original design intentions for the project?

The design intent was that the two blocks facing onto Chapel Street, which was areas of car park, would be more traditional because it's a conservation area as it is at the centre of Bicester. Intent was to do a traditional looking building and the other two blocks on the rear side would be more contemporary looking. As Bicester has been chosen as an Eco-town, the council had the intension to show some deliverables. The idea was to do a split of Code 4 and Code 5, to see what could be achieved using a more traditional design approach, with slate roofs, stone walls, timber windows. It didn't need to look as contemporary. The idea was how to do Code level 4 or 5 in a traditional manner.

2. What strategies were used to attain each of the above goals?

The strategies were developed by PRP. The main strategy was essentially through the fabric of the building. That was the principle way of achieving energy savings. PV was always sought to being used and it became an opportunity for Sanctuary to test out certain things like the ASHP.

Mix of renewables and fabric performance. It was a wide open strategy that was given and became more complex as we developed the design and more issues became apparent such as the reason we had to use an ASHP. The reason was that the cost was prohibiting to put a gas main across the brook that we opened up. That was one of the issues that came up. There were thoughts about using gas, traditional boilers with PVs and when we uncovered the stream it became apparent there was no gas main across this part of the site. It would involve a lot of digging up this road up the back which is a private lane with various ownerships. So that kind of presented the opportunity to splitting the strategy to gas and PVs on one side and ASHP and PVs on the other side.

3. Did you apply the learning from a past project into the design?

Yes. We had done Code level 3 homes for Sanctuary before so the fabric approach was there. We knew that getting fabric first is a good starting point. The use of a light weight construction as well. In the past timber frame had worked well as a building method and that's what was originally designed to be built but the steel frame actually in our opinion as a system to use is good, we would use it again. We hadn't used steel frame before.

4. Could you relate the design intentions to the following issues?

Sustainability

In terms of design intention part of this project was to see if you could get a sustainable home done with a more traditional kind of appearance.

Low Energy/Low Carbon

I suppose the design intention was to provide for low energy during use. It wasn't a case of carbon cutting across the whole development process, so it wasn't looking at the mileage of materials and embodied carbon really. It was more about in use energy savings.

Cost benefits/Life cycle costing

By the type of contract we knew it was going to be a design and build contract. The fabric first approach in order to cut on energy consumption during use was the initial design intent, really thinking about the costs benefits to the users in that sense rather than life cycle costing of materials etc.

During construction we tried to use a similar construction method for the development, through like an off-site frame situation. Also we limited the palette of materials down to three: stone, render and brick. As stone is expensive we limited its use. We only did three dwellings out of the lot that were entirely covered by stone.

5. How well has the built product matched your original design intentions?

Space planning?

It is more or less as we designed it originally, both the houses and the outdoors. However, the initial site masterplan did have some small units in the centre just next to the play area, but due to issues such as overlooking the neighbours it was decided not to put them there, fairly early on.

Orientations were chosen mainly based on the proximity to the neighbours and how it stood on site rather than any sustainability criteria, which is unfortunate, because we ended up being E-W rather than something more favourable (in this block).

Comfort and Control?

We were out of that decision making process in terms of the controls. We only helped develop strategies which were then taken on by the contractor and they then decided on the specific controls. We took advice from Kate Mansfield who developed the strategy with PRP and then the contractors (Mansell) decided on the actual selection of controls and type of ASHP. It was Mansell that selected the controls and the strategy they were supposed to work. Regarding the position of controls and systems, it was partly the contractor's decision. We had originally envisioned the MVHR unit to be in the bedroom cupboards (ex. House 2, bedroom 3) instead of the loft. This didn't happen. The hot water tanks were also supposed to be in the bedroom cupboards. But there is not enough space after all. And it has worked out as an awkward space. The boilers were originally going to be in the kitchens, if they were going to be gas boilers.

We put our intentions down in the drawings but the reality is we didn't know how big the tank or the MVHR unit was going to be. In the majority of the houses it went in well in the indicated spaces, in some of them, like House 2, it didn't work out as we planned. The decision to place the MVHR unit in the loft was taken on site, by the contractor (Mansell).

Flexibility?

We always asked for the internal partitions to be non-load bearing and they are not. So you can alter the partition if need be. The size of the ground floor WC and the intention was to have a shower built in the future. But when the contractor were doing the installations on site maybe they were not aware of that or they decided they needed to put some boxing in so now it is not possible to put an extra shower.

6. Did you have to do any changes from the original design?

We changed to light weight steel frame (from timber frame). That actually increased the wall thicknesses to a great degree of what we had originally planned for, and so we did actually have to go back and get the planning amended to allow for a 50mm increase around every single block. This was before we went on site. We had done the tender documentation to be a timber frame, post tender, when the contract was awarded to Mansell we changed to steel frame and that resulted in a slightly thicker wall which went outside. Normally you would lose that internally, but because of the space requirements in the Housing Quality Indicators scoring for Sanctuary and the fact that in some units we were very tight on that space, the decision was made to alter the planning. Other than that, the internal layouts and everything remained the same. And it was only when it was too late that issues like the size of this cupboard (House 2, bedroom 3) became an issue. The steel beams on the roofs was a late addition to the design and that is probably why issues like thermal bridging and detailing have not been addressed properly. And their size was bigger than anything we had expected.

Also, we were originally going to use gas boilers that would be placed in the kitchen. The change from that strategy did have an impact on storage space in cupboards, so it is something we will keep as learning for the future and something we have learned from various previous projects as well. We are learning that the use of renewables does have some different space requirements from the conventional and that changing them does have an impact on the layouts.

Also, the appearance of the scheme turned out to be slightly more traditional than our original intention. We wanted the dwelling on the back to be a bit more contemporary than the ones facing the street. For example the led dormers we envisioned them to be in zinc with crisper detailing but the contractor had them done in led which has more rough corners.

7. Would you repeat this design?

Yes, we would use the system again. There will always be slight changes, to internal layouts maybe, as just discussed. For example, having the MVHR unit in the loft space is clearly one of the things that we would need to review.

Regarding the wall construction, we would use this system again; we found it to be a benefit over timber frames so we would recommend using a steel construction frame over a timber frame.

8. What would you do differently, if you had the chance to now?

Typology?

We have used a lot of typologies. It is more costly and adds complexion in construction to have this weaving of typologies, one next to the other. Issues with floor heights arise. When you are mixing houses with flats it is not so straight forward as having house in a row. Maybe not having so many typologies would reduce complexity and costs.

Space planning?

We came across an unforeseen situation in this site, by finding archaeological remains. There was archaeological work carried out which turned out to be a big issue.

In terms of space within the units, in future design try and make sure that storage spaces are enough and that layout of fittings is adequate. It's a fine level of coordination between space and the technologies that are going in. Maybe, if the decisions were made earlier on in the process we could have allowed for that space sooner.

Technology?

Had we known from the start that ASHP would have been used, maybe some more thought could have gone into the position of them, instead of just placing them randomly in the back garden. And we had to adapt some bin stores for the flats to take the ASHP, as the flats do not have private gardens.

Also, in the future we would think more about the positioning of the MVHR grills and room furniture.

Comfort and Control?

As we are now learning, getting an understanding of the systems is very important. We only had a very wide sort of strategy on how to achieve the code and what kind of renewables were going to be used. If we had a specific strategy early on: ex. if we knew it was definitely going to be ASHPs and MVHR we could have planned for them systems to work better.

Materials?

We would use these materials again.

9. Which was the ventilation strategy followed in the design?

I think it was always to be MVHR, but how that was to work we were not involved in. Initially PRP were involved in that, they developed the initial strategy and the initial SAP. Mansell and their subcontractors then developed that further. Sanctuary was involved in discussions along with Kate Mansfield. The problem is that the strategy and the selections were not really finalised until stuff were happening on site, so decisions needed to be made.

Section B: COMFORT AND CONTROL

10. How well do you think the building has met your design aspirations in terms of comfort and control

Heating strategies?

Having underfloor heating has met our aspirations, but the fact that it is not working properly everywhere is a certain issue. Underfloor works well giving even heat, even though it is different and less responsive to having radiators and people are not very used to it

Ventilation strategies?

I think the MVHR unit and how it has been installed has been an issue and hasn't worked as well as we thought. The position of the MVHR outlets is something we would reconsider in the future; possibly design them to be close to the door and not above places where the beds could be placed. And also planning enough space for the MVHR unit to go in.

Lighting strategies?

We did want to achieve a high level of natural lighting but when the Code assessor was involved after planning, we found out that some of the windows were not big enough to achieve the DF required, and that was an issue. I think natural daylight levels were unsuccessful in terms of achieving what we wanted to achieve. That needed to be coupled with the planning that did require windows of certain proportions and sizes to fit with the context. That was a requirement of the council to achieve planning.

The roof light above the staircase works well.

Section C: FLEXIBILITY AND SPACE STANDARDS

11. How well has the building met your design intentions in terms of flexibility and space standards?

I think it has met them. In social housing we design bedrooms so they can be a double or a twin and it can be in more than one position. This mainly happens in the larger rooms. Some of the rooms have been successful, others were slightly compromised.

Section D: OPERATION AND USAGE PATTERNS

12. How are the operational controls performing? This would include programmers, lights, ventilation controls, temperature settings etc.

We were not involved in the selection and how things would work together and we are not aware of the strategy the controls are performing. There was no consultant on board to design the 'masterplan' of the systems.

Section E: MAINTENANCE

13. Have there been any issues related to maintenance, reliability and reporting of breakdowns?

We are not involved in that process.

14. Do the occupants have an easy access to a help service?

We are not involved in that process.

15. Have issues being logged in a record book?

We are not involved in that process.

Section F: ENERGY MANAGEMENT

16. Does the energy and water consumption of the dwelling meet the original expectations?

We hope it does but we do not know for sure, and that is the benefit of the BPE study.

Section G: GENERAL

17. What are the best aspects of the house?

The size of the rooms, the public spaces, the overall appearance of the schemes and the fabric that has been very successful.

18. What are the worst aspects of the house?

The coordination and the complexity of the services that are going in.

We didn’t have all the information we needed form the start and we had to leave stuff open.

Also, issues regarding electricity consumption, ASHP and the MVHR are becoming apparent.

Finally, the air tightness came out to be lower than expected.

19. How effective was the communication between the different project team members?

It started off really well, the coordination with Mansell and the contractors doing the steel frame. That aspect worked well. The lack of an M&E consultant, an electrical subcontractor, a heating subcontractor who are used to doing that stuff instead of designing the systems, I think that didn’t work so well. Also, the archaeological findings caused some delays and that resulted in some reprogramming which meant we had to fast track some aspects of the project while strategies such as the heating strategy still needed to be figured out. Communication was good but in some cases coordination was unsuccessful.

Cooperation with Mansell was very good; we had regular meetings on and off site and design team meetings early on with the steel frame manufacturers. So we got all the details sorted.

It was in the services issue where communication was not so good.

20. What were the lessons to be learned about the design features/ technologies in this building (during construction, commissioning)?

Construction-wise: we learned that it is easier to do the coordination of details when you’re still working on the designs and drawings than trying to deal with these issues on site, because a change is easy to make at that stage. A lesson learnt is going to be thinking about space requirements for systems and allowing enough robustness, room and flexibility in the initial design: to allow enough wall thickness, enough storage areas, to make junctions simpler, so if decisions are made later on there is still space to deal with them.

We were not involved during commissioning.

21. Which sustainability features would offer potential learning for the design community?

The fabric approach, probably with adding some better detailing to avoid thermal bridging from steel beams. The understanding of how the ASHP and the MVHR unit work together

22. Are there any other comments you’d like to make?

Overall I think that the complexity of the services is one of the main problems of the house. It is reassuring to know that the fabric is performing well.

The high air permeability rate is something that came as a surprise. It seems that some of the details were properly detailed but not executed well enough. Maybe some details were complicated to carry out on site and perhaps a simpler detailing would work better in the end.

END OF INTERVIEW

Appendix C

Interviews with occupants

House 1

Project: House in Chapel street, Bicester
Date: 2/7/13
Property: House 1
Type of dwelling: End-terrace , 2 storey, 3 bed

Section A – SATISFACTION

1. **How satisfied are you generally with living in this house?**
   - Appearance
   - Arrangement/set up
   - Family friendly
   - Liveability

   I am satisfied with the appearance of the house, internally and externally. I am happy with the layout of the house; it is suitable for a family.

2. **How satisfied were you with the induction process?**
   The induction process was clear. We were shown the MVHR boost in the kitchen and how to operate the room thermostats. However, we were told that there would be a follow up visit to show us how the systems worked but this did not happen.

3. **How satisfied were you with the home user guide?**
   - Understandable?
   - Easy to read?

   The smaller guide was very clear but the bigger one about the heating is a bit confusing.

4. **How easy is it to clean and maintain the house?**
   It is easy to clean and maintain the house.

5. **Is there anything you do not understand about your home?**
   - Renewables
   - Equipment
   - Fixtures
   - Control interfaces

   Yes. We do not understand how the solar panels work and how we get any payback from them. We do not understand how to program the hot water, instead of having it on at all times. Several technicians that have come over to check on the systems at times have confused us and they had told us to use the immersion heater when the sun is down. Someone set it to come on once a month, instead of once a week. It is confusing because there are two different water heating systems.

Section B – OPERATION, COMFORT AND CONTROL

B1. HEATING

6. **How well does the heating system perform?**
   - How satisfied are you with the room temperatures?
   - At what temperature do you set your thermostats (masterstat?)

   It warms up the house very well but does not always work properly. We have noticed that the heating is always on, even when we turn the thermostats down, resulting in very high temperatures in some of the rooms. We have trouble controlling the heating.

   We set the thermostats around 19^{o}C but some of the rooms can reach 26^{o}C during winter and still the heating is on.

7. **How easy is it to use the heating system?**

- How quickly does the home warm up (responsiveness)?
- How satisfied are you with the quality of heat (dry, stuffy)?
- Do you feel you have control over heating?

  It is easy to use the thermostats but we do not seem able to control the heating system. As I said, sometimes when you turn it on and you want it at a certain heat sometimes it goes higher. The quality of the heat is good. System responsiveness could be quicker.

8. How well do the renewable energy systems perform?

I do not know how the PVs perform. I know it shows up on the Ewgeco but I don't understand that and it does not show anything on the bills we are getting. I do not know how it comes off from the electricity bill. I tried to contact the electric company but they weren't very helpful.

B2. LIGHTING

9. How effective is the day lighting in the home?

We are absolutely happy with the daylight in the house.

10. How effective is the electrical lighting in the home?

It is effective. No problem.

B3. WATER

11. How well does the water system perform?

- Are you satisfied with the temperatures?
- How easy is it to use the system?
- How quickly does the water warm up?
- Is the hot water sufficient for your daily needs or do you use the immersion heater?

  The water system performs very well apart from the tap in the bath, the water is not hot enough there. Someone who inspected it told us that the mixing valve is not working properly but he was not able to fix it. We have reported it to the council and are waiting for them to fix it. It is easy to heat the water, we do not have to do anything, it is the heat pump that heats the water. We used to use the immersion heater whenever we wanted to take a bath as the water in the bath was not hot enough and we had turned off the heat pump. We do not use the immersion heater anymore; that comes on once a week now to prevent legionella. Someone came recently and changed the settings of the immersion heater from once a month to once a week. We had turned off all the systems to save electricity as our bills are very high, but Blount told us that we should not do that and turned the systems back on. We are now waiting to see what happens with the bills.

B4. ACOUSTICS

12. Are there any acoustic issues in the home?

- Inside/outside

  We don't have any noise issues. When the windows are closed we don't get noise from the outside. Sometimes we can hear the neighbours next door going up and down the stairs but that's all.

B5. VENTILATION

13. Do you ventilate the house?

- When during the day?
- Using what ?
- Any problems?

- Are you satisfied with the air quality?
- How easy is it?
- How quickly is the home ventilated (responsiveness)?

  We open windows and doors, especially when cooking. Not so much during winter though. We are satisfied with the air quality in the house. We can ventilate the house quickly and use the boost if we feel the need for it.

14. How easy is it to use the ventilation system? Do you feel you have control over ventilation?

It is easy to use. We use the boost in the kitchen a lot, not so often in the bathrooms.

15. How are the heating controls performing? Do you find them easy to use/understand?

The room thermostats are easy to use. We do not know how to operate the masterstat. During winter we had turned the heat pump off from the main switch, during the night, to save energy, and we would turn it on during the night to heat the house. As it is very well insulated it retains the heat during the day.

16. How are the lighting controls performing? Do you find them easy to use/understand?

The lighting controls are easy to use.

17. Are you satisfied with the performance of the MVHR system (e.g. responsiveness, ease of use)?

The system works really well. It is really quick.

18. Did you have sufficient guidance and training/instructions to use the ventilation system?

Yes. They showed us the boost buttons and all.

19. Is the operation / display panel of the MVHR intelligible and accessible for the occupant?

The boost controls are in the kitchen and in the bathrooms. There is no control to turn it off. The unit is in the loft and is very difficult to access.

20. Do you understand how to use the ventilation system (e.g. boost, summer bypass mode)?

Yes, we know how to use it.

21. Were there operational issues (e.g. display, maintenance, filter cleaning/replacement, consistence of service, filter, noise)? Have you had problems with the MVHR system? Have there been complaints of draughts? Did you try to disable the system? If so why?

No. It is on and it is working. We don’t touch it. Brookes had the filters changed recently. Sometimes you feel really cold draughts coming from the vents. It is right above the beds in the bedrooms and it is uncomfortable. There should be a switch so we could switch it off completely. I really don’t think it needs to be on 24/7. It would be nice to be able to turn them up or down individually in each room depending on our needs. We can turn the vents on and off, so we keep them shut unless it is really stuffy or hot. We feel we do not have control over it since we cannot shut it off. We would like to turn it off because it consumes electricity but we haven’t. It makes noise and you can hear it at night. We know there is a switch on the loft but it is not easily accessible and we cannot climb up and down every time we want to turn it off.

Section C: MAINTENANCE

22. Have there been any issues related to maintenance, reliability and reporting of breakdowns?

Yes. The heating broke down quite a lot when we first got here. It kept turning itself off and there was a flashing light in the cupboard saying 'error'. We couldn't even read what the error code was; I just phoned them up and said there was an error. They had to come many times in the first few weeks and then they had to put a new part in. It's been ok since, apart from the little pistons kept sticking in the bedroom and sometimes the pressure dropped and the house was not heating well. We don't know why that was. The pistons would stick at shut. The big bedroom was not heating up which I think did affect the heating in some of the other rooms as well, because it didn't feel like they were warm enough. We reported that but it took them a very long time to show up. I had to call them a couple of times before they came. I rang Sanctuary, whether it is Sanctuary or the heating people, I do not know who is responsible for the delay.

23. Do you have easy access to a help service?
We have phone numbers. We have the line to Sanctuary, that's our first port of call, but I also actually have the number of Blount now because I have been speaking to them a lot to arrange visits and stuff.

Section D: ENERGY MANAGEMENT

24. Are you satisfied with the energy and water consumption of the dwelling?
Not at all. We had to turn the heat pump off during winter to save money as our bills are very high. When we don't have the heating on, energy consumption is fine. The man from the electricity company told me that under floor heating is very expensive as you have to have the pump on all the time. Even the water is ok. The water bills are quite reasonable. We have never been on a meter before, but the water bill here is lower than what we had in our old house, which was a one bedroom flat.

25. Did you feel cold when you had the heating off?
Well, when the heating was not working it got quite cold in the house. Sanctuary did provide us with two air convector heaters, but these ones consume a lot of energy so we didn't use them. We had a little oil heater of our own so we used that and we would move it around the house to heat it up, because when the house is heated it stays warm for quite a long time. It is very well insulated this house. When we decided to turn it off ourselves we didn't feel so cold because we would turn it on during the night, when the temperature outside drops, and then we would turn it off again in the morning and it kept quite warm.

Section E – FLEXIBILITY AND SPACE STANDARDS

26. How flexible is the house in accommodating your needs?
The space is great. It is good for accommodating our needs.

27. How satisfactory are the room sizes?
The room sizes are good.

28. How satisfactory is the storage space in the house?
We could use a bit more storage space. We use the shed, the cupboard in the living room and the loft for storage.

29. Do you think each room is appropriate for its function?
Yes, apart from the third bedroom which could have been slightly bigger. The bedroom in the

front didn't need to be quite that big, and they could have made the smaller room slightly bigger. There is an odd corner there that could have been avoided.

30. How well do you think this house could accommodate your future needs?

- Old age
- Disability
- Growing family/shrinking family
- Workspace

It is quite flexible. When our older son moved out we used his bedroom as our daughter's playroom. The smaller room can become a nice office space as there is a phone line there.

Section F - GENERAL

31. What are the best aspects of the house?

The location is great. We can get to town easily, the bus stop is close, all the shops are very close. It is nice to have a garden.

32. What are the worst aspects of the house?

I do not like the stream outside our front door, because it is dangerous for our young daughter. I am afraid she might fall in. I don't like where they put the residents parking. It is quite far from the house and we cannot see the car from the house. It is really annoying. We would like to have a slightly bigger garden and a slightly smaller shed. The shed takes up a lot of space and its position is bad. Also, the high electricity bills during winter.

House 2

Project: House in Chapel street, Bicester
Date: 2/7/13
Property: House 2
Type of dwelling: Mid-terrace , 3 storey, 4 bed

Section A – SATISFACTION

1. How satisfied are you generally with living in this house?

- appearance
- arrangement/set up
- family friendly
- liveability

I am very satisfied with the appearance of the house, it looks nice. We are happy with the layout of the spaces. It is very suitable for our family. It is quite a big house.

2. How satisfied were you with the induction process?

I was not present during the induction process. My father participated in it and I think he was quite satisfied with it, he had lots to say afterwards.

3. How satisfied were you with the home user guide?

- Understandable?
- Easy to read?

We had a look at it about the heating. There were some bits in it that were quite confusing. It was not easy to read.

4. How easy is it to clean and maintain the house?

It is not very easy to clean the house yet because there is no flooring in. We do not have carpet yet so it is easy to collect dust and everything.

5. Is there anything you do not understand about your home?

- Renewables
- Equipment
- Fixtures
- Control interfaces

I do not understand the Ewgeco meters; I do not know what it is about. We do not understand the thermostats; we have had a lot of trouble with them. We would set the thermostats to one temperature and they would go above, they do not respond. Temperatures in the home are really really high; it is always really hot in here. We set it at 17^{o}C and it goes above 23-26^{o}C. We do not understand how the PVs work. I do not know what the unit in the garden is [referring to the ASHP]. The unit in the garden is quite noisy, it is annoying and it seems dangerous for the kids.

Section B – OPERATION, COMFORT AND CONTROL

B1. HEATING

6. How well does the heating system perform?

- How satisfied are you with the room temperatures?
- At what temperature do you set your thermostats (masterstat?)

The heating does not perform very well. The unit is quite noisy and the heating is impossible to control. We set the thermostats at one temperature but it goes higher and it is really hot in the house. The technicians from Blount who came by turned the heating off in the middle floor but it still feels very hot. We set it at 17^{o}C and it goes above 23-26^{o}C.

7. How easy is it to use the heating system?

- How quickly does the house warm up (responsiveness)?
- How satisfied are you with the quality of heat (dry, stuffy)?
- Do you feel you have control over heating?

The house is always hot. We are not satisfied with room temperatures; they are always higher than we set them to be. We do not have any control over heating despite all the thermostats in each room. It does get quite stuffy in here.

8. How well do the renewable energy systems perform?

We do not know how the PVs perform. We haven't received any payback and it doesn't show on the bills we get, so we don't know.

9. How are the heating controls performing? Do you find them easy to use/understand?

We understand them we just can't get them to work. They are not working at all. We cannot control the heating. We set it at one temperature and it shows on the screen that the room temperature is higher and we can feel the heating still on. It is a bit excessive to have one in each room, having to set temperatures in all of them, one by one. It is good in some cases, for example in the baby's room, to keep it warmer. But, it might have been easier to have one in each floor.

B2. LIGHTING

10. How effective is the day lighting in the home?

Most rooms have quite good day lighting; it is the living room that does not have that much daylight. It can get quite dark in here during the day. There is only one patio door and it is our only source of natural light in here. Bedrooms have good daylight. The staircase has a roof light and has plenty of light as well.

11. How effective is the electrical lighting in the home?

It is quite good.

12. How are the lighting controls performing? Do you find them easy to use/understand?

Yes, they are easy.

B3. WATER

13. How well does the water system perform?

- Are you satisfied with the temperatures?
- How easy is it to use the system?
- How quickly does the water warm up?
- Is the hot water sufficient for your daily needs or do you use the immersion heater?

We are generally satisfied with the hot water temperature, apart from the bath. We cannot get hot water in the bath at all. The showers are really good, they heat up fast. We do not have to do anything to heat up the water, it is automatic. We never had a problem running out of hot water, it is always sufficient for our daily needs.

B4. ACOUSTICS

14. Are there any acoustic issues in the home?

- Inside/outside

There is some noise from between floors, you can hear someone walking around even from the ground floor to the second floor. Sometimes you can hear people next door as well, from both sides. We do not have any trouble with noise from the outside. It is a quiet neighbourhood and once the windows are closed you can't hear anything.

B5. VENTILATION

15. Do you ventilate the house?

- When during the day?
- Using what ?
- Any problems?
- Are you satisfied with the air quality?
- How easy is it?
- How quickly is the home ventilated (responsiveness)?

We open windows and doors to ventilate the house. We rarely do that during the winter though. We don't know what these vents on the ceiling are for. The air in the house can be stuffy at times. It is easy to ventilate the living room, the bedrooms are a bit harder because they are not fully openable, only half of the window opens and the other bit opens only a bit.

16. How easy is it to use the ventilation system? Do you feel you have control over ventilation?

We have never used the MVHR system and do not know how to use it.

17. Are you satisfied with the performance of the MVHR system?

- Responsiveness
- Ease of use

No, it is broken. We did not know that it is broken.

18. Did you have sufficient guidance and training/instructions to use the ventilation system?

I think my dad did have some training, yes. There is also a manual for it somewhere. But we do not know how to use it.

19. Is the operation / display panel of the MVHR intelligible and accessible for the occupant?

We do not know where it is.

20. Do you understand how to use the ventilation system

- Boost
- Summer bypass mode

No

21. Were there any operational issues (display, maintenance, filter cleaning/replacement, consistence of service, filter, noise)? Have you had problems with the MVHR system? Have there been complaints of draughts? Did you try to disable the system? If so why?

It broke down. It is not working at the moment and we have never used it. I do not think it ever worked.

Section C: MAINTENANCE

22. Have there been any issues related to maintenance, reliability and reporting of breakdowns?

As said above, the MVHR broke down. Also, the heating is not working properly and we are waiting for it to get fixed.

23. Do you have an easy access to a help service?

I do not know. Normally my father would be responsible for contacting people and sorting things out.

Section D: ENERGY MANAGEMENT

24. Are you satisfied with the energy and water consumption of the dwelling?
We are satisfied. I know the electricity bill is a lot cheaper in this house that it was in our last one. We pay around £50/month on the electricity bills. We get a bill every month. Water comes at £120 every three months.

Section E – FLEXIBILITY AND SPACE STANDARDS

25. How flexible is the house in accommodating your needs?
It is a big house. It is good for our family.

26. How satisfactory are the room sizes?
The living room size is all right, I just don't like the layout so much; how that cupboard sticks out in the space. The single bedroom is quite small for single bedroom. The size of the kitchen is good.

27. How satisfactory is the storage space in the house?
There is not much storage room and that's our main problem. We do not have enough storage space, for such a big house.

28. Do you think each room is appropriate for its function?
Yes, apart from the small single bedroom.

29. How well do you think this house could accommodate your future needs?

- Old age
- Disability
- Growing family
- Shrinking family
- Workspace

There are five of us here. I don't think it would be good for a growing family. It is already full.

Section F - GENERAL

30. What are the best aspects of the house?
The location is very good; even though it is so close to town it is very quiet here. The size is pretty good.

31. What are the worst aspects of the house?
The garden; it is a bit small for a family house. The heating is quite a big problem.

Appendix D

Sound Insulation: Part E & Section 5
Airtightness: Part L & Section 6
Ventilation: Part F

BSRIA Compliance

Ventilation Measurement Test Sheet

Date of Test: 17 July 2013

Report Number: PFV - OXF01 - NA001 - BRY01 - 170713 - PL9 - T1

Client & Dwelling Information

Client: OXFORD BROOKES ENTERPRISES Region: N/A Address: OXFORD BROOKES ENTERPRISES HEADINGTON CAMPUS GIPSY LANE OXFORDSHIRE OX3 0BP	Plot Number: 9 Development: BRYAN HOUSE Address: CHAPEL STREET BICESTER OXFORDSHIRE OX26 6DW

Measurement Equipment Information

Device	Manufacturer	Model	Equipment Identifier
Flow Hood	Observator	DIFF	PFV1-1
Power Logger	Acksen	AL-2VA	201926

Measurement Data - Extract

Room	Mode	Filters: Clean		Filters: 50% Blockage	
		Low Rate (l/s)	High Rate (l/s)	Low Rate (l/s)	High Rate (l/s)
Kitchen	Extract	4.40	7.10	5.00	7.20
Bathroom	Extract	4.30	6.10	4.40	6.00
WC	Extract	4.70	6.50	4.50	6.60
END OF DATA	-	-	-	-	-
	Total	13.40	19.70	13.90	19.80

Measurement Data - Supply

Room	Mode	Filters: Clean		Filters: 50% Blockage	
		Low Rate (l/s)	High Rate (l/s)	Low Rate (l/s)	High Rate (l/s)
Lounge	Supply	2.10	2.50	2.20	2.60
Bedroom 1	Supply	2.40	3.10	2.50	3.90
Bedroom 2	Supply	7.50	11.00	7.40	9.50
Bedroom 3	Supply	6.6	6.4	5.7	6
	Total	18.6	23	17.8	22

Measurement Data - Energy Consumption

Measurement (1 minute intervals)	Filters: Clean		Filters: 50% Blockage	
	Low Rate Energy (w)	High Rate Energy (w)	Low Rate Energy (w)	High Rate Energy (w)
1	24	44	26	49
2	24	45	25	49
3	24	47	26	50
4	24	45	25	50
5	23	44	25	50
6	24	45	25	49
7	24	44	26	48
8	24	46	25	49
9	24	46	25	50
10	24	44	26	50
11	23	45	25	49
12	24	48	26	50
13	24	45	25	49
14	24	45	25	49
15	25	45	24	50
Average	**23.8**	**45.2**	**25.4**	**49.2**

Name: Chris Knights
Position: Compliance Engineer

BSRIA Compliance
Old Bracknell Lane West
Bracknell
Berkshire, RG12 7AH

T: **0800 5871000**
F: **01344 465691**
E: **compliance@bsria.co.uk**
W: **www.bsria.co.uk/services**