Cross Lane Development

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Innovate UK project number	450021
Project author	Sheffield Hallam University
Report date	2012
InnovateUK Evaluator	Fionn Stevenson (Contact via www.bpe-specialists.org.uk)

No of dwellings	**Location**	**Type**	**Constructed**
22 properties: 18 tenanted, 4 in shared ownership*	Royston, Barnsley	2 detached, 20 semi-detached*	2011

Area	**Construction form**	**Space heating target**	**Certification level**
82 - 120 m^2	Timber frame	N/A	CSH Level 4

Background to evaluation

*The BPE study concentrated on plot 5 for the building fabric testing. The two semi-detached houses were traditionally designed and procured development which meets Level 4 of the *Code for Sustainable Homes*. The properties were predominantly off-site manufactured and assembled on site. A timber-frame panellised system using on-site modern methods of construction were employed. Thermal mass was added through a combination of either cedar cladding or brickwork finish to the external facades. The properties were tested for air permeability, whole house heat loss test, *in-situ* U value measurements, and infra-red thermography.

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

The houses were supplied with grid electricity and a 2.4 kWp photovoltaic array, designed to supply up to 1938 kWh of electricity per annum. Heating was by mains gas-fired condensing boiler and radiators. A detailed analysis of the water harvesting system was conducted. The design and construction audit did not reveal any significant changes between the as-designed and as-built. The designed SAP for Plot 5 was 93 whereas the reviewed SAP figure remained at 93. The air permeability test prior to testing was 6.15 m^3 (m^2.h) @ 50 Pa. The post testing air permeability was 5.96 m^3 (m^2.h) @ 50 Pa. The heat loss coefficient was 103.12 W/K (design value: 107.41 W/K, reviewed design value was 108.58 W/K).

Occupant survey type	**Survey sample**	**Structured interview**
BUS Domestic	11 of 18 (61 % response rate)	Yes

Air conditions in the summer were humid and stuffy, whereas for winter its was too still. Temperature fluctuations were evident in the winter. This may have been due to the air tight nature of the house and heat losses as identified. The occurrence of light in the building, either natural or artificial edged towards 'too much'. Interviews were undertaken with residents in six properties at Cross Lane.

Contents

Attachments

(3806-31140) 1 SAP analysis as-designed (y value = 0.08)

(3806-31140) 2 SAP analysis as-built (y value = 0.08)

(3806-31140) 3 SAP analysis as-built (y value = 0.05)

(3806-31140) 4 SAP analysis as-built (y value = 0.15)

(3806-31140) 5 Pre air pressure testing

(3806-31140) 6 Post air pressure testing

(3806-31140) 7 Installation and commissioning datasheet

(3806-31140) 8 Gas boiler system commissioning checklist

(3806-31140) 9 Dwelling characteristics data capture form (Excel format)

1 Introduction and overview

Technology Strategy Board guidance on section requirements:	This section of the report should be an introduction to the scope of the BPE project, the expected results and will include a summary of the key facts, figures and findings. Give an introduction to the project covering the project team and a broad overview of the energy strategy, design strategy rationale and soft and hard monitoring. Also summarise the building type, form, materials, surrounding environment and orientation, as well as related dwellings in the development (which may or may not be part of the BPE project). Other amenities, such as transport links, cycling facilities, etc. should also be outlined where relevant. Give information on any environmental requirements issues that are relevant to the site, but not to the research. Only the basic facts etc. should be included here - more detailed information should be given in the relevant sections in this document and added to the data storage system as appropriate.

1.1 Building types at Cross Lane Development

The buildings in the study were developed by South Yorkshire Housing Association (SYHA, Figure 1). The development consists of 22 properties, 18 for rental tenants with the remaining 4 for shared ownership (normally split 50:50 between SYHA and the tenant). The aim is for the tenant to 'staircase' their proportion of ownership to 100% over a period of time. The BPE study will mainly concentrate on plot 5 (Figure 2) for the building fabric testing. A plan of the development is given Figure 3 and the floor plans of plot 5 (and 6) are given in Figure 4.

Image ref:	**Figure 1**	**Floor:**	**-**	**Room:**	**--**

Cross Lane development

Image ref:	Figure 2	Floor:	-	Room:	--

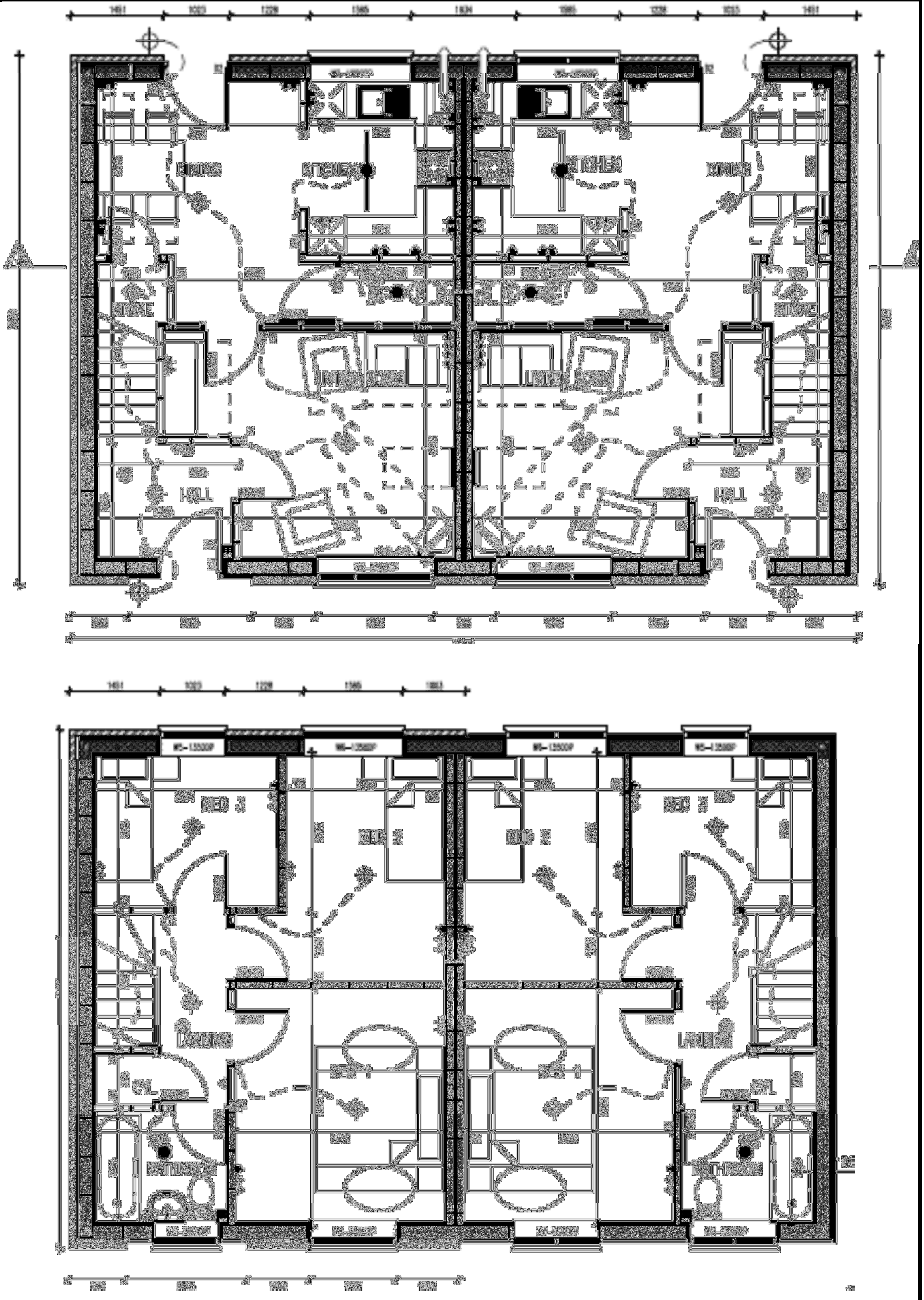
Plot 5 (left) in the Cross Lane development

This is a traditional designed and procured development which meets Level 4 of the Code for Sustainable Homes. The properties are predominantly off-site manufactured and assembled on site. Thermal mass considerations have being taken into account through a combination of either cedar cladding or brickwork finish to the external facades. The properties benefit from large, high performance, double glazed picture windows to maximise levels of natural light entering the properties. High ceilings are a feature on the first floor to make the space more impressive which also helps to mitigate the effects of overheating if present. Some of the properties have an inverted design where the kitchen and sitting room is located on the first floor with all bedrooms and bathroom on the ground floor.

Image ref:	Figure 3	Floor:	-	Room:	--

Plan of the Cross Lane development

Image ref:	Figure 4	Floor:	Ground/first	Room:	All



Plan of plot 5 (left) and plot 6 (right). Ground floor plan (top) and first floor plan (bottom)

Timber frame panellised system using on-site modern methods of construction (MMC) were employed. External facades use cedar panelling or brick with blockwork in the inner leaf separated by an insulated 75mm cavity. Suspended floors consisting of timber joists and chipboard are used. The roof consists of integrated modular PV panels and tiles with 200mm of mineral wool insulation between the joists and a further 200mm on top (400mm total).

The properties have been deliberately orientated to benefit from south facing roofs which are both offset and symmetrically pitched at 35 degrees. A 2.4 kWp photovoltaic (PV) array is integrated into the roofs. Two electricity meters are provided, one for grid consumption and one to cover generation from the PV arrays. The PV has been designed to supply, on average, up to 1938kWh of electricity per annum. Mains gas fired condensing boiler and radiators, natural cooling with mechanical ventilation.

The Green Corridor (www.thegreencorridor.org.uk) has supplied funding of £8k per plot to enable SYHA to improve the environmental performance of the properties (i.e. fitting water saving taps, rainwater harvesting, installation of renewables). The Green Corridor is a housing led project, developed by Doncaster, Barnsley and Wakefield local authorities for an area of Yorkshire which has a common rural mining legacy, a need for regeneration in parts and a strong future because of location and accessibility.

A bus stop is located on Cross Lane in front of the development for those residents wishing to avail of public transport.

1.2 Energy and design strategy

Grid electricity and a 2.4 kWp photovoltaic array, designed to supply, on average, up to 1938kWh of electricity per annum, supply electricity to the properties. Mains gas fired condensing boiler and radiators supply heating.

In terms of the energy credits section of the Code for Sustainable Homes, the design concentrated on two Code sections in particular, Energy and Water Use, as these were the easiest to quantify and are wholly within the designer's control in terms of design and specification.

1.3 Scope of the project/monitoring

The following is a summary of the scope of the project in Work Packages (WP):

- WP1 Design and construction audit, drawings review: Review concentrated on 2No. 3b4p properties as these are of more benefit to SYHA (only 2 No. 4b6p properties were built and the majority of their developments consist of 3b4p properties). It concentrated on

plots 5 and 6 which have different construction detail on the upper level (brick/cedar cladding)
SAP calculation review: Review concentrated on 1 No. 3b4p property as in-depth information will be obtained from WP3 below. Plot 5 was selected as the construction detail is more relevant to the future aspirations of SYHA

- WP2 Air permeability test, whole house heat loss test, in-situ U value measurement, infra-red thermography:
  - Review concentrated on 1 No. 3b4p property with an adjacent 3b4p property also held back for assisting the test.
  - Dr. Fin O'Flaherty conducted the testing as opposed to sub-contracting, with sub-contractor fees being used as part payment to purchase the equipment.
  - Additional heat flux sensors were used to determine heat flux data with a minimum of three sensors per wall for cross reference
  - A CO2 decay test was conducted to validate the co-heating results and estimate background ventilation (air changes per hour, ACH)
  - A detailed analysis of the water harvesting system was conducted by a water conservation expert. The findings of this study will not only be useful in this project but also to future developments by SYHA (it is a mandatory part of the CSH)
- WP3 Evaluation of hand-over process and guidance to occupants: A simulated handover was conducted on a similar property to the test property (plot 5)
- WP 4 Qualitative Semi-structured interviews/walkthroughs with occupants and design team, photographic survey: This concentrated on the test property (plot 5) and adjacent property (plot 6) for the design team. The walkthrough with occupants was conducted on different properties as plots 5/6 were unoccupied.
- WP5 Review of system design and implementation (commissioning checks): This concentrated on the test property and a simulated commissioning check was conducted using a suitably qualified building services engineer. Services are similar on all of the 3b4p properties
- WP 6 Standardised housing survey (BUS): Dr. James Pinder/ Ms. Saxon Bond. All properties were included that were occupied

1.4 Project team

Sheffield Hallam University (SHU) as lead applicant organised and delivered the main body of the work required in the project. Dr. Fin O'Flaherty is a Chartered Civil Engineer and has knowledge and experience of undertaking evaluations of similar projects. He has experience of engaging and consulting with project stakeholders and building users and designing and implementing data monitoring sensors and systems. Dr. James Pinder has a background in building surveying and over fifteen years experience of undertaking a wide range of property/building related issues. He has expertise in designing robust research and evaluations, engaging with building users and project stakeholders and writing high-quality and easily accessible reports.

Ms. Saxon Bond's primary role is to act as the interface between SYHA and its tenants. She built up a rapport with the tenants in addition to advising them on sustainability matters such as energy savings and understanding how renewable energy technologies operate. Mr. Craig Jackson is a Senior Architectural Technician who was responsible for the design of several SYHA project including the Cross Lane development. His main role will be advising the team on various design and construction issues and conducting as-built evaluations such as SAP analysis and as-built audit.

1.5 Key facts and findings

The following is a summary of the key facts and findings from WP 1-6. More detailed information on these findings can be found in the following sections.

WP1: The design and construction audit did not reveal any significant changes between the as-designed and as-built. The designed SAP for Plot 5 was 93 whereas the reviewed SAP figure remained at 93. It was clear that the time and effort that went into the design and delivery of the scheme reaped dividends. However, one area worthy of further consideration was how to interact at an earlier stage with the Distribution Network Operator (WP4). The DNO had concerns over the amount of electricity that could be generated by the PV (2.4 kWp per property), meaning delays were experienced since a sub-station had to be built on site and it was initially thought that this would not be required (there was another sub-station close to the site). It was difficult to engage the DNO early in the process and this had knock-on effects, they were only interested once the development was underway.

WP2: The air permeability test prior to testing was 6.15 $m^3/h.m^2$ @ 50 Pa for plot 5. The post testing air permeability was 5.96 $m^3/h.m^2$ @ 50 Pa in plot 5. The heat loss coefficient was 103.12W/K (design value: 107.41W/K, reviewed design value was 108.58W/K). Due to accredited detail methodology being employed in the construction, a y-value of 0.08 was used in the SAP analysis. However, the report also investigates the sensitivity of the y-value with respect to its influence on the heat loss coefficient. Due to the strong correlation of the co-heating data (Figure 17), if it is assumed that the as-built heat loss coefficient of 103.12 W/K is the correct value then by a trial and error process, a y value of 0.05 in addition to using the in-situ u values would yield a SAP heat loss coefficient close to the measured value.

The SAP rating would stay at 93. Therefore, thermal bridging has not only met accredited detail standards but exceeded it.

For comparison, if a default y value of 0.15 was used (non-accredited detail methodology) using measured u value data, the SAP heat loss coefficient would be 120.87 W/K with the SAP rating dropping one point to 92.

Analysis of the CO_2 decay data showed that the permeability of the property was 0.58 ACH on the sealed property, the SAP effective air change rate was 0.64 (as-designed and as-reviewed). This had an effect of residents' perception of the level of stuffiness encountered in the dwellings (WP6).

The average heat flux measurements were:

Wall	Measured & corrected U value (W/m^2K)	Design u value (W/m^2K)
North (party wall)	0.24	0.20
East	0.10	0.13
South	0.14	0.13
West	0.12	0.13

The biggest difference in comparable performance is the u value for the north (party) wall (0.04 W/m^2K higher) followed by the south (0.01 W/m^2K higher). The east and west walls had lower u values compared to design (0.03 and 0.01 W/m^2K respectively). The Standard Assessment Procedure (SAP) was conducted under SAP version 9.90, NHER Plan Assessor version 5.4.1. For the party wall, a default u value of either 0.2 or 0.5 W/m^2K can only be selected within this version of SAP so 0.2 W/m^2K was chosen as this was the closest match to the measured u value and, therefore, the reason for the greatest discrepancy. During testing, the adjacent property remained unheated. Although building regulations stipulate that insulation is not required in party walls, 120mm of insulation was inserted for sound insulation. This is an area worthy of further consideration, since eliminating the 75mm cavity and filling with insulation would give a total insulative thickness of 315mm, perhaps resulting in a better thermal performance. However, it is not clear what effect this would have on sound insulation and further research is required to confirm this.

WP3: The evaluation of the hand-over process and guidance to occupants and review of the written documentation suggests that there is a need to strike a balance between overloading residents with information/guidance and leaving them to work out themselves how to use their houses (with support from written documentation). Consideration needs to be given to communicating the information more effectively by ensuring the right information is in the right place at the right time.

WP4: The qualitative semi-structured interviews/walkthroughs with the design team uncovered no significant findings. There was some water ingress over the front door most likely due to the detail employed, the head of the frame would be more watertight if it was sloping and a bead of silicone employed. The main issue in delivering the scheme was the installation of a sub-station on site due to concerns raised by the Distribution Network Operator (see WP1 above). The very bad winter of 2010/11 led to severe delays.

The qualitative semi-structured interviews/walkthroughs with the occupants showed that the residents are generally very satisfied with their properties but some snagging issues were identified and suggestions were also made on how future schemes could be improved, for example,

- the smallest bedroom could have been more spacious by making it the same size as the second bedroom
- fences should be erected around the front gardens, so that people cannot walk across the lawns
- street lighting could be improved

WP5: The review of the system design and implementation (simulated commissioning checks) showed that the services (PV, heating & hot water, lighting and vents) were installed and commissioned correctly with no issues to report.

The rainwater harvesting review showed that with an average installed cost per system of £3,806, simple payback is 48 years for the larger houses and 68 years for the smaller dwellings. However, there are alternative ways to meet Code Levels 5 and 6 by slightly changing the appliance specification and these should be considered by SYHA in the future.

WP6: The standardised BUS housing survey had a 61% return rate. The main findings for this section refer to the air conditions in the summer which are humid and stuffy and winter when it is still. Temperature fluctuations are evident in the winter. This may be due to the air tight nature of the house and heat losses as identified and described by the thermal survey in Section 3.

Overall, the properties relate very positively to other buildings in the benchmark dataset with relatively low running costs.

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

Technology Strategy Board guidance on section requirements:	This section should cover the project up until before commissioning. Give more details on the building type, form, materials, surrounding environment and orientation, as well as related dwellings in the development (which may or may not be part of the BPE project). Other amenities, such as transport links, cycling facilities, etc. should also be outlined where relevant to the design specification. Also provide comments on the design intent, construction process and the product delivered (including references to drawings, specifications, commissioning records, log book and building user guide). If the original specification is available, describe how closely the final design meets it, what the discrepancies are and why these occurred. Indicate whether the explanation comes from the design team or from evaluator judgement. Identify any discrepancies between the design and SAP and whether the design accurately reflected in the SAP calculations and describe where these discrepancies lie. Does the SAP performance match the specified performance and was this informed through measured or calculated data. As far as possible provide an explanation of the rationale behind the design and any changes that occurred. In particular, it will be helpful to understand the basis for making key decisions on the choice of measures and technologies. These may have been chosen to suit the particular property or a physical situation, or they may have been chosen to test an innovative material or a new product. List and describe any aspects of the design that are likely to introduce performance issues – e.g. cold bridges? Describe any aspects of the design that were a challenge to construct robustly - e.g. introduction of air leakage paths. Finally this section should also outline the construction and construction management processes adopted, construction phase influences i.e. builder went out of business, form of contract issues i.e. novation of design team, programme issues etc. Describe the overall construction process, highlighting any supply chain issues, delays in construction, contract(or) issues Important: please describe steps taken to overcome any stated challenges and issues. Report perceptions, concerns and positive nuggets raised by the client, designers, and construction team. Complete this section with conclusions and recommendations.

2.1 Design intent, building type and surrounding environment

The aim of the scheme is to provide affordable and sustainable housing to the highest levels of design quality. SYHA's intention is to create a thriving & stable community and a place where people want to live.

The scheme is designed with contemporary architectural styling to distinguish it from other housing in the surrounding area. Large windows and high ceilings to upper floors add character to the elevations and maximise the feeling of light and space within the properties. Locally and sustainably sourced materials are proposed which will be enhanced by high quality architectural detailing.

The road layout enables easy wayfinding for residents and visitors. Shared surfaces and free-form access ways and the use of sculptural garden walling and high quality landscaping provide visual interest within the streetscene.

The site is served by the local public transport network and a request stop is located along the frontage of the site and is within easy reach of Royston town centre with access to a wide range of local amenities.

The tenure & accommodation mixes have been developed in consultation with Barnsley MBC's Strategic Housing team in response to their 2005 Study of Housing Needs and the subsequent master planning exercise conducted by EC Harris which specifically covered the Royston area. The scheme is being developed to provide the high quality, affordable & sustainable family housing identified as being required within those studies.

The overall site layout is constrained by two large diameter public sewers that cross the site. The main roadway into the site off Cross Lane has therefore been positioned to follow the line of the sewer to afford ongoing access required by statutory bodies. The clients design brief also demanded that future access to land to the North be made available.

Wherever possible natural, locally sourced materials have been used. All of the plots are constructed using a prefabricated, timber frame system manufactured and installed by a Leeds-based specialist company. Bricks were sourced from a local, independent brickworks located within 5 miles of the site. Windows were sourced from a Sheffield-based manufacturer and doors from a Barnsley-based manufacturer. Of the major external walling elements, only the Western Red Cedar cladding was sourced from outside the immediate local area, however this was sourced from a Forestry Stewardship Commission (FSC) approved supplier to minimise the environmental impact of the product.

Further information on the development was given in Section 1.1.

2.2 Construction process

The construction process is based on a traditionally procured building contract with full design drawings and specifications being provided by SYHA Architects. Clayfield Construction were employed under a standard JCT building contract to deliver the project.

All of the major design decisions were taken and agreed prior to the appointment of the building contractor. There is, therefore, a high level of correlation between the original design intent and the delivered project.

The number of Architects Instructions to cover variations to the specified works is very low, reflecting the high level of prior experience the design and project management teams have in providing high quality, low carbon social housing schemes. This experience and ability to deliver closely to initial design specification and cost is critical in the successful delivery of modern social housing construction projects. Cost overspends are monitored continuously by the funding provider (e.g. Homes and Community Agency) and SYHA are benchmarked against cost and delivery.

2.3 Construction Management processes

The major Construction Management issues revolved around the addition of a new electricity substation that had not been identified as being necessary prior to the commencement of the build programme. The District Network Operator (DNO) believed that the provision of a large number of solar photovoltaic arrays would adversely affect their local infrastructure. The effect of this on the project was two-fold. Firstly, a revised site layout had to be prepared to physically accommodate the substation and associated access. The delay in receiving detailed technical requirements from the DNO negatively impacted on the build programme for Clayfield Construction. The project subsequently completed 13 weeks later than originally anticipated. The cost of both providing the substation and the additional costs associated with the delay to the build programme totalled approximately £97,000.

Other Construction Management issues included the provision of Rainwater Harvesting equipment. A final decision on which system to be used was not made until several weeks into the build programme. This was because the requirement for the RWH systems under the Code for Sustainable Homes was unclear. Clarification of this matter took several weeks and eventually caused some adaptation works to floor beams already installed on approximately 12 plots to accommodate ductwork from rear garden areas, where the RWH collection tanks were to be sited, and the inside of the plots where the control gear and valves for the systems were to be sited.

The project was managed by SYHAs In-house design team with support from a Clerk of Works also employed by SYHA. Progress meetings at 4-weekly intervals, attended by the client and other briefing group stakeholders, were supplemented by interim Technical Meetings where issues pertinent to more detailed, technical matters could be discussed and resolved. This combination ensured that the majority of the planned works progressed smoothly and according to both time and cost projections. Clayfield Construction were, therefore, able to be given the advice and support they needed to ensure that the design intent was being realised and that quality was being maintained. The Technical Meetings also helped to mitigate the effects of the addition of the Substation.

Post Construction works have been challenging due to the winding up of Clayfield Construction. Rectification of defects to specialist equipment is covered under Sub-Contract Warranty agreements required under the main building contract provisions, however not having a main contractor to coordinate those works adds time and complexity to the process.

2.4 Specification audit

The following are minor deviations from the original specification (across the development):

In accordance with SYHA dwg AK02.1.03f

- curved bin stores omitted and bin stores added between house with fence screens
- additional communal landscaped area omitted and boundary fencing with trellis added to plot 15 & 20
- railings to front garden of plot 13 omitted retaining kerb on edge detail added
- paving added to plots 15 & 18 to suit 180 degree shed rotation
- extended gabion walling added adjacent to pump station area
- tarmacadam at rear of bus stop added up to curve wall
- fix metal bollards & removable bollards to pump station and grasscrete area entrance added

Amendments to accommodate revised kitchen unit layouts as follows:

- higher spec taps to 4 sale plots 2,4,5 & 6 added; Messrs Tapstore quest deck sink mixer.
- wiring for and under pelmet light fittings added to sale plots 2,4,5 & 6
- cooker hood socket cooker outlet and cooker unit repositioned due to revised kitchen layout.
- Additional power outlet for electric hob added to plots 2,4,5,6
- double socket behind the larder unit blanked off in plot 5.

2.5 Performance issues

SYHA has gained a great deal of experience in designing & developing properties of this type. Performance issues in general have been overcome by calling upon that previous experience. The major challenges often revolve around some construction team partners not sharing the same levels of experience. It is important, therefore, to ensure that elements such as the technical meetings take place to mitigate the effects of a lack of experience.

Prefabricated steel lintels, manufactured by Catnic, type CTF5, were used in the development. Whilst these are designed & installed to minimise cold bridges, they inevitably provide an element of design weakness into the thermal envelope.

Great efforts were taken to minimise air leakage paths, such as mastic sealing around skirting board perimeters, ceiling pendants etc. Quality control inspections on site helped to ensure reasonable air permeability results were achieved. Subsequent testing has highlighted that air infiltration through electrical socket boxes and the external tap served by the RWH system was in evidence and that the measures to minimise leakage in those cases was relatively weak.

2.6 SAP calculation review

The Standard Assessment Procedure (SAP) was conducted under SAP version 9.90, NHER Plan Assessor version 5.4.1. The design U value for all walls is taken as 0.13 W/m^2K, however, for the party wall, a u value of either 0.2 or 0.5 can only be selected within this version of SAP for the review. The thermal bridge default value of 0.08 was used in the calculation as construction was to accredited detailed methodology. The as-design versus as-built SAP is further analysed in the next chapter.

2.7 Conclusions and key findings for this section

The main conclusion and key findings emanating from this section comes from the SAP calculation review are as follows:

- It is possible to set and deliver against high quality environmental targets if the scheme is well conceived and managed throughout.
- Specifying photovoltaics requires wider consultation at an earlier stage. Some partners are not prepared to have discussions at the design stage, only at build stage when the project is advanced and this impacts on costs and delivery times.
- DNOs require more data on electricity flow to the grid as current understanding is based on a worst case scenario. In Summer, when all arrays are operating at peak, design of flow to the grid is based on little or no consumption in the property. This leads to the rash decision of insisting on a new sub-station to be built to cope with the capacity.

3 Fabric testing (methodology approach)

Technology Strategy Board guidance on section requirements:	This section should provide a summary of the fabric testing undertaken as part of the mandatory elements of the BPE programme, *plus* any other discretionary elements that have been undertaken. Ensure that information on u-value measurements; thermography, air-tightness, any testing on party wall bypasses and any co-heating tests are covered. Give an overview of the testing process including conditions for the test any deviations in testing methodology and any measures taken to address deficiencies. Confirm whether any deviations highlighted have been rectified. As some tests (particularly the thermographic survey) are essentially qualitative it is important that the interpretation is informed by knowledge of the construction of the elements being looked at. Comment on the use of particular materials or approaches or their combination or installation methods lessons learned. Complete this section with conclusions and recommendations for future projects.

3.1 Test set-up

A co-heating test was conducted in the first two weeks of February 2012 by following the guidelines given by the TSB[1]. The layout is given in Figure 5. The equipment used broadly followed that specified in the guidance document as shown in Table 1. Two No. 3kW fan heaters were positioned in the property, one downstairs and one upstairs (Figure 6). Air was circulated via 18 inch diameter fans, two no. upstairs and two no. downstairs. The energy used to maintain the property at approximately 25°C was monitored via 2 no. single phase electric meter with pulse output (Figure 6). CO_2 was also monitored daily using a 302 series regulator (Figure 7). Temperature and RH was monitored inside the property at four locations (two up, two down). A total of twelve Hukseflux sensors (three per external wall) measured the in-situ U values (Figure 8-Figure 11). Externally, a Vaisala weather station monitored, amongst others, air temperature and wind speed whereas a pyranometer was used to monitor solar flux (Figure 12). Two data loggers were remotely interrogated (one for the heat flux sensors, another for the remaining sensors, Figure 13). All vents and extracts were sealed before the test began (Figure 14).

The construction of the wall and properties of the layers are given in Figure 15 and Figure 16.

[1] Whole House Heat Loss Test Method, Leeds Metropolitan University

Image ref:	Figure 5	Floor:	Ground/first	Room:	-

Location of co-heating test equipment; ground floor (top) and first floor (bottom)

Table 1 Specification of test equipment

Component	Equipment Used
Co heating test equipment specification	
Temperature and Relative Humidity Sensor	Eltek GC-10 Temp/RH Transmitter
Fan Heater	Delonghi THE332-3 3kW Fan Heater
Circulation Fan	Prem-I-Air HPF-4500 Air Circulator
Thermostat	Honeywell T4360B Thermostat, 16A load
kWh Meters	100amp Single phase single rate electricity
Pulse Transmitter	Eltek GD90 Pulse Transmitter
Datalogger	Eltek RX250 Squirrel Datalogger
GSM Modem	Wavecom Fastrak GSM Modem
Weather station equipment specification.	
Weather Station	Vaisala WXT520 Weather Transmitter
Pyranometer	Kipp & Sonnen CMP3 pyranometer
Datalogger	Eltek RX250 Squirrel Datalogger
GSM Modem	Wavecom Fastrak GSM Modem
Heat flux equipment specification.	
Heat Flux Sensors	Hukseflux HFP01 Flux Sensor. Attached to
Thermal Paste	Corning 340 silicone heat sink compound
Datalogger	Datataker DT85
CO2 decay measurement equipment specification	
CO2 Sensor	Vaisala GMW25 CO2 sensor
CO2 Transmitter	Eltek WPGD47
CO2 Dispensing System	Disposable CO2 Cylinder (10 litres),302 Series

Image ref:	Figure 6	Floor:	First	Room:	Bed 2

Thermostat, 3kW fan heater and transmitter

Image ref:	Figure 7	Floor:	Ground	Room:	Living

CO2 dispensing system

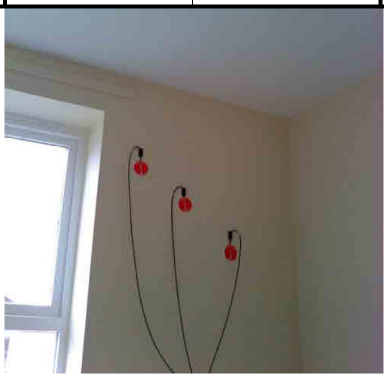
Image ref:	Figure 8	Floor:	First	Room:	Bed 3

Heat flux sensors on west wall

Image ref:	Figure 9	Floor:	First	Room:	Bed 1

Heat flux sensors on north wall

Image ref:	Figure 10	Floor:	First	Room:	Bed 1



Heat flux sensors on east wall

Image ref:	Figure 11	Floor:	First	Room:	Bed 3

Heat flux sensors on south wall

Image ref:	Figure 12	Floor:	-	Room:	-

Weather station and pyranometer, south facing

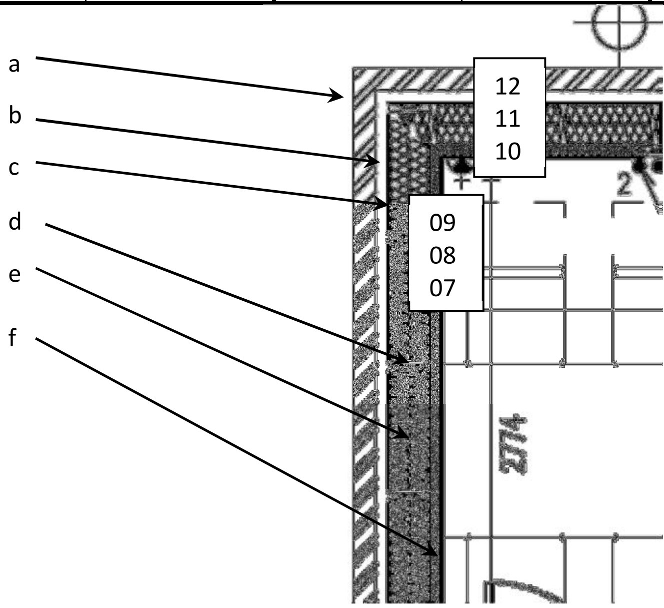
Image ref:	Figure 13	Floor:	First	Room:	Bed 1

Remote data logging systems

Image ref:	Figure 14	Floor:	Ground	Room:	kitchen

Example of sealing all vents and extracts

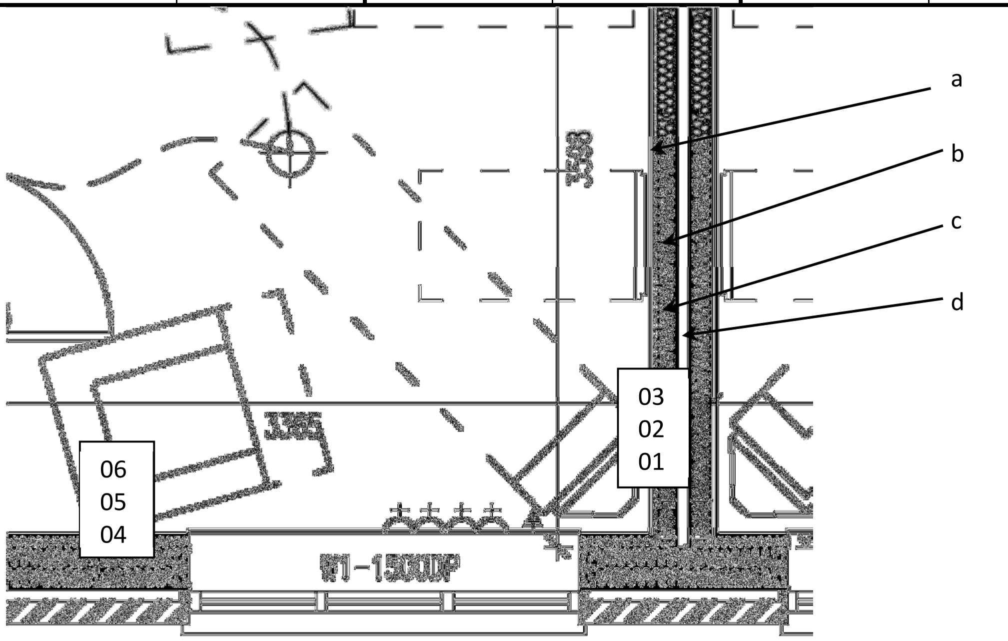
Image ref:	Figure 15	Floor:	-	Room:	-



No.	Component	Details	Thickness (mm)
a	Outer leaf	Clay facing brickwork	103
b	Cavity	-	75
c	Insulation sheathing to cavity face of external wall studs	62.5 Kooltherm K18 (50mm insulation and 12.5mm bonded plasterboard)	62.5
d	Timber stud		190
e	Insulation	Mineral fibre quilt to BS 5803 Part 1	190
f	Internal leaf of external wall	12.7 Gyproc square-edged wallboard, 3mm plaster finish	15.7

Composition of east, south and west wall and position and number of heat flux sensors

Image ref:	**Figure 16**	**Floor:**	**-**	**Room:**	**-**



No.	Component	Details	Thickness (mm)
a	Internal leaf of external wall	12.7 Gyproc square-edged wallboard, 3mm plaster finish	15.7
b	Timber stud		120
c	Insulation	Mineral fibre quilt to BS 5803 Part 1	120
d	Cavity	-	75

Composition of north wall and position and number of heat flux sensors (east wall also included with position and number of heat flux sensors

3.2 In-situ U values

The in-situ U values are given in Table 2 (corrected for wind speed and solar gain). The measured U values were obtained as described in Section 3.1. Composition of the walls is given in Figure 15 and Figure 16. Referring to these values in Table 2, the biggest difference in comparable performance is the u value for the north (party) wall (0.04 W/m^{2}K higher) followed by the south (0.01 W/m^{2}K higher). The east and west walls had lower u values compared to design (0.03 and 0.01 W/m^{2}K respectively). During testing, the adjacent property remained unheated. The east, south and west walls are all insulated with 190mm of mineral wool. Although building regulations stipulate that insulation is not required in party walls, 120mm of insulation was inserted for sound insulation. This is an area worthy of further consideration, since eliminating the 75mm cavity and filling with insulation would give a total insulative thickness of 315mm, perhaps resulting in a better thermal performance. However, it is not clear what effect this would have on sound insulation and further research is required to confirm this.

Table 2 In-situ and design U values

	North (party wall)	East	South	West
Measured U value (W/m^{2}K)	0.24	0.11	0.15	0.12
Corrected U value (W/m^{2}K)	-	0.10	0.14	0.12
Design U value (W/m^{2}K)	0.20	0.13	0.13	0.13

The design SAP u values are also given in Table 2. These are calculated as 0.13 W/m^{2}K for east, south and west walls and 0.20 W/m^{2}K for the party wall in the u value calculation (SAP 2009 Worksheet, SAP version 9.90). To enable the impact to be assessed between the as-designed and as-built values, the SAP was reanalysed using the in-situ u values. Findings are given in the following sections.

3.3 SAP review

The Standard Assessment Procedure (SAP) was conducted under SAP version 9.90, NHER Plan Assessor version 5.4.1. The design u value for east, south and west walls is taken as 0.13 W/m^{2}K, however, for the party wall, a u value of either 0.2 or 0.5 W/m^{2}K can only be selected within this version of SAP so 0.2 W/m^{2}K was chosen as this was the closest match to the measured u value (Table 2). The thermal bridge default value of 0.08 was used in the calculation as construction was to accredited detailed methodology.

The as-designed SAP value was 93 and this remained unchanged after the review, meaning that the negligible difference between calculated and measured u values did not alter the as-designed SAP value.

The SAP worksheets for the above can be found as the following attachments:

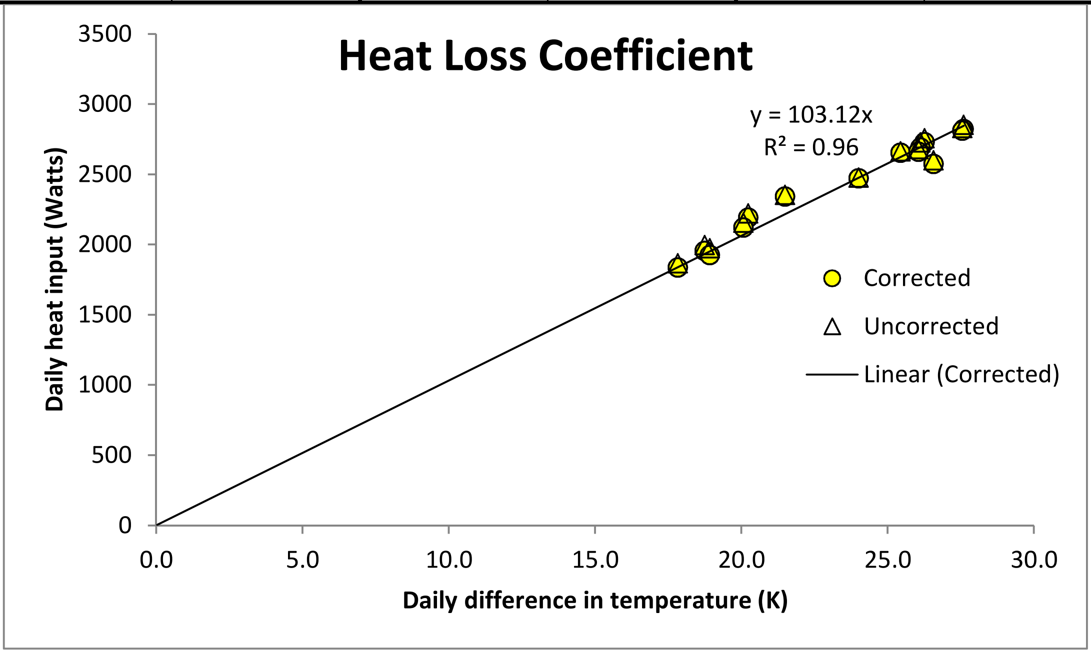
(3806-31140) 1 SAP analysis as-designed (y value = 0.08)

(3806-31140) 2 SAP analysis as-built (y value = 0.08)

3.4 Heat Loss coefficient review

The heat loss coefficient, which is a plot of the daily heat input (in Watts) to the dwelling against the daily difference in temperature between the inside and outside, is given in Figure 17. This was obtained from the co-heating test (Section 3.1) and the coefficient is attributable to heat loss through the building fabric and background ventilation. The slope of the plot gives the heat loss coefficient in W/K, in this case, 103.12 W/K and is corrected for wind speed and solar gain. However, it is clear to see from the plot that these environmental conditions have a negligible effect on the heat loss coefficient, the average

Image ref:	**Figure 17**	**Floor:**	**-**	**Room:**	**-**



Heat loss coefficient chart for plot 5

daily wind speed throughout the test period was only 0.94 m/s, the daily solar flux averaged 91 W/m^2 (building is a timber frame with a low thermal mass so these results are unsurprising).

The as-designed SAP gives a heat loss coefficient of 107.41 W/K but when reviewed using in-situ data, the heat loss coefficient only slightly increases to 108.58 W/K, a negligible difference between the two. The difference was mainly due to a slightly higher post-test air pressure tests - see Section 3.5. However, due to the strong correlation of the co-heating data presented in Figure 17 (see also Section 3.5), if it is assumed that the as-built heat loss coefficient of 103.12 W/K is the correct value then by a trial and error process, a y value of 0.05 in addition to using the in-situ u values would yield a SAP heat loss coefficient close to the measured value. However, the SAP rating would stay at 93.

For comparison, if a default y value of 0.15 was used using measured u value data, the SAP heat loss coefficient would be 120.87 W/K with the SAP rating dropping one point to 92.

The condition of the party wall in the above analysis is explained in Section 3.3.

Main conclusion to emanate from this analysis is that minimising the thermal bridge losses will have a positive impact on heat losses. Giving even more consideration to construction detail will lead to even better energy efficient dwellings and is likely to have as much impact, if not more, on energy efficiency than trying to specify wall components with lower u values.

The additional SAP worksheets for the above can be found as the following attachments:
(3806-31140) 3 SAP analysis as-built (y value = 0.05)
(3806-31140) 4 SAP analysis as-built (y value = 0.15)

3.5 Validation of data - Air tightness

The air permeability test prior to construction was 5.96 $m^3/h.m^2$ @ 50 Pa for plot 5. The post testing air permeability was 6.15 $m^3/h.m^2$ @ 50 Pa in plot 5. Figure 18 shows the air pressure testing underway.

Image ref:	Figure 18	Floor:	Ground	Room:	Hall

Air pressure testing (front door blower)

It was observed during the air pressure test that the external wall electrical sockets and the access hole for opening/closing the valve for the external water tap (Figure 19) were primarily the permeable areas during the test. Other service outlets for waste pipes from the sinks and toilets were well sealed. The influence of the air tight nature of the building is further discussed in Section 6 (BUS survey).

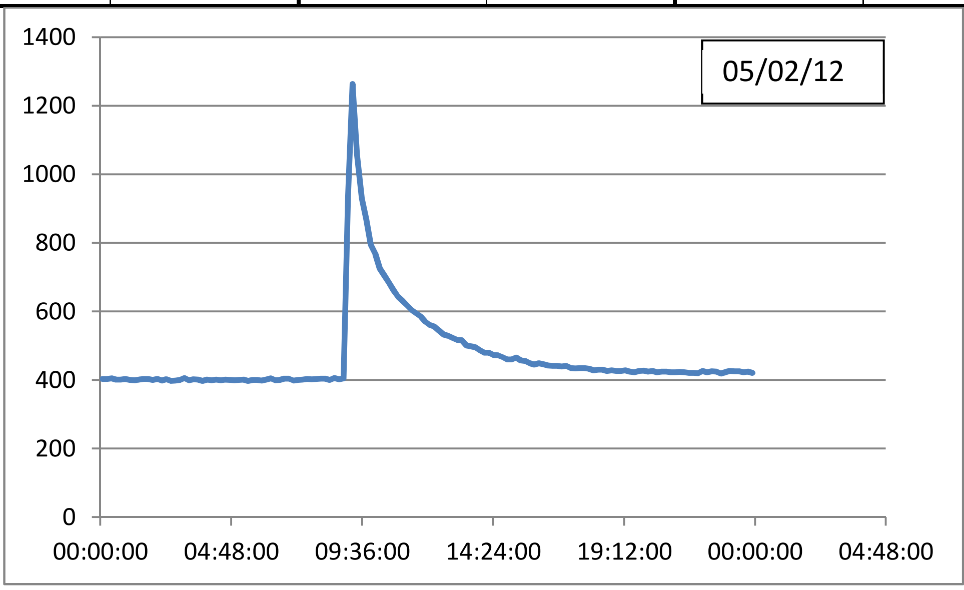
Image ref:	Figure 19	Floor:	Ground	Room:	Under stairs

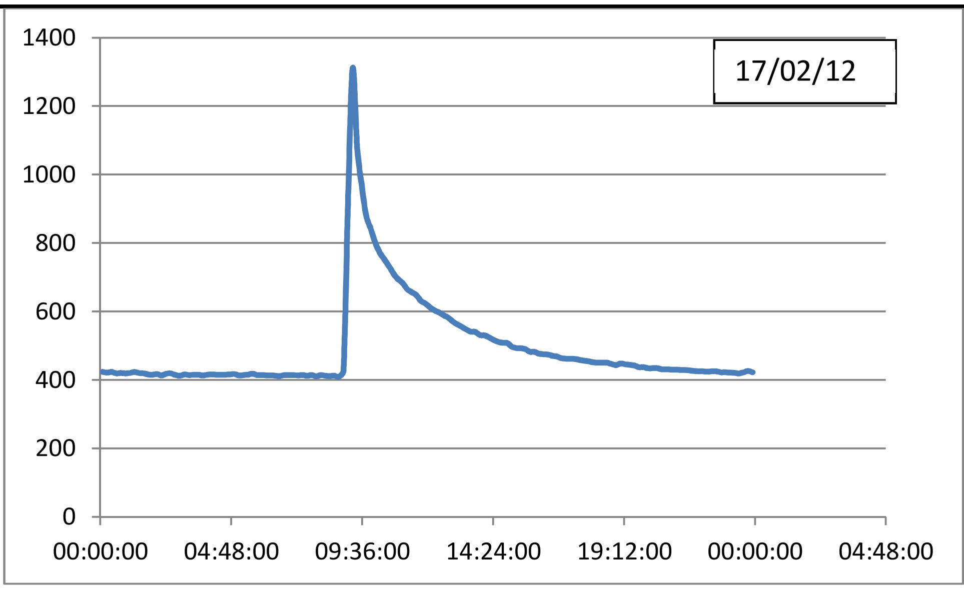
Access hole for valve of external water tap

Due to external circumstances, the post-testing air pressure test was not conducted immediately after the completion of the co-heating test. It was, however, conducted about 3 months later and the results show that the permeability of the building has not changed significantly during this time and, therefore, despite its lateness, the results of the co-heating test are still valid, albeit with the caveat that the second test was conducted late. However, as a result of this matter, the following analysis investigates the accuracy of the co-heating test results which supports its validation.

The first piece of information relates to the CO_2 decay test data. The CO_2 valve was automatically opened at approximately 9am and sufficient tracer gas was discharged (>1000ppm) to enable the gas to decay within 'office hours', this was most likely the time that the property would be entered by stakeholders. A 10l cylinder of gas was used as there were local H&S implications regarding transporting larger (30l) gas canisters so this was used sparingly to avoid having to replenish the gas on a more frequent basis and, thereby, having to enter the sealed property. The lower discharge of CO_2 tracer gas also enabled the curve to decay to base concentration levels as this value is required in the analysis. Examples of two CO_2 decay curves are presented in Figure 20, one at the beginning of the co-heating test and one at the end. This CO_2 decay data is used to estimate the background ventilation rate for the building during test conditions, and also, to determine if there were any significant changes/defects arising to the building during testing which would influence the background ventilation rate.

Image ref:	Figure 20	Floor:	-	Room:	-



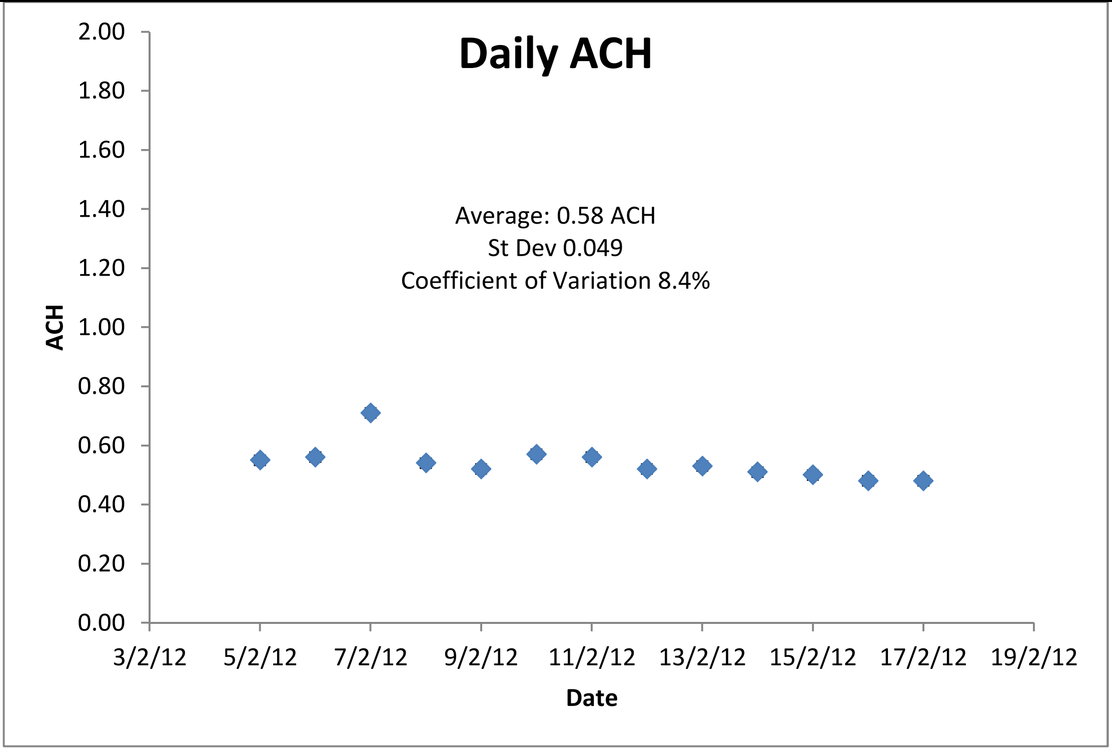


Typical CO2 decay curve from the start and end of the co-heating test

Using the recommendations given by Roulet and Foradini[2], the number of air changes per hour (ACH) is estimated from the tracer gas decay curves (as shown in Figure 20. Note: the normalised concentration equation given in p41 of the paper[2] is incorrect, it should read C_N=(C(t)-Co)/(C(0)-Co), confirmed with the author, June 2012). The daily ACH values are plotted in date order as shown in Figure 21 and show that the average ACH is 0.58 with a standard deviation of 0.049 (coefficient of variation 8.4% which is within research parameters). It is unclear why the ACH for 7/2/12 is higher than the rest of the data (0.71), the heat loss coefficient for this day is actually lower than on other days tested although ΔT was at its highest (as will be shown in Figure 22). The base CO_2 was also higher throughout the night (462ppm) when the average was 426ppm. Further research is required, it may simply be due to equipment or transmission of data. If this value was omitted from the analysis, the ACH would drop marginally to 0.57. Apart from the rogue reading on 7/2/12, the statistical analysis suggests quite a high level of confidence can be placed on the results of the co-heating test (Figure 17) as there appears to be no significant changes/defects arising to the building during the rest of the testing period.

[2] Claude-Alain Roulet, Flavio Foradini, Simple and cheap air change measurements using CO2 concentration decays, International Journal of Ventilation, Vol. 1, No. 1

Image ref:	Figure 21	Floor:	-	Room:	-

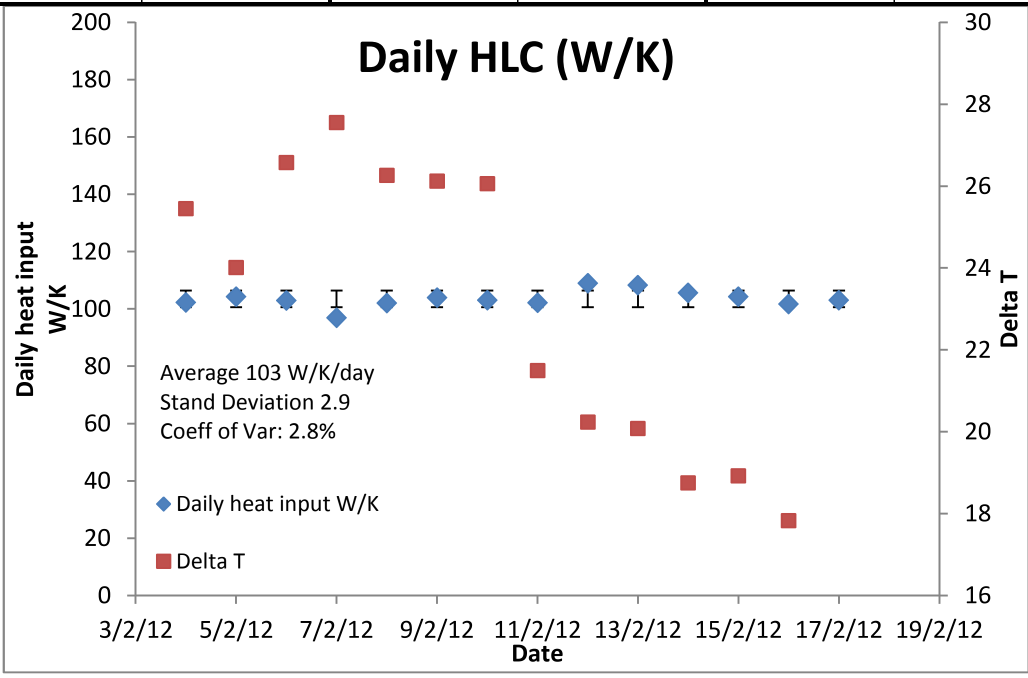


Typical CO2 decay curve from the start and end of the co-heating test

The effective air change rate given in the SAP analysis is 0.64 for February so the air change rates are slightly lower in practice compared to as-designed. It is possible that even greater accuracy could be gained by increasing the amount of CO_2 tracer gas to cover a 24 hour period as opposed to a period covering 'office hours' as described above, but this would have the disadvantage of not having measured base CO_2 levels for use in the calculations and would also require entry to the sealed property if a 10l gas cylinder was used.

The second piece of information to validate the co-heating test is based on normalising the co-heating data to determine if significant changes have taken place in the building during the course of the co-heating test. This is presented in Figure 22, where the corrected daily heat input/K is plotted in chronological order (standard deviation error bars also included). The difference between internal and external temperature (ΔT) during this period is also given and range from 27.6°C to 17.8°C. The lowest value (97 W/K) is recorded on 7/2/12 but this coincided with the largest ΔT as was discussed in the previous paragraph so it is unclear why this occurred.

Image ref:	Figure 22	Floor:	-	Room:	-



Normalised co-heating (W/K/day)

The resulting plot is, nevertheless, quite linear meaning that the building is consuming a similar amount of energy on a daily basis across the two week test period, 103 W/K (standard deviation 2.9 which corresponds to a coefficient of variation of 2.8%). This value naturally corresponds to the heat loss coefficient as shown in Figure 17. This plot and statistical analysis again indicates that the building has not suffered any significant changes or defects during the co-heating tests and despite the lateness in conducting the second air pressure test, the heat loss coefficient (Figure 17) can be relied upon.

3.6 Thermographic Survey

A thermographic survey was conducted inside and outside the building on the morning of Thursday 16th February 2012. A Flir B425 Series infrared camera with an IR resolution of 320 x 240 pixels was used in the study. The day was dry, overcast and still, there was no rainfall in the days or hours preceding the study. The average temperature during the time of the study was 8.3°C externally and 26.8°C internally (the co-heating test began on 2nd February 2012). Average wind speed was 2.2 m/s.

A selection of thermographic images is given from Figure 23 to Figure 29 for key areas with further images provided in the Appendices, Section 11. Referring to Figure 23 through to

Figure 28, it is clear from the internal thermal images that the roof detail has a bearing on heat loss. The pitch of the roof is such that it is impossible to get 400mm of insulation at eaves level - see Figure 31. This was also highlighted by the developer in the walkthrough survey and is something they want to rectify in future developments. Construction details at the eaves/valley junction are given in Figure 32 and Figure 33. The ground floor/wall junctions were also monitored using the thermal camera but no heat loss was evident (images were not recorded).

Image ref:	**Figure 23**	**Floor:**	**First**	**Room:**	**1**

Photo and thermal image of bedroom 1 party wall

Image ref:	**Figure 24**	**Floor:**	**First**	**Room:**	**1**

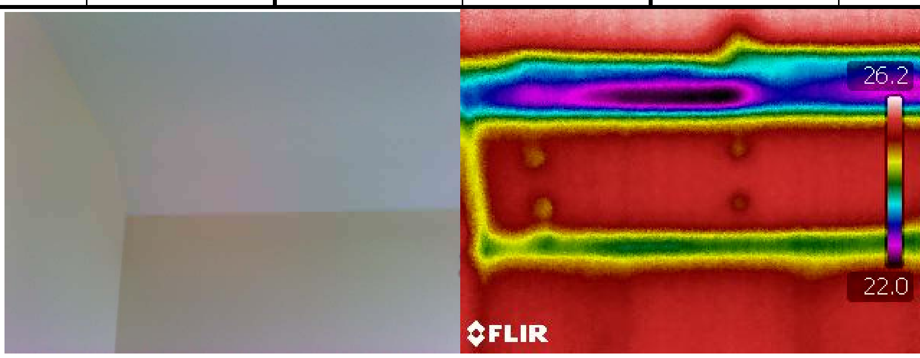


Photo and thermal image of bedroom 1 party wall

Image ref:	Figure 25	Floor:	First	Room:	1

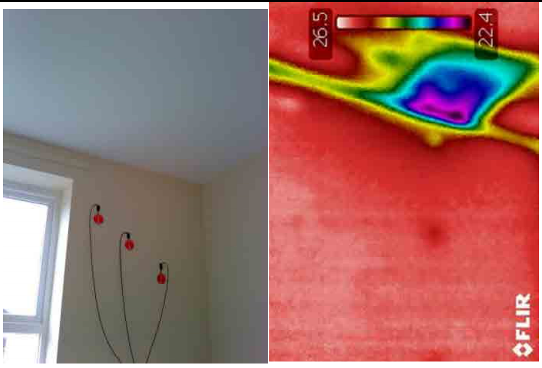


Photo and thermal image of bedroom 1 east wall

Image ref:	Figure 26	Floor:	First	Room:	3

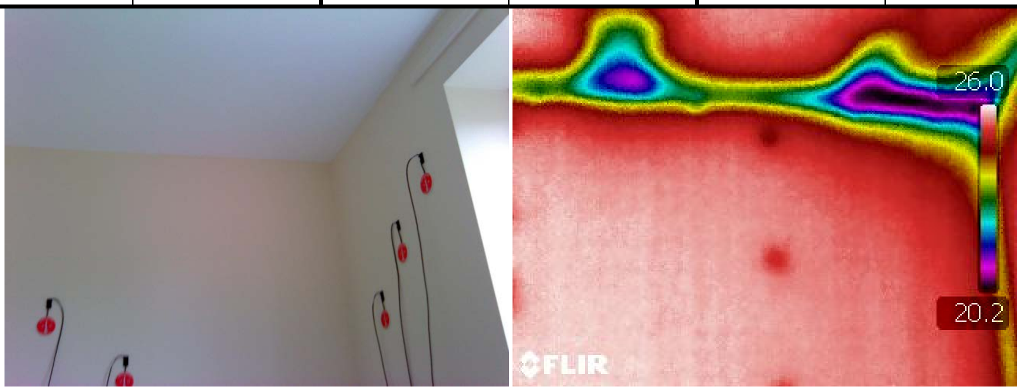


Photo and thermal image of bedroom 3 south/east wall

Image ref:	Figure 27	Floor:	First	Room:	3

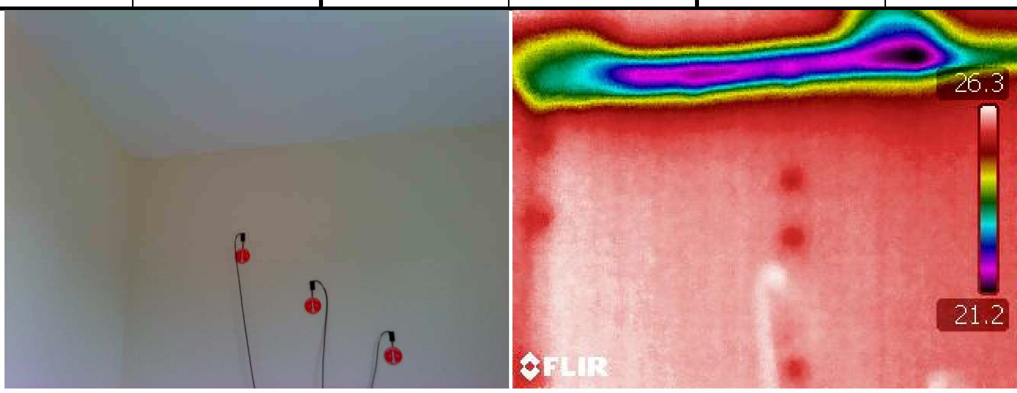


Photo and thermal image of bedroom 3 west wall

Image ref:	Figure 28	Floor:	First	Room:	Landing

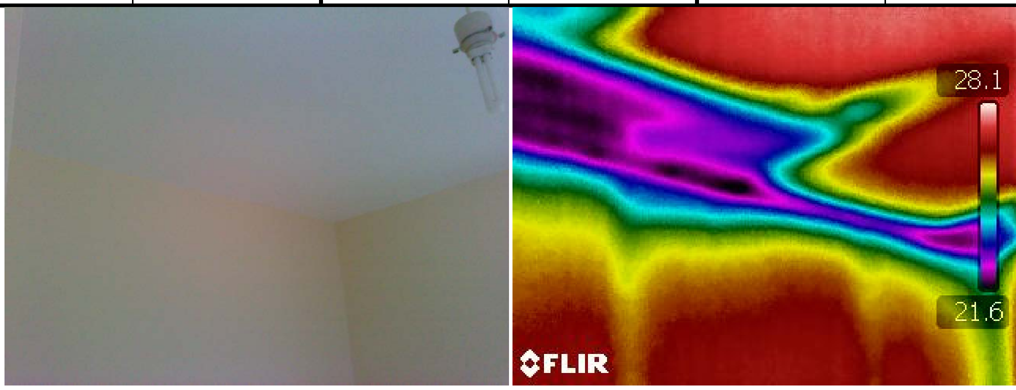



Photo and thermal image of landing south wall					

Image ref:	Figure 29	Floor:	First	Room:	Landing

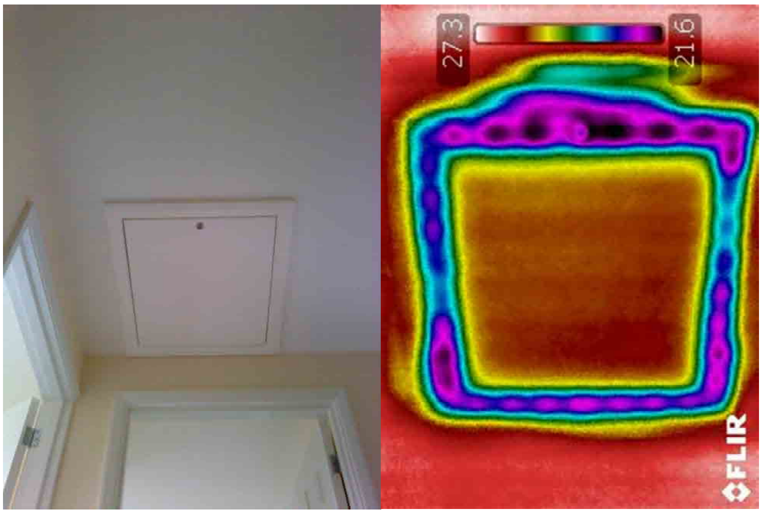



Photo and thermal image of roof space hatch					

Image ref:	Figure 30	Floor:	-	Room:	-

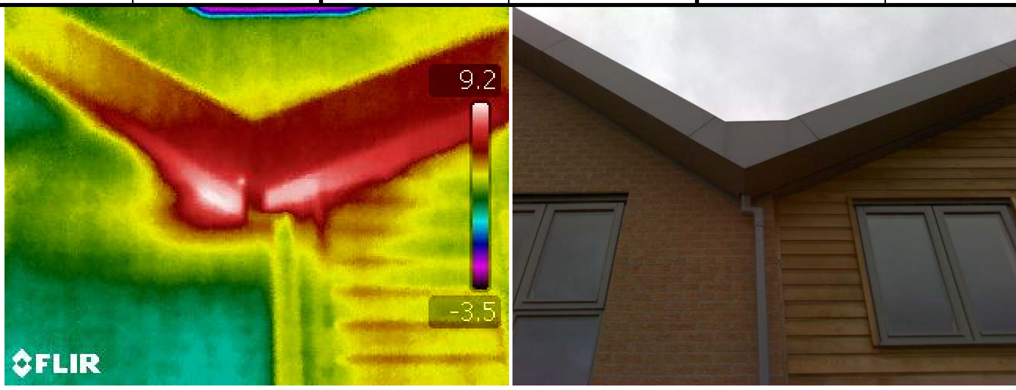
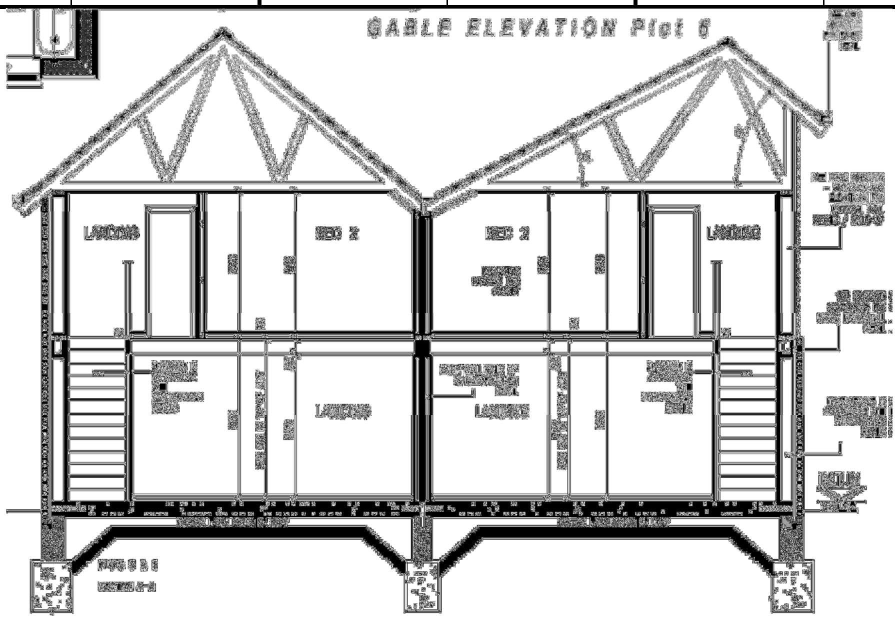


Photo and thermal image of front eaves junction

Image ref:	Figure 31	Floor:	-	Room:	-



Section through plots 5 (left) and 6 (right)

Image ref:	Figure 32	Floor:	-	Room:	-

Roof construction detail at valley

Image ref:	Figure 33	Floor:	-	Room:	-

Valley gutter detail

3.7 Conclusions and key findings for this section

The study established the in-situ u values as shown in Table 2. The design u values were 0.20 W/m^2K for the party wall and 0.13 W/m^2K for all others. The biggest difference between the as-designed and as-measured u value is for the north (party) wall (0.04 W/m^2K higher) followed by the south (0.01 W/m^2K higher). The east and west walls had lower u values compared to design (0.03 and 0.01 W/m^2K respectively). During testing, the adjacent property remained unheated. The east, south and west walls are all insulated with 190mm of mineral wool. Although building regulations stipulate that insulation is not required in party walls, 120mm of insulation was inserted for sound insulation. This is an area worthy of further consideration, since eliminating the 75mm cavity and filling with insulation would give a total insulative thickness of 315mm, perhaps resulting in a better thermal performance. However, it is not clear what effect this would have on sound insulation and further research is required to confirm this.

The above u values were used in the SAP review. SAP version 9.90, NHER Plan Assessor version 5.4.1 was used. The y value was taken as 0.08 due to accredited construction processes being employed. There is a very good correlation between the design SAP values and the values obtained through the review. The in-situ heat loss coefficient is 103.12 W/K whereas the as-built SAP value is 108.58 W/K. The difference was mainly due to a slightly higher post-test air pressure tests - see Section 3.5. However, due to the strong correlation of the co-heating data presented in Figure 17, if it is assumed that the as-built heat loss coefficient of 103.12 W/K is the correct value then by a trial and error process, a y value of 0.05 in addition to using the in-situ u values would yield a SAP heat loss coefficient close to the measured value. However, the SAP rating would stay at 93. For comparison, if a default y value of 0.15 was used using measured u value data, the SAP heat loss coefficient would be 120.87 W/K with the SAP rating dropping one point to 92.

When using this version of SAP (9.90, NHER Plan Assessor version 5.4.1), a u value of either 0.2 or 0.5 W/m^2K can only be selected for the party wall so 0.2 W/m^2K was chosen as this was the closest match to the measured u value of 0.24 W/m^2K.

The thermography survey has highlighted that the roof design has an impact on heat retention. The design specifies that 400mm of loft roll should be inserted, but due to the reduced headroom at the rafter/joist interface (eaves), it is impossible to get 400mm in place. The thermography survey highlights colder spots in the ceiling as a result. Consideration should be given to increasing the headroom at these locations to enable 400mm of insulation to be installed.

The air pressure testing highlighted areas which were permeated during the test - the external wall electrical sockets and the access hole for the valve to the external tap.

4 Key findings from the design and delivery team walkthrough

Technology Strategy Board guidance on section requirements:	This section should highlight the BPE team's initial studies into possible causes and effects, which may require further study. The section should reveal the main findings learnt from the walkthrough with the design and delivery team covering the early stage BPE process and the design intentions. Comment on lessons learned, key findings, conclusions and recommendations on what would be done differently next time. A critical feature of this section is reviewing the original aspirations for the project as stated by the design team and comparing with the delivered building. This often goes beyond what is stated in supporting documentation and is a crucial initial discussion which then frames the discussion about what changed during the process and why. The purpose of the walkthrough is to compare design intent with reality and why there is a gap between the two. Explore the degree to which the design intent has been followed through in terms of delivery and subsequent adoption by the occupant(s). Focus on what constraints or problems they had to accept or address in delivering the project. Cover construction team issues and how these were cascaded through the project for example: training for design team on utilising specific technologies and new materials, sequencing of trades. Describe and evaluate the documentation generated to confirm and record the commissioning and hand-over from specialist contractor to house builder. Include in the appendix if necessary. How did this process influence the design and delivery team walkthrough? Can anything be improved? Capture and assess how decisions were made and captured when the team are together e.g. the materials being used and whether they are required or desired – is there the possibility of changing materials and if so it this known by the procurement and constructions teams. Are there any issues relating to the dwelling's operation? This would include: programmers; timing systems and controls; lights; ventilation systems; temperature settings; motorised or manual openings / vents. Do the developer / manufacturer produced user manuals help or hinder the correct use of the dwelling? Have there been any issues relating to maintenance, reliability and reporting of breakdowns of systems within the dwelling? Do breakdowns affect building use and operation? Have issues been logged in a record book or similar? Add further explanatory information if necessary. Explain any other items not covered above that may be relevant to a building performance study. This walkthrough should be compared and contrasted with the occupant walkthrough (see later section) with comments on whether the design intent was desired, delivered and valued by the occupant and where and how differences between intent and expectation have arisen. If action was taken to remedy misunderstandings, improve support or feed occupant preferences into future design cycles this should be explained. Graphs, images and test results could be included in this section where

	it supports a developing view of how well or otherwise the design intent has been delivered during the pre and post completion phases. This section should provide a summary of the initial aftercare process, post completion building operation, and initial maintenance and management – particularly in relation to energy efficiency, reliability, metering strategy, building operation and the approach to maintenance i.e. proactive or reactive. Guidance on walkthroughs is available in the document *TSB BPE Domestic - Guidance on handover and walkthroughs.doc*, which can be downloaded from the Building Performance Evaluation site on `_connect'.

4.1 Design and delivery team walkthrough

A design and delivery team walkthrough was conducted on plots 5 and 6 in February 2012. Since both properties are similarly designed (one is a mirror image of the other), the information presented below covers the walkthrough of both properties.

4.2 Dwelling operation and usage patterns

- Previously in these types of designs, the consumer unit, PV isolator and switch gear were located in the hallway and were considered unsightly. They are now located under the stairs (Figure 34). The PV isolator switch is to be replaced by a less intrusive isolator switch in future designs.

Image ref:	**Figure 34**	**Floor:**	**Ground**	**Room:**	**Under stairs**

Consumer unit, switch gear and pv isolator switch located under the stairs

- Originally passive stack was considered but both toilets were designed with mechanical ventilation. In the Loft Living properties (where the kitchen is upstairs), there is not enough room for the stack effect, both due to the shallow roof pitch and amount of bends required in addition to looking unsightly.

- The living room was designed with large picture windows to provide maximise access to natural light & minimise artificial lighting requirements. Potential overheating problems associated with large windows were mitigated by orienting them to east & west elevations only and adopting a suitable ventilation strategy. However, the residents had not experienced a very warm summer yet and overheating may yet be an issue, especially if climate change leads to warmer summers. Having said that, these designs replicate a similar design concept on a previous development completed in 2007 that has reported few overheating complaints. Both developments enjoy a suburban location with significantly lower noise & air pollution issues than those associated with dense urban developments. A summer cooling ventilation strategy using openable windows and purge cross ventilation between the warmer east or west elevations and the shaded, cooler air on the opposite side of the dwelling was therefore incorporated.
- The heating thermostat is located in the hallway so easy to view (Figure 35). It is digital so the occupant can easily see what temperature the building is operating at and control is easier via a dial.

Image ref:	**Figure 35**	**Floor:**	**Ground**	**Room:**	**Hallway**

Heating thermostat located in the hallway

- an electric shower is provided over the bath. It is not clear to the designers if this design (with pv) is better than a shower fed from the bath mixer taps (with solar thermal). They are undertaking a small scale trial elsewhere to determine which is better.

Image ref:	Figure 36	Floor:	First	Room:	Bathroom
					
7.5 kW electric shower over bath					

4.3 Other points

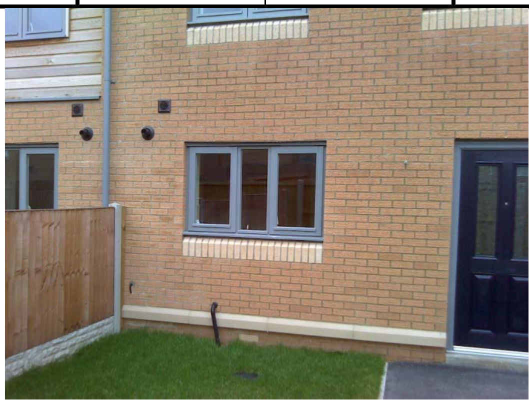
- In the properties for sale (4 off), low energy lighting was installed instead of halogen spots which was not greatly appreciated by the sales team
- The location of the boiler crops up on most designs. It is located in the kitchen on an external wall and hidden in a ventilated cupboard since there is no other logical place for it (Figure 37).

Image ref:	Figure 37	Floor:	Ground/First	Room:	Kitchen
					

Boiler located within a cupboard space in the kitchen

- Double glazed timber windows were installed as these were considered easier to repair over time as opposed to PVC. However, it is not know which product offers better longevity (Figure 38).

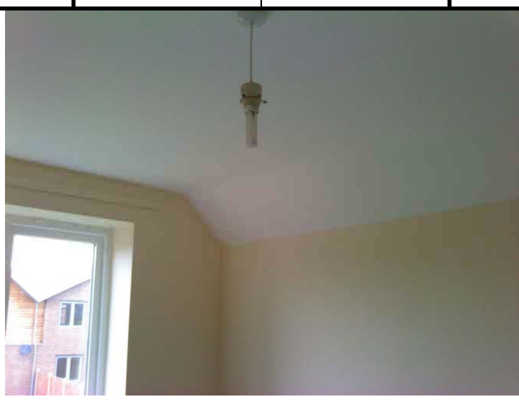
Image ref:	Figure 38	Floor:	Ground	Room:	Kitchen



Example of a timber window, ground floor kitchen

- Due to the shallow roof pitch, some of the upstairs rooms have a chamfered ceiling which is unsightly (Figure 39). In properties where the design is inverted (kitchen upstairs), the kitchen units had a reduced depth due to this detail. This also had implication on the depth of insulation that could be installed in the roof at these locations (see also Section 3.6).

Image ref:	Figure 39	Floor:	First	Room:	Bedroom 2



Example of a chamfered ceiling due to shallow roof pitch

- The design included a detail where an allowance was made for settlement of the timber frame. The timber frame can settle by 6-10mm per floor, hence the brickwork was stopped short of the roof and the gap filled by a compressible filler to accommodate the settlement (Figure 40).

Image ref:	Figure 40	Floor:	-	Room:	-
					
Examples of compressible filler between roof and brickwork					

- There were signs of water ingress above the front door (Figure 41). This may be as a result of the detail where the door frame meets the wooden cladding as this is the likely place where the water entered. It would be better if the wooden batten (Figure 43) was sloped away from the building and a strip of silicone included to make this zone watertight. Water ingress was also evident in another property during the interviews, see Figure 43).

Image ref:	Figure 41	Floor:	Ground	Room:	Hall
					

Water ingress over front door

Image ref:	Figure 42	Floor:	Ground	Room:	Hall
					
Door frame/cladding detail					

4.4 What would be done differently next time

Main issues arising were external as opposed to internal.

Changing the detail between the head of the door frame and cladding for a sealed sloping batten would eliminate the water ingress problems encountered.

In addition, this was the first time that water harvesting was included in a scheme. The full benefits of this are yet to be realised but an estimate of benefits is presented from Section 7.1 onwards.

4.5 Conclusions and key findings for this section

The design team are very open and aware of how they can improve the appearance and performance of their buildings as highlighted in Sections 4.2. Further user-based recommendations on how the design can be improved are given in Section 6.3.

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

Technology Strategy Board guidance on section requirements:	It is essential that this section provide a critical evaluation of any guidance provided, therefore there should be an explicit review and critique of the materials used for the handover. The evaluation of the written documentation is a separate exercise from the walkthrough and needs to tackle clarity, comprehensiveness, layout, longevity, ease of access and relevance (i.e. are some aspects season specific). What was the main source of material? Were these written or visual, bespoke or generic? Does the guidance use good English with a comprehensive and user-friendly layout? In addition to the comprehensive handover literature / guidance evaluation, the section should cover the occupier handover process, initial aftercare process, post completion building operation, and initial maintenance and management – particularly in relation to energy efficiency, reliability, building operation and the approach to maintenance i.e. proactive or reactive. The evaluation must cover the use of training and operating manuals, aftercare and any interviews and discussions. The aim is to compare how well the demonstrator uses and communicates the written guidance provided by the developer to the occupant and how well they demonstrate the home. Special attention should be given to how interactive the tour is, and whether the occupant allowed to try things out for themselves or not. It is imperative that the observer does not intervene in the proceedings at any point, but is simply a 'silent witness'. Any conflicting advice given in relation to the functioning of the home or the written guidance provided should be noted with the reason why this has occurred where possible. This will help to improve training of demonstrators where needed or pick up on changes needed to procedures, documentation etc. Was the demonstrator clear on what aftercare entails? How were the handover processes carried out? Were the handover materials (i.e. user manual) used and referred to constantly throughout the handover. How were occupiers trained to use equipment and do they demonstrate the right competences? Was there a proper handover and a system put in place to log problems, and did this help resolve teething issues? If any handover processes were not completed, please detail why. Comment on key findings, conclusions, and lessons learned and investigate recommendations on what would be done differently next time. This walkthrough should be compared and contrasted with the delivery and design team walkthrough (see previous section) with comments on whether the design intent was desired, delivered and valued by the occupant and where and how differences between intent and expectation have arisen. If action was taken to remedy misunderstandings, improve support or feed occupant preferences into future design cycles this should be explained. Ideally the observer should tape the proceedings and analyse a transcript. The occupiers' permission must be sought to do this. If

	recording is not possible, then notes should be taken using the document *TSB BPE Domestic - Guidance on handover and walkthroughs.doc* (available on `_connect') as a guide to establish whether the home demonstrator has communicated all relevant aspects in relation to the written home user guidance provided and manuals.

5.1 Observation of handover

Due to the fact that the evaluation commenced after residents had moved into their homes, a mock handover was carried out on 8 November 2011. The mock handover was carried out by Saxon Bond from South Yorkshire Housing Association and was observed (and recorded, with the residents' consent) by James Pinder on behalf of Sheffield Hallam University. The interviews with occupants (Section 6.3) had revealed that, when moving into their moves, residents had simply collected their keys from a show home and were not provided with a formal handover. However, all residents were visited a month or so after they had moved in and were provided with guidance about their home, the details of which formed the basis of the mock handover. This method was employed since, due to previous experiences of South Yorkshire Housing Association, moving can be a stressful event and feeding face-to-face handover information immediately upon moving in add to the levels of stress experienced by residents. Therefore, residents were allowed to settle for a short while before a face-to-face meeting was conducted.

Table 3 provides a summary of the items that were covered in the mock handover and the handover documentation (which was given to residents when they moved into the house). Very few of the issues in the table were covered in the mock handover, which was primarily focused on energy efficiency advice. Issues covered in the handover included:

- An explanation of how residents could get the most benefit from the solar PV system fitted to their home, for instance by running long cycle appliances during the day and staggering the use of larger electrical items.
- The fact that residents would not receive the feed in tariff (because the scheme had received grant funding)
- The fact that the homes were fitted with a rainwater harvesting system, although residents had reported that this had not been functioning properly.
- Advice on buying energy efficient appliances and light bulbs, and the importance of switching off electrical appliances when they are not being used.

Overall, the handover could best be described as 'challenging', in that one of the residents was sceptical about the benefits/effectiveness of the solar PV and rainwater harvesting systems, and repeatedly questioned the advice/knowledge of the demonstrator. The handover was therefore frequently ‘sidetracked’ and it's questionable as to how much of the advice/guidance was taken onboard by the residents.

Table 3 Items covered in mock handover

	Explained in handover	Explained in documentation
Kitchen		
User guide and manuals explained		✓
All appliances and warranties including energy labelling	✓	✓
Heating and hot water controls (if located here)		✓
Location of stop cock		✓
Lighting and lighting controls		✓
Operation of rear door / outside access		
Living rooms		
Fire (if fitted), flue position (if provided) and class (i.e. 1 or 2)		n/a
Window/ ventilation controls		✓
Heating controls		✓
Lighting and lighting controls		✓
Operation of rear door / outside access		
Bathroom and en-suites		
Window / ventilation controls		✓
Heating and hot water controls		✓
Shower and bath operation including any special fittings	✓	✓
Door lock and operation		
Extractor fan and isolator switch, if applicable		✓
Lighting and lighting controls		✓
Bedrooms		
Telephone, television point		n/a
Door		
Window/ ventilation controls		✓
Storage		
Heating controls		✓
Roof lights		n/a
Lighting and lighting controls		✓
Hallways, stairs and landings		
Operation of front door		
Smoke alarms		✓
Lighting and lighting controls		✓

	Explained in handover	Explained in documentation
Loft access, including insulation, renewables, controls, aerial termination points, loadings i.e. boarding out and storage, risks		
Airing cupboard		
Systems and controls – boiler, heating / heat recovery		
Cut off points		✓
Type of cylinder		n/a
Immersion heater		n/a
MHVR or other controls		n/a
Renewables and controls		✓
Boiler service		✓
Any additional features / controls		
Room thermostat / other heating controls		✓
Consumer unit and trip switch / fuses		✓
Internal services and fixings		
External		
Meter box position		✓
Gas cut-off point		✓
Outside tap and stop cock location		✓
Water meter location		✓
Location of any microgeneration technologies	✓	✓
Miscellaneous		
Certificates		✓
Utility company info	✓	✓
Security and alarm systems		n/a
On completion of the tour		
Overview of any dwelling performance monitoring		n/a
Outline procedure of legal completion day		
Outline post completion procedure		
After sales procedure and emergency numbers		✓

5.2 Review of written documentation

A *Home User Guide* was provided to residents when they moved into their new home which included some basic description of the construction. In addition to this guide, residents were also provided with copies of a *User Manual,* which included information for the boiler, solar PV system, shower and other appliances installed in their homes. As well as providing information about the house itself, the *Home User Guide* also provide information about local transport services, emergency services, contact numbers and flow charts for diagnosing faults (smoke alarms, lighting, heating, electrical sockets).

Many of the items in Table 3 were covered in the *Home User Guide*, although some superficially and not always with the utmost clarity. For instance, the *Home User Guide* says that stop cock is under the kitchen sink, but does not provide any other information about how to identify and use the stop cock (it is assumed that residents will know this). The *Home User Guide* was generally well written but the clarity and detail of information varies in the *User Manual*. The *User Manual* is quite detailed and includes a quick start guide to providing heating and hot water. Information is given on the location of the wall mounted thermostat and radiator TRVs. These components will be further investigated in Section 6.2. Maximum temperatures of the hot water is limited to 48°C and maximum flow rates from the taps and showers are given (further analysis in Section 7.4). Extractor fans are continuously-running silent fans and do not require to be turned on or off. For rented dwellings, rainwater harvesting process is described to feed the downstairs toilet, washing machine and outside tap. The PV is also described in the quick start but it does not say that no action is necessary for operation nor how to maximise use of free energy.
The *User Manual* includes information as you would expect to find, but it is a case of information overload. The Quick Start Guide at the beginning should be used to highlight pertinent tips on how to get the best from the property, for example, use long cycle appliances during the daytime (e.g. washing machine) when the solar PV is operating at its peak. Original and/or glossy brochures may be easier to read than a manual full of poorly copied pages.

5.3 Conclusions and key findings for this section

- The interviews reported in Section 6.3 revealed that residents were not provided with a formal verbal/face-to-face handover when they moved into their homes – they were simply provided with the keys and user manuals for their homes
- A month or so after moving into their homes, residents were visited by a representative of SYHA and provided with advice about how to be more energy efficient in their new homes

- Observation of the mock handover suggested that providing guidance and advice to residents can be challenging, particularly if they are not willing to listen to the advice or are sceptical of the information provided.
- Most of the guidance about the homes was provided in writing in the form of *Home User Guide* and *User Manual*. The *Home User Guide* was generally well written and structured, but the quality and clarity of information in the *User Manual* was very mixed, particularly as it was comprised of user manuals from manufacturers.
- Observation of the mock handover and review of the written documentation suggests that there is a need to strike a balance between overloading residents with information/guidance and leaving them to work out themselves how to use their houses (with support from written documentation).
- The handover process in this scheme clearly did not address most of the issues in Table 3 and residents will, therefore, be reliant on written documentation, some of which they may find difficult to interpret. Consideration needs to be given to communicating the information more effectively by ensuring the right information is in the right place at the right time.
- Our findings suggest that in future schemes SYHA should ensure that residents are provided with a formal handover, but should also consider delivering guidance and advice via other media, such as a website or DVD. This might enable guidance to be targeted more specifically and be more interactive.

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

Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the early stage BPE process and in particular from the Building Use Survey. This section should be cross-referenced with findings from the occupant handover process and be informed by the design and delivery team walkthroughs. This section should draw on the BPE team's initial studies into possible causes and effects, which may require further study. BUS information will be stored in the data repository, but the link for BUS anonymised results should be included in this report. The BUS results come in 3 forms: • An anonymous web-link that will contain the result and benchmark graphic for each variable (question), a summary of the 12 main variables and some calculated summary variables. • Appendix A (.pdf) which contains largely the same set of results and graphics as the link above. • Appendix B (.pdf) which contains all the text comments from the questionnaires Reference the variable percentile scores, which show the percentile that the score is ranked at in the benchmark set, and comment on as appropriate. **Important:** The comments from Appendix B can be used in this section. However, great care must be taken when using comments to ensure that no personal information is divulged, no individual can be identified and no confidentiality is breached when publishing the comments. This is especially important if referring to a respondents' background. Graphs, images and test results could be included in this section where it supports a developing view of how well or otherwise the design intent has been delivered during the pre and post completion phases. Note where the dwelling is being used as intended and where it is not; what they like / dislike about the home; what is easy or awkward; what they worry about. It should cover which aspects provide occupant satisfaction and which do not meet their needs, result in frustration and / or compensating behaviour on the part of occupants. Any misunderstandings occupants have about the operation of their home should also be addressed. Are there any issues relating to the dwelling's operation? This would include: programmers; timing systems and controls; lights; ventilation systems; temperature settings; motorised or manual openings / vents. Do the developer / manufacturer produced user manuals help or hinder the correct use of the dwelling? Have there been any issues relating to maintenance, reliability and breakdowns of systems within the dwelling? Do breakdowns affect building use and operation? Does the occupant have easy access to a help service? Does the occupant log issues in a record book or similar? Does the occupant have any particular issues with lighting within the dwelling (both artificial lighting and natural day lighting)? Add further explanatory information if necessary From the occupiers point of view what improvements could be made to the dwelling to make it more user friendly and comfortable to live in. Cover what the teams' would do differently in future (or wanted to do differently but could not) and why.

6.1 Building User Survey - background

The BUS questionnaires were distributed between November 2011 and February 2012 to all occupied properties within the development. This totalled 18, the tenure being rental. The four 'for-sale' properties were unoccupied at the time.

Numerous attempts were made to get the residents in as many properties as possible to return the questionnaire. This involved calling at the properties (5-6 visits), dropping questionnaires through the letter box (November and February) or writing to them (once). In the end, 11 households completed the survey giving a 61% response rate. The following section gives a snapshot of the results.

The BUS anonymised results can be found at:
homepage.mac.com/busmethodology/9015/index.html

6.2 Building User Survey - results

A snapshot of the BUS results is given in Table 4. The study variables are graded as either red, amber or green. Study variables have further information given in the 'Comments' section - the study mean score (between 1-7), the study building percentile in relation to other buildings in the benchmark dataset and quintile. This section will mainly concentrate on the study variables graded red with other positive variables (good practice) discussed as appropriate. 'Slider' scale and benchmarking are also given for these variables.

Referring to Table 4, the air in summer is considered humid and stuffy but in Winter it is still. However, this is an area worthy of further investigation since residents moved into their properties in September 2011 and they would not have experienced a very warm Summer so these residents may become even more uncomfortable in due course. No specialist ventilation is provided except mechanical extraction in the kitchen and downstairs toilet and bathroom. No other comments on this were made in the BUS. However, referring to the fabric test results (3), the analysis of the CO_2 decay test show that, on average, the building has an average background ventilation rate of only 0.58 air changes per hour (measured during the co-heating test). This is an area for further consideration at the handover stage, where residents should be made aware of the air tight nature of the building and stuffiness may result unless manual ventilation is managed in the building (i.e. opening windows).

Temperature in the winter is considered to vary and this may be due to losses as identified and described by the thermal survey in Section 3 (loss of insulation in the roof space at the eaves junction). In addition, some respondents commented:

It works well with the layout. Living area warm, sleeping cool. Occasionally too cold downstairs though.

Radiators don't get hot unless you have them on full.

Still used more heating whilst weather is bad.

but a further resident commented:

Our house doesn't need the heating on for long periods of time.

It may be that the residents are unaware of how to use the TRVs on the radiators or use the heating thermostat to control indoor temperatures and this needs to be highlighted during the handover process and in the documentation. In the *Home user guide*, there is also a flow chart on how to deal with problems associated with heating but it needs to be expanded, for example, it assumes the resident will know what a 'room stat' is and where the 'thermostatic radiator valves' are in the property. Thumbnail pictures would help. These components are described in more detail in the *User Guide* via manufacturers' literature but this guide is not user friendly and difficult to read (see Section 5).

The occurrence of light in the building, either natural or artificial edges towards 'too much' but is graded red. This is not necessarily an issue as the design intent was to get as much natural light as possible into the properties through the specification of large picture windows. However, one resident commented:

Too many light fittings in living room, hall and kitchen.

When asked to grade the 'Lighting overall', the study mean was 6.09 giving a percentile score of 99.

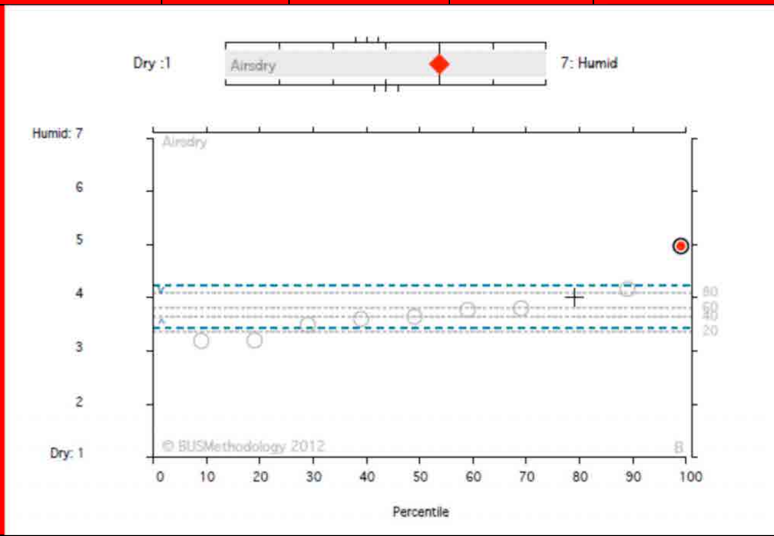
Noise from neighbours and from outside also gets a red grade as it is in the 'too little' side of the scale but again, this is a positive outcome as residents are happy with this (the residents perhaps mis-interpreted how to complete the survey). However, location within the development can lead to noise pollution as '*Kids congregate outside'*.

The running costs are towards the lower end compared to what they were paying previously. Utilities costs for electricity, heating and water were 32, 10 and 32 percentile respectively.

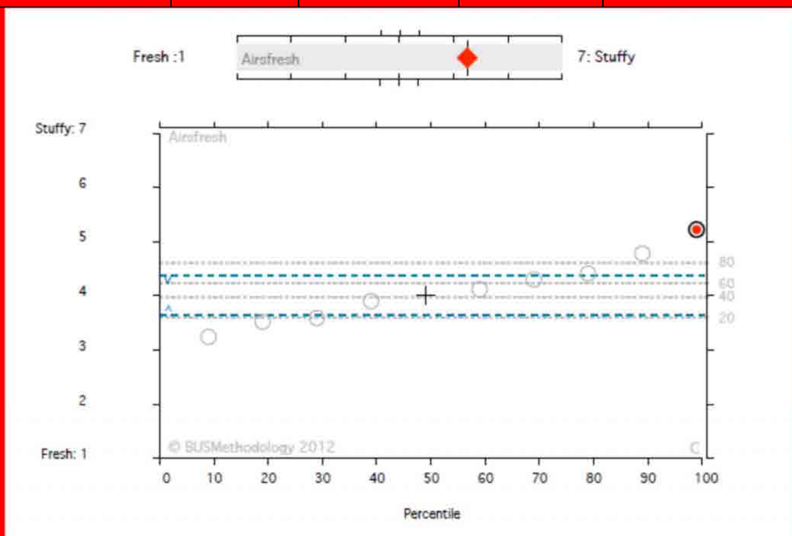
The Summary, Comfort, Satisfaction and Forgiveness Indices are all 99 percentile.

Table 4 Summary of BUS User Survey results

	Red	Amber	Green	Comments
STUDY VARIABLES				
Air in summer: dry/humid	✓			Study mean: 5 Study building percentile: 99 Quintile: 5

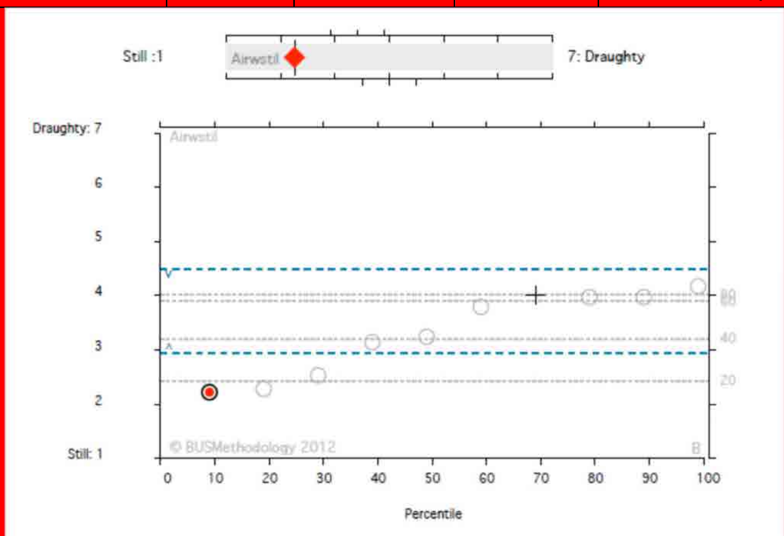


	Red	Amber	Green	Comments
Air in summer: fresh/stuffy	✓			Study mean: 5.25 Study building percentile: 99 Quintile: 5



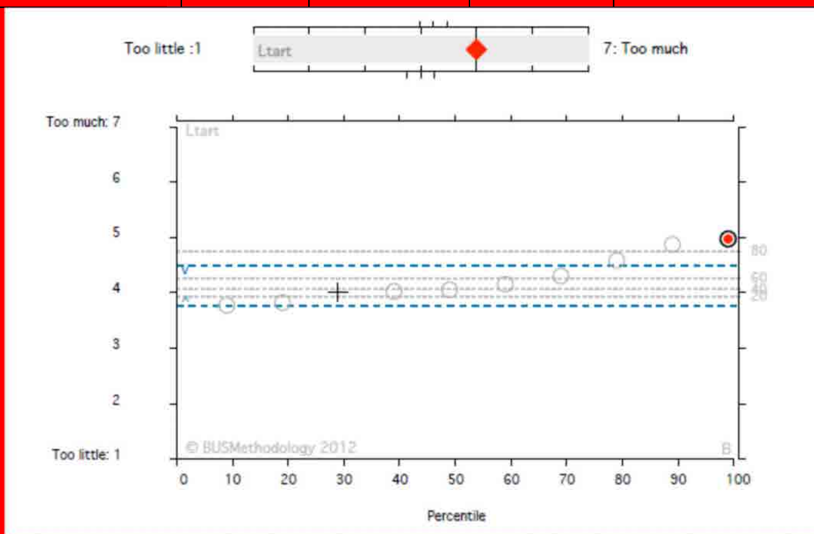
	Red	Amber	Green	Comments
Air in summer: odourless/smelly		✓		Study mean: 3 Study building percentile: 59 Quintile: 3
Air in summer: overall		✓		Study mean: 4 Study building percentile: 39 Quintile: 2

Air in summer: still/draughty		✓		Study mean: 3 Study building percentile: 39 Quintile: 2
Air in winter: dry/humid		✓		Study mean: 3.63 Study building percentile: 69 Quintile: 4
Air in winter: fresh/stuffy			✓	Study mean: 3 Study building percentile: 19 Quintile: 1
Air in winter: odourless/smelly		✓		Study mean: 2.38 Study building percentile: 19 Quintile: 1
Air in winter overall			✓	Study mean: 5.78 Study building percentile: 99 Quintile: 5
Air in winter: still/draughty	✓			Study mean: 2.25 Study building percentile: 9 Quintile: 1

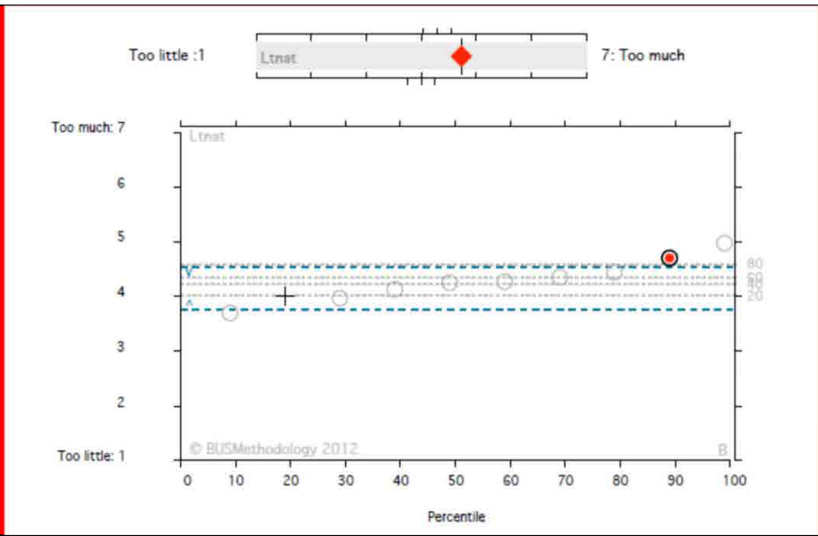


Control over cooling		✓		Study mean: 4.67 Study building percentile: 69 Quintile: 4
Control over heating			✓	Study mean: 6.22 Study building percentile: 99 Quintile: 5
Control over lighting			✓	Study mean: 6.2 Study building percentile: 99 Quintile: 5
Control over noise		✓		Study mean: 4 Study building percentile: 79 Quintile: 4
Control over ventilation			✓	Study mean: 6.11 Study building percentile: 99

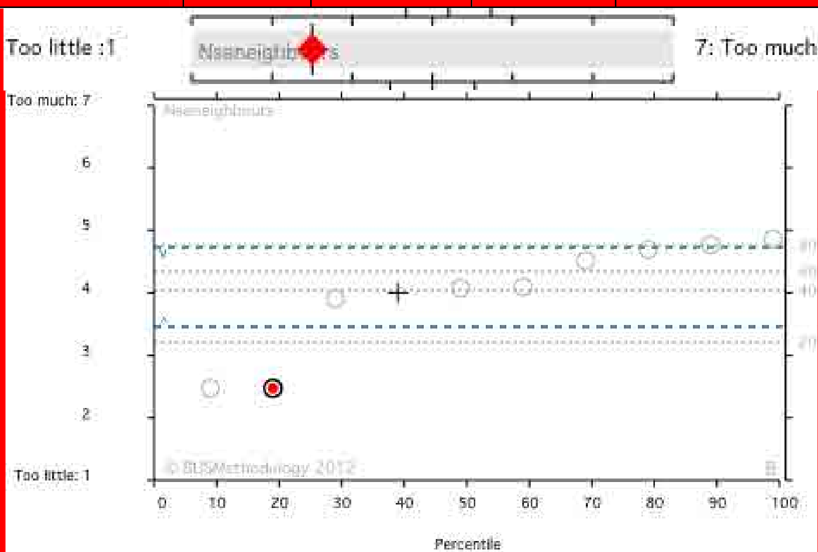
				Quintile: 5
Comfort: overall			✓	Study mean: 6.4 Study building percentile: 99 Quintile: 5
Design			✓	Study mean: 6.36 Study building percentile: 99 Quintile: 5
Health (perceived)			✓	Study mean: 5.18 Study building percentile: 99 Quintile: 5
Appearance from the outside			✓	Study mean: 6.82 Study building percentile: 99 Quintile: 5
Layout		✓		Study mean: 5.82 Study building percentile: 77 Quintile: 4
Location		✓		Study mean: 6.09 Study building percentile: 69 Quintile: 4
Space			✓	Study mean: 5.64 Study building percentile: 69 Quintile: 4
Storage			✓	Study mean: 4.6 Study building percentile: 89 Quintile: 4
Lighting: artificial light (too little/too much)	✓			Study mean: 5 Study building percentile: 99 Quintile: 5



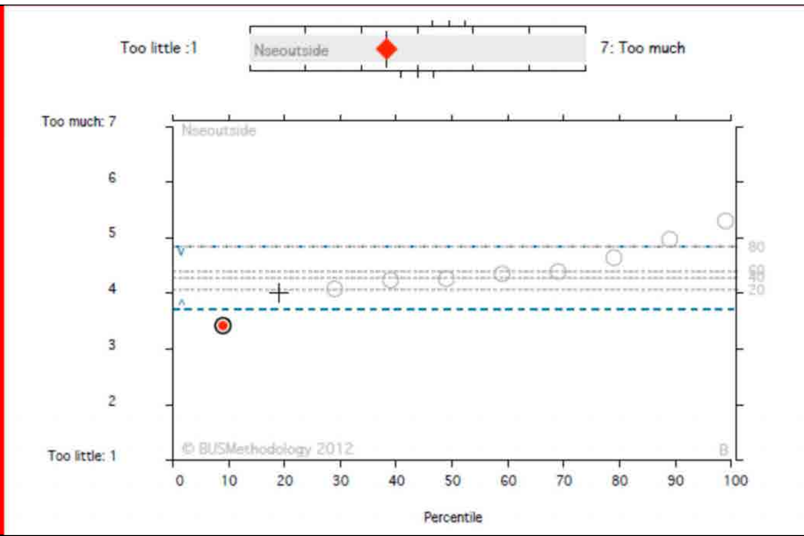
Lighting: natural light (too little/too much)	✓			Study mean: 4.73 Study building percentile: 89 Quintile: 5



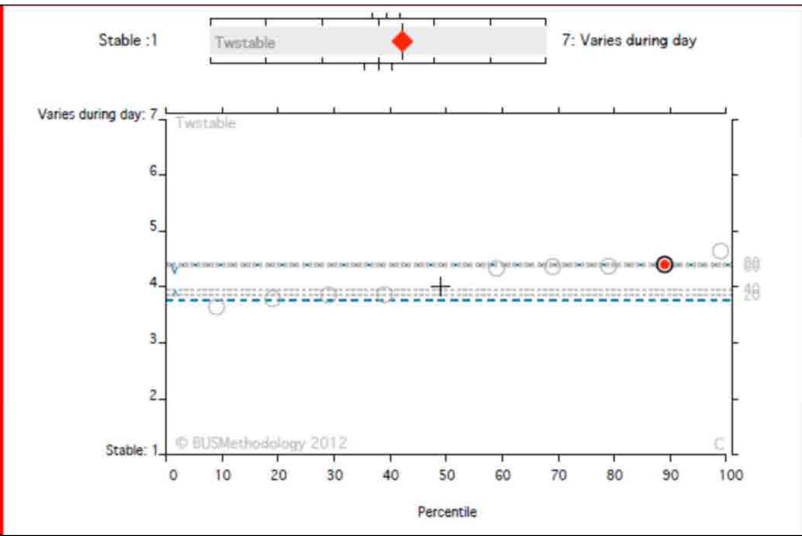
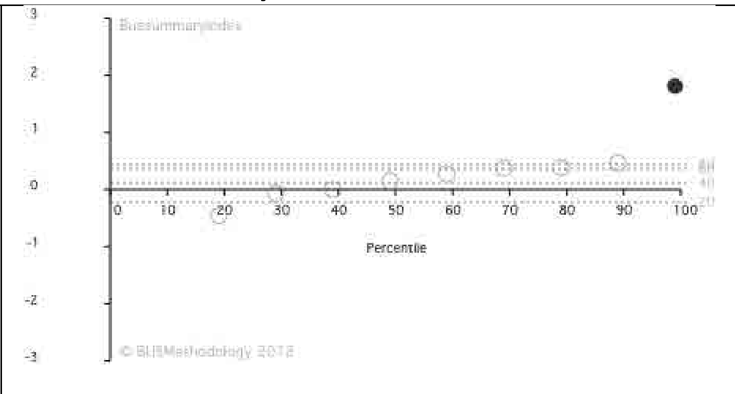
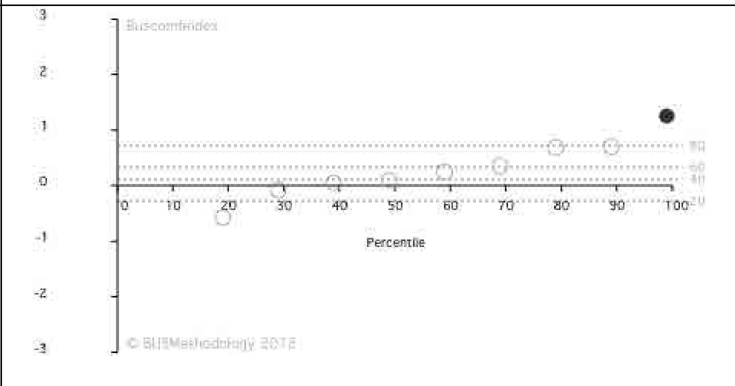
Lighting: overall (unsatisfactory/satisfactory)			✓	Study mean: 6.09 Study building percentile: 99 Quintile: 5
Needs			✓	Study mean: 6.45 Study building percentile: 99 Quintile: 5
Noise from neighbours (too little/too much)	✓			Study mean: 2.5 Study building percentile: 19 Quintile: 1

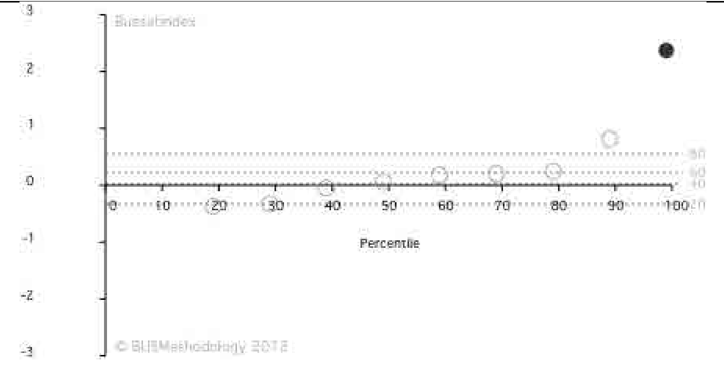
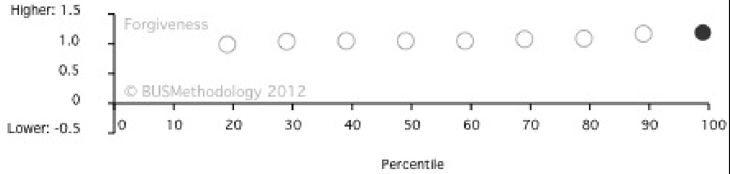


Noise: noise from outside (too little/too much)	✓			Study mean: 3.45 Study building percentile: 9 Quintile: 1



Noise: overall			✓	Study mean: 5.64 Study building percentile: 79 Quintile: 4
Noise: noise from other people			✓	Study mean: 4.36 Study building percentile: 62 Quintile: 4
Temperature in summer: hot/cold		✓		Study mean: 3 Study building percentile: 29 Quintile: 2
Temperature in summer: overall		✓		Study mean: 3.75 Study building percentile: 29 Quintile: 2
Temperature in summer: stable/varies		✓		Study mean: 4.2 Study building percentile: 89 Quintile: 5
Temperature in winter: hot/cold		✓		Study mean: 4.38 Study building percentile: 49 Quintile: 3
Temperature in winter: overall			✓	Study mean: 6.22 Study building percentile: 99 Quintile: 5
Temperature in winter: stable/varies	✓			Study mean: 4.43 Study building percentile: 89 Quintile: 5

					
Utilities costs for electricity (much lower/much higher)				✓	Study mean: 2.75 Study building percentile: 32 Quintile: 2
Utilities costs for heating (much lower/much higher)				✓	Study mean: 2.57 Study building percentile: 10 Quintile: 1
Utilities costs for water (much lower/much higher)				✓	Study mean: 3.67 Study building percentile: 32 Quintile: 2
INDICES derived from main study variables					
Summary Index					Study mean: 1.84 Study building percentile: 99 Quintile: 5
Comfort Index					Study mean: 1.28 Study building percentile: 99 Quintile: 5

Satisfaction Index		Study mean: 2.4 Study building percentile: 99 Quintile: 5
Forgiveness Index		Study mean: 1.22 Study building percentile: 99 Quintile: 5

6.3 Interviews with residents

Interviews were undertaken with residents in six properties at Cross Lane. The interviews were undertaken on Wednesday 7 December 2011 and recorded with the consent of the interviewees. The interview questions are given in Table 5 and the household type is summarised in Table 6.

Table 5 List of interview questions

1. When did you move into your new home?
2. How many people live here and what are their ages?
3. What are the typical occupancy patterns in your home?
4. What are your first impressions of your new home?
5. Have you had any problems with your home since moving in?
6. Have these problems been resolved and were you happy with how they were dealt with?
7. How did you find the handover process?
8. Did anyone explain to you about the solar panels (and rain water harvesting system) installed in your home?
9. Have you had any problems with the solar panels or rain water harvesting system? If so, have these been resolved?
10. Do you think that you have been provided with enough information and guidance about your new home?
11. Has moving here made any difference to your lifestyle?
12. Do you find your home comfortable to live in?
13. What do you like most about your new home?

14.	What do you like least about your new home?
15.	As moving here made any difference to your attitudes towards energy efficiency or the environment?
16.	How do you think the design of your home could have been improved?
17.	Do you have any other comments or feedback about your new home?

Table 6 Household type

Interview no.	No. adults	No. children	House configuration	Move in date
1	2	2	Living space upstairs	21/9/11
2	2	1	Living space downstairs	21/9/11
3	2	3	Living space upstairs	21/9/11
4	1	2	Living space upstairs	21/9/11
5	3	1	Living space downstairs	21/9/11
6	2	1	Living space upstairs	21/9/11

All of those interviewed had experienced the same handover process – they collected their keys from no. 10 Cross Lane, signed the tenancy agreement, shown how to operate the boiler and given a copy of the *Home User Guide* and *User Manual*. Residents were not shown around their own property but did receive a visit from Saxon Bond at a later date, in which she explained about the solar PV systems and rainwater harvesting, and provided them with energy efficiency advice. All of those interviewed said that they were happy with the handover process and information provided to them. Their comments included:

> *"No it doesn't bother me because I wouldn't have taken it in anyway because when you first move in you're too interested in looking around rather than listening, so it's always good to learn it yourself really I think"*

> *"Yeah, they [SYHA] have been absolutely brilliant!" "And if I need anything I ring up and they're really good"*

> *"I think it's always best to find things out yourself – you know it's kind of an adventure moving into another house"*

The handover process is discussed further in Section 5.

On the whole, the residents interviewed were very satisfied with their new homes. Residents described their homes as *"lovely", "absolutely spot on", "just a lovely house generally"* and *"a nice place to live"*. One interviewee commented that

> *"I think they're a very good house, they've been very well thought out actually, to be honest, you know the insulation and everything, I can't complain"*

Most interviewees had previously lived in poor quality private rented accommodation, so their new homes represented a significant improvement. All of those interviewed reported feeling more comfortable than they had in their previous homes. Other aspects of the houses that interviewees particularly liked included:

- the spaciousness of their homes (compared with their previous accommodation)
- the solar PV and rainwater harvesting systems, which had made them feel more environmental conscious
- the warmth of the properties – interviewees reported that they hadn't used their heating systems as frequently as in their previous properties
- the gardens (many interviewees hadn't previously lived in a house with a garden)

However, interviewees did report that they had experienced problems with theirs homes since they had moved in. These problems were as follows:

- all interviewees had experienced an electricity cut/surge soon after moving into the property. This was due to a fault in a local sub-station. The problem had been resolved, although it had caused damage to some electricity appliances, including boilers (which subsequently had to be repaired). It also created problems with the rainwater harvesting systems and some systems had to be repaired.
- one resident reported that their electricity supply tended to trip out when they were using one or more high demand electrical appliances (e.g. ironing at the same as the oven being switched on). This problem had been reported but had yet to be resolved.
- two residents reported water ingress through their front door of the house in the entrance hallway (Figure 43) during wet and windy weather. It was not clear as to whether the water was coming through the door threshold or through the letter box. The problem had been reported but had yet to be resolved.

Image ref:	Figure 43	Floor:	Ground	Room:	Hall
Example of where water ingress through the front door of one property					

- one household had problems with their downstairs toilet, which had to be repaired and was found to blocked with building waste. This problem was reported and resolved.
- one resident reported dampness above the window in the lounge (Figure 44) and that water was leaking from the wastepipe in the bathroom sink. Both problems had been reported but had not been resolved.

Image ref:	Figure 44	Floor:	Ground	Room:	Kitchen
Example of dampness above the window in the kitchen of one property					

- one interview reported that their radiators in the bedrooms (upstairs) felt cold, even though they had been bled and the thermostat (in the hallway) had been set to 21^{o}C. The radiators only felt warm if the thermostatic radiator valves were on full setting
- one resident reported that the water to their bath never ran hot, even though the water in the rest of the house was at the right temperature. This problem had been reported but had yet to be resolved.
- one residents reported that the extract fan in his bathroom was not very effective at removing condensation and that they had to open a window when using the shower

In addition to these problems, interviewees also made some suggestions for how the houses could be improved:

- one resident felt that their smallest bedroom could have been more spacious by making it the same size as their second bedroom

one resident suggested that fences should be erected around the front gardens, so that people cannot walk across the lawns

- two residents did not like the open plan layout between the kitchen and lounge area and would have preferred a door between the two rooms (Figure 45)
- a number of residents felt that the street lighting could be improved

Image ref:	**Figure 45**	**Floor:**	**Ground**	**Room:**	**Kitchen**
Suggested improvement to include a door between the lounge and kitchen area					

6.4 Conclusions and key findings for this section

Questionnaire Survey

The main findings for the questionnaire survey refer to the air conditions in the summer which are humid and stuffy and winter when it is still. It may be that these residents have moved from draughty, poorly insulated properties to new build properties with high levels of insulation and they may need to get more accustomed with this environment. Residents should be made aware of the air tight nature of the building and stuffiness may result unless they manage ventilation into the building. However, this has to be managed in a way that maximises fresh air entering and minimises heat exiting i.e. it is not just a case of leaving windows open. Trickle vents in windows can be new to people if they have not had the experience of dealing with them in the past so this should be made clear in the handover process.

Temperature fluctuations are evident in the winter. This may be due to losses as identified and described by the thermal survey in Section 3 or radiators not working correctly (identified in the interviews with residents).

Overall, the properties relate very positively to other buildings in the benchmark dataset with relatively low running costs.

Interviews with residents

The interviews revealed that residents were satisfied with their new homes, particularly since most had moved from very poor quality private rented accommodation. They were also satisfied with the information provided to them about their new homes. Residents reported a number of problems with their homes, such as water ingress through front doors and a leaking sink, however most of the problems had been resolved in a satisfactory manner. The interviewees also identified ways in which the houses could be improved, the most significant of which was to include a door between the kitchen and lounge and the others were:

- the smallest bedroom could have been more spacious by making it the same size as the second bedroom
- fences should be erected around the front gardens, so that people cannot walk across the lawns
- street lighting could be improved

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

Technology Strategy Board guidance on section requirements:	Provide a review of the building energy related systems, including renewables, regulated and unregulated energy and additional energy users that fall in to different areas (such as pumps for grey water use) and any results found. This section should enable the reader to understand the basic approach to conditioning spaces, ventilation strategies, basic explanation of control systems, lighting, metering, special systems etc. Avoid detailed explanations of systems and their precise routines etc., which will be captured elsewhere. The review of these systems is central to understanding why the building consumes energy, how often and when. Where possible this commentary should be split into the relevant system types. Explain what commissioning was carried out, what problems were discovered and how these were addressed. Discuss as to whether the initial installation and commissioning was found to be correct and any remedial actions taken. Prompt for any training scheme or qualifications that were found to be required as part of the study. Comment on whether the original operational strategy for lighting, heating/cooling, ventilation, and domestic hot water has been achieved. Compare original specification with equipment installed, referring to SAP calculations if appropriate. Give an explanation and rationale for the selection and sizing (specification) of system elements. Use this section to discuss the itemised list of services and equipment given in the associated Excel document titled *TSB BPE_characteristics data capture form_v6.xls*. For each system comment on the quality of the installation of the system and its relation to other building elements (e.g. installation of MVHR has necessitated removal of insulation in some areas of roof). Describe the commissioning process Describe any deviation from expected operational characteristics and whether the relevant guidance (Approved Documents, MCS etc.) was followed. Explanation of deviations to any expected process must be commented in this section. An explanation of remedial actions, if any, must also be given. Describe the operational settings for the systems and how these are set. Comment on lessons learned, conclusions and recommendations for future homes covering design/selection, commissioning and set up of systems. Also consider future maintenance, upgrade and repair – ease, skills required, etc. The document for capturing commissioning information is titled *TSB BPE_Domestic_commissioning sheets.doc*, which can be downloaded from `_connect’.

7.1 Rainwater harvesting

This section of the report is to evaluate how well the rainwater is performing, what could be done to improve any performance issues, and whether this is a good strategy to pursue in the future for South Yorkshire Housing Association (SYHA). This section of the report was written by Cath Hassell of ech2o consultants ltd, www.ech2o.co.uk, cath.hassell@ech2o.co.uk

There are 22 properties on the site. 18 are inhabited by SYHA tenants and four are for private sale. All 18 properties belonging to SYHA have a rainwater harvesting (RWH) system fitted.

Rainwater harvesting system design

- All properties have a completely independent RWH system.
- Storage is 2000 litres ($2m^3$) per dwelling.
- Rainwater is collected from all the roof area, filtered and stored underground.
- The pump is situated in the rainwater storage tank and pumps directly to the WCs and an outside tap.
- The mains back-up is controlled by a solenoid valve in the dwelling. It is activated when there is not enough stored rainwater to meet demand. The mains back-up is delivered to the rainwater storage tank. This means that mains water back-up is pumped, adding to the overall carbon footprint of the system.

Costs of the installation

- There was a provisional sum of £44,000 for the rainwater harvesting.
- Installed costs were greater at £68,513.20.
- Average installed cost per system was £3,806.

7.2 Design of the rainwater harvesting system

Design specification to meet the Code for Sustainable Homes (CfSH)

- The original design detail was for the dwellings to meet Level 4 of the Code for Sustainable Homes (CfSH). This requires a calculated water consumption of 105 litres of water per person per day, and can be met by specifying water efficient appliances.

- It was subsequently decided that the dwellings should meet Level 5 and 6 of the CfSH with regard to water use. Levels 5 and 6 require a use (as calculated by the Code water calculator) of 80 litres per person per day.
- To meet Levels 5 and 6, the usual solution is to rainwater harvesting or greywater recycling.
- Without rainwater or greywater, flow rates etc. can be so low that they cause dissatisfaction among residents.

Attenuation requirements

- Under the CfSH, run-off post development can be no greater than run-off pre development. As the original site was a Greenfield site, run-off post development would necessarily be greater. Therefore the choice was to dispose of the excess rainwater on site or to collect it and use it back in the dwellings.
- Site conditions did not suit soakaways, and attenuation was required to prevent run-off into the nearby river during storm events.
- Installing rainwater harvesting systems to all dwellings on the site would provide a source of water for WC flush and outside use, thus reducing the demand on the mains supply.
- Attenuation for stormwater was required by the Environment Agency as stormwater runs into the River Deame adjacent to the site. Attenuation was designed to ensure surface water run-off rates did not exceed 5 litres/second during a 1:100 year storm event (a standard Yorkshire Water requirement). SYHA were unable to provide the actual attenuation volume that was provided on the site.
- There is a combined on-site attenuation from the RWH of $36m^3$ (18 x $2m^3$ of storage per property). However, as RWH was not specified during the original design calculations for stormwater attenuation, none of this on-site storage could be used to offset the final attenuation volume. If RWH had been specified at the start of the project, it is likely that the final attenuation volume could have been reduced, thus offsetting some of the rainwater harvesting costs.

Design specification to meet Level 4 of the CfSH

- Table 7 shows the original specification to demonstrate compliance for water use.
- It can be seen that the specification easily met the target of a total consumption of 105 litres or less per day.

Table 7 Specification of rainwater harvesting

	Volume	Flow rate	Calculated usage
WC	6/4		20.59
bath	140.00		15.40
shower		4.03	17.61
basin taps		2.50	5.53
sink taps		4.00	12.12
Washing machine		default	17.16
Dishwasher		default	4.50
Calculated Use			92.9
Normalisation			0.91
Total consumption			**84.6**
Code Level			**3/4**
Note: Figures are those as stated in the CfSH Water Calculator			

- **Design specification to meet Levels 5 and 6 of the CfSH**Table **8** shows the calculated usage once it was decided to install rainwater harvesting (based on the calculations as entered by the Code Assessor).

Table 8 Water usage after installing rainwater harvesting

	Volume	Flow rate	Calculated usage
WC	6/4		20.59
bath	140.00		15.40
shower		4.03	17.61
basin taps		2.50	5.53
sink taps		4.00	12.12
Washing machine		default	17.16
Dishwasher		default	4.50
Net internal water			92.9
Rainwater collection			20.60

Normalisation			0.91
Total consumption			**63.9**
Code Level			**5/6**
Note: Figures are those as stated in the CfSH Water Calculator			

- It can be seen that once rainwater is entered, the specification easily met the target of a total consumption of 80 litres or less per day.

Rainwater harvesting

- 16 of the houses fitted with rainwater are three bed houses with a footprint of 42.5 m^2 (85m^2 floor space).
- The remaining two houses are four bed and have a footprint of 60m^2 (120m^2 floor space).
- Barnsley lies in the rain shadow of the Peak District. Its average yearly rainfall is 700mm.
- With a drainage factor of 0.85 (pitched, tiled roof) and a filter efficiency of 90% (industry standard), a house with a footprint of 42.5m^2 can supply 22,760 litres (22.8m^3) of rainfall a year. This will offset the same amount of mains water. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £56 a year.
- With a drainage factor of 0.85 (pitched, tiled roof) and a filter efficiency of 90% (industry standard), a house with a footprint of 60m^2 can supply 32,130 litres (32.1m^3) of rainfall a year. This will offset the same amount of mains water. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £79 a year.

Rainwater harvesting to demonstrate compliance with the CfSH

- The water calculator printout provided by SYHA showed the yield from rainwater as 42,600 litres per year.
- This figure is greater than the calculations as detailed above. We are confident that our figures are correct. They have been calculated using recognised industry design guidance.

It is unclear whether the yield as detailed in the Code submission for the site was due to the Code Assessor stipulating the wrong rainfall for Barnsley or the wrong footprint of the building.[3]

- Table 9 details the difference in yearly calculated yield of rainwater and the subsequent available rainwater per day per person.

Table 9 Difference in yearly yield

Calculation from where	Yearly	Daily rainwater	Occupancy	Litres
SYHA Water Code calculator	42,600	117	5	23.3
ech$_2$o for a 3 bed house	22,760	62	4	15.5
ech$_2$o for a 4 bed house	32,130	88	5	17.6
Note: The requirement for WC flush is 20.6 litres. Therefore rainwater will not offset all WC				

7.3 Installation of the rainwater harvesting system

- The rainwater harvesting system was installed by Oaklands International (the supplier of the system).
- The architect reported that logistically, this was very difficult to organise. Rainwater harvesting tanks need to be installed when the ground works are occurring, whereas the second fix does not happen until very close to the end of the build. Ensuring that Oakland's contractors were on site at the correct time for each of the properties, so as not to hold up the rest of the build was crucial.
- Using installers who know the particular RWH system, and the specific regulations pertaining to rainwater, is key as it results in a well installed and correctly commissioned system, thus leading to better performance over its lifetime.
- It is recommended that SYHA continue to use approved contractors in all future RWH system installations.
- The standard of installation was very high. For example, Figure 46 shows a close up of the mains back-up. Note that the outlet from the mains back-up finishes above the tundish. This is helped by the good design of the support bracket that keeps the solenoid and the tundish apart. However it would still be possible to install the mains back-up so it does

[3] The background data for the calculation is not shown in the water calculator printout, merely the yearly litres yield as calculated.

not conform to the Water Regulations. Using Oakland's own plumbers to install the system ensured that the Water Regulations were not contravened.

Image ref:	**Figure 46**	**Floor:**	**-**	**Room:**	**-**
					
Close up of the mains back-up					

- A comprehensive overview of the rainwater harvesting system was conducted at one property which was working very well at the time of the site visit. Figure 47 shows the insides of the rainwater storage tank.
- The tank floor was completely free from debris and the water was exceptionally clear.
- The biofilm at the base of the tank is standard, and does not detract from the water quality.
- This system was currently working on mains back-up (due to a lack of rain in previous weeks) but from the inspection it was considered that the system water will also be clear when it is operating on rainwater.
- The lid of the filter had fallen off and can be seen at the bottom of the tank. This could not be retrieved.[4]
- Water can be seen in the overflow trap. If water is not present the trap needs to be manually filled to stop drain smells inside the tank and potentially into the house through the 100mm duct pipe.

[4] This seems to be a common problem in that the filter lid in (address removed) was secured by tape, presumably to prevent the lid here also falling off.

- The 110mm ducting (carrying black hose with green marking to denote non potable/recycled water supply and electrical connections) can be clearly seen.

- Cables are neat and tidy and are not unduly stressed

Image ref:	**Figure 47**	**Floor:**	**-**	**Room:**	**-**
					
View inside rainwater storage tank					

Inspection of system

- The pump is upright and the floating filter is securely attached.

- The tank access cover is housed in a tray which is filled with pea shingle. (Figure 48) This is a good design detail as it means that when accessing the tank only pea shingle (as opposed to earth) is likely to be kicked into the tank, ensuring that the quality of the stored rainwater is not impaired. It also makes it less likely that run-off from the surrounding ground seeps into the rainwater storage tank.

- There was no evidence of air in the pump (a common fault with poorly installed or poorly commissioned RWH systems.)

Image ref:	Figure 48	Floor:	-	Room:	-
					
Tank cover					

- The outside tap had frozen. As the pipework to the tap was boxed in (and with the householder's permission) the flow to the outside tap was isolated. The householder was showed how to turn the supply back on to the outside tap once the warmer weather comes. (The isolating valve is to the side of the RWH control panel.)

Cleaning the filters

- Both systems that were checked had debris in the filter reducing the effectiveness of the filter and therefore the amount of rainwater that can be collected.
- The filter in (address removed) had quite a lot of leaf debris, whilst the filter in (address removed) had mud and grit in it (Figure 49). Both filters were cleaned on site.
- The systems were commissioned in Sept/Oct 2011. Therefore this build up had happened quite rapidly.
- As the filters on this system are inside the storage tank, the lid to the tank has to be removed to clean the filters. In most RWH systems, it is recommended that the filter is cleaned 2-4 times a year.
- The tank lids are screwed down to conform to health and safety requirements.

Image ref:	Figure 49	Floor:	-	Room:	-

Leaves and mud removed from a filter (left), cleaning mud and grit from the filter

- If the householder was required to clean the filter, there is a risk that the tank lid would not be re-secured correctly, leading to a risk of children accessing the tank.
- It is recommended that householders are not instructed to clean the filter and that SYHA need to set up a maintenance schedule to clean the filters at least twice a year.

7.4 Evaluation of water usage

Flow rates on site

- The flow rate at the basin tap in the bathroom was 5.5 litres/min for the cold and 4.5 litres/min for the hot, averaging a 100% greater flow rate than specified (Figure 50).
- It was not possible to access the kitchen sink to check flow rates there, but from discussion with the tenants they, too, are greater than specified.
- The shower is a Mira Sport electric shower. Subsequent research showed this was rated at 9.8 kW, and that the flow rate from the shower at 35°C is 4.5 litres/min (as opposed to 4.03 as specified).

Image ref:	Figure 50	Floor:	Ground	Room:	Bathroom

Checking flow rate at wash basin

- The tenants report that the water from the bath tap is only warm. This is due to legislation in Part G of the Building Regulations that all hot bath taps require a thermostatic mixing valve set to 48 degrees C to prevent scalding.
- It was not confirmed whether the bath volume was 140 litres as stated in the original design specification. However, from the appearance of the bath, 140 litres is a likely volume (Figure 51).

Image ref:	Figure 51	Floor:	Ground	Room:	Bathroom

bath in one of the properties

Checking actual specification against proposed specification

- As the design specification had been changed for the shower and the taps, and because the rainwater yield is lower than calculated, the new information was entered into the water calculator to check if the performance still met CfSH Levels 5 and 6.
- Table 10 shows the new calculation with the actual recorded changes (in ***italics***).
- As can be seen even with the increased flow rates, and lower rainfall yields the dwelling comfortably meets the required usage per person per day, which is 80 litres or less.

Table 10 Re-calculated water usage

	Calculated usage per day (original spec) litres	Volume litres (actual)	Flow rate litres/minute (actual)	Calculated usage per day (actual spec) litres
WC	20.59	6/4		20.59
bath	15.40	140.00		15.40
shower	17.61		***4.50***	***19.67***
basin taps	5.53		***5.00***	***8.69***
sink taps	12.12		***6.00***	***13.00***
Washing machine	17.16		default	17.16
Dishwasher	4.50		default	4.50
Net internal water	92.9			**99.0**
Rainwater collection	20.60			**15.50**
Normalisation	0.91			0.91
Total consumption	**63.9**			**74.6**
Code Level	**5/6**			**5/6**
Note: Figures are those as stated in the CfSH Water Calculator				

7.5 Instructions to householders

- There are no clear instructions to the householders about how their rainwater harvesting system works, or how to identify if it is working inefficiently (e.g. the filter needs cleaning).
- The only information in their home packs are the installation instructions (*User Manual*)

7.6 Rainwater harvesting defects

- As the rainwater harvesting system is used to provide water for WC flushing, defects with the system as classed as urgent priority.
- The architect reported that there had been commissioning issues with most of the systems but these now seem to have been rectified.
- The architect also reported that there had been "14 separate calls to RWH faults. Most have been down to the operation of the pump, but we don't know why the pumps have failed." He commented that the defects reporting procedure is poor at capturing *why* things have gone wrong.
- The defects data was analysed by property (Table 11) and diagnosed the fault from the information given in the report.
- Studying the defects list, it seems that once the reported fault has been repaired it does not occur again, leading to the conclusion that the issue is probably one of initial commissioning/set up not being carried out properly.
- To build up a level of expertise about RWH within the HA, there needs to be a way to gather data from the plumber or electrician carrying out the repair, as they have to diagnose the fault to repair it.

Table 11 Rainwater harvesting defects by property

Address	Date	Defect
Removed	26-Sep-	Air in pump
Removed	06-Oct-	Mains back-up not working
Removed	07-Oct-	Same problem. Was not rectified on previous visit.
Removed	31-Oct-	Reported as a fault. No other details
Removed	11-Oct-	Mains back-up not working or a discrete pump problem
Removed	25-Oct-	Mains back-up not working or a discrete pump problem
Removed	11-Oct-	Mains back-up not working or a discrete pump problem
Removed	31-Oct-	Scalding hot water from the outside tap sound like cross
Removed	09-Feb-	Mains back-up not working or a discrete pump problem
Removed	30-Nov-	Sounds like a pump lockout from the report. So mains
Removed	19-Dec-	Mains back-up not working or a discrete pump problem
Removed	13-Jan-	Mains back-up not working or a discrete pump problem
Removed	18-Jan-	Pump is tripping electrics
Removed	31-Jan-	Mains back-up not working or a discrete pump problem
Removed	20-Feb-	Outside tap pipeline frozen?

Mains back-up

- The tenants at (address removed) reported that the mains back-up runs for about 10 minutes when it is on,[5] and that this was noisy when it happened during the night.
- The mains back-up is triggered automatically when the stored water level drops to a pre-determined level, and once it kicks in cannot be stopped until it has delivered the set amount of back-up water supply.
- The procedure was explained to the tenants and by not flushing the WC at night will stop this problem.
- The tenants reported a lot of initial problems with their system. This issue did not seem to have been picked up in the defects report.
- Following detailed questions to the tenants, the problem was diagnosed as the mains back up not kicking in early enough, with the result that air gets into the pump, the pump protection kicks in and shuts down the pump and subsequently the WCs cannot be flushed (this would often be reported as a "pump fault" but in fact the pump is working properly to shut down when there is air rather than water in the pump intake).
- At one point the plumber filled the rainwater storage tank up with a hose to ensure that the tenants would not run out of water during the Christmas break.

Should SYHA specify RWH on future developments?

- If SYHA is concerned about the initial costs of installing rainwater harvesting systems and ongoing maintenance costs, it may like to consider on future developments whether Levels 5 and 6 of the CfSH can be met by maintaining the specification as installed at Royston, but without the need for RWH.
- As Table 12 and Table 13 show, SYHA could keep the same bath volume and use the same shower, bath, sink and basin taps as currently being used on the Cross Lane site.
- SYHA would need to specify 4/2.5 litre flush WCs in place of 6/4 litre flush WCs.

[5] This would be right in that flow rate from the mains back-up is at about 10 -12 litres per minute and 100 – 120 litres of mains back-up a time is a standard amount for mains back-up into rainwater storage tanks, to ensure the optimum amount of available space in the tank for when it subsequently rains.

- They would also need to specifying a washing machine with a water efficiency of 6.67 litres/kg or better and a dishwasher with a water efficiency of 1.07 litres/place setting or better.
- This specification would meet the requirements for Code Level 5and 6, and means that the cost of installing RWH will be saved.

Table 12 Alternative water usage 1

	Volume litres	Flow rate	New calculated usage
WC	6/4		20.59
bath	140.00		15.40
shower		4.50	19.67
basin taps		5.00	8.69
sink taps		6.00	13.00
Washing machine		6.14	12.89
Dishwasher		0.71	2.56
Net internal water consumption			**92.8**
Normalisation factor			0.91
Total consumption			**84.5**
Code Level			**3/4**
Note: Figures are those as stated in the CfSH Water Calculator.			

Table 13 Alternative water usage 2

	Volume litres	Flow rate	New calculated usage
WC	4/2.5		13.24
bath	140.00		15.40
shower		4.50	19.67
basin taps		5.00	8.69
sink taps		6.00	13.00
Washing machine		6.67	14.01
Dishwasher		1.07	3.85
Net internal water consumption			**87.9**
Normalisation factor			0.91
Total consumption			**79.9**
Code Level			**5/6**
Note: Figures are those as stated in the CfSH Water Calculator.			

7.7 Services check

An installation and commissioning datasheet was completed for the domestic services in the dwelling. This included the ventilation systems, heating and hot water systems, lighting and microgeneration (photovoltaic), see attachment: *(3806-31140) 7 Commissioning sheets (Word format).*

To summarise, the boiler is a Greenstar 25Si Wall Hung Condensing Combination boiler from Worcester Bosch. It is installed in the kitchen (see Figure 37) with sufficient clearances for a ventilated compartment. The boiler was subjected to a global reset and re-commissioned as outlined in the manufacturers' instructions. No issues were identified. The condensate pipe is unblocked and free to discharge condensate. However, during the 'Interviews with Residents', Section 6.3, a power surge/cut caused damage to a boiler in a different property which subsequently had to be repaired/reset.

The central heating system did not exhibit any problems, all radiators heated evenly. Thermostatic radiator valves have been fitted and were set to mid-range (setting 3). The thermostat was also adjusted and the boiler reacted accordingly. The commissioning data as recorded during the installation (August 2011) were confirmed as being correct [see (3806-31140) 8 Gas boiler system commissioning checklist.pdf].

The PV was checked by investigating the wiring of the system into the main fuse board. No issues were identified and the PV system was generating electricity. A single Sunny Boy SB 2500 inverter was installed. Future schemes may benefit from the specification of micro-inverters since if problems arise with the single SB 2500 inverter then the whole array will cease to generate electricity. Failure of a single micro-inverter would only cause the associated PV panel to drop out whilst the remaining panels would remain in-service.

The ventilation consists of *System 1* services only. Greenwoods Unity CV100 single point extract fans were used in the downstairs toilet and bathroom. They were installed with a recommended clearance of 75mm on one side to allow removal of the internal grille. The factory setting of these fanes is 5 l/s but were set to extract a maximum 15 l/s. The measured extract rates confirmed this.

The resident would benefit from having access to original product brochures as the ones provided in the *User Guide* are poorly copied and thus, unlikely to be read and understood.

7.8 Conclusions and key findings for this section

Rainwater harvesting

- Initial calculations for available rainwater must use correct rainfall data and actual footprint of the dwelling.
- RWH if specified, must be done so at the outset to reduce extra costs and to take advantage of the attenuation provide at each rainwater storage tank.
- The 16 houses three bed houses with a footprint of 42.5 m^2 can supply 22.8m^3 of rainfall a year. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £56 a year off their water bill.
- The 2 four bed houses with a footprint of 60 m^2 can supply 32.1m^3 of rainfall a year. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £79 a year off their water bill.
- With an average installed cost per system of £3,806, simple payback is 48 years for the larger houses and 68 years for the smaller dwellings.
- High standard of installation. Arrived at from using the system supplier's own installation team. We recommend that SYHA continue to use approved (and experienced) contractors in all future RWH system installations.
- Stored water very clear. No strain on electric cables inside the rainwater storage tank.
- Filters needed cleaning even though handover less than four months previously. SYHA need to set up a maintenance schedule to clean the filters at least twice a year.
- The actual specification on site was different to the original design specification.
- Actual Flow rates from taps and showers were greater than specified. However, the dwelling still met CfSH Levels 5 and 6 even with the measured flow rates
- The HA should prioritise writing a one page clear overview of the system. This information should also explain how to prevent the mains back-up coming on at night.
- The defects reporting works well in that the first visit is carried out promptly and it appears that the defect is usually sorted on the first visit as the report is not subsequently reported. However, one property had several problems all due to the same fault, which was not correctly rectified on the first visit.
- To build up a level of expertise about RWH within the HA, there needs to be a way to gather data from the plumber or electrician carrying out the repair, as they have to diagnose the fault to repair it.
- There are alternative ways to meet Code Levels 5 and 6 by slightly changing the appliance specification and these should be considered by SYHA in the future

Other services

- No issues were identified with the boiler. The condensate pipe is unblocked and free to discharge condensate. However, during the 'Interviews with Residents', a power surge/cut caused damage to a boiler in a different property which subsequently had to be repaired/reset.
- The central heating system did not exhibit any problems, all radiators heated evenly. Thermostatic radiator valves have been fitted and were set to mid-range (setting 3). The thermostat was also adjusted and the boiler reacted accordingly.
- The PV was checked by investigating the wiring of the system into the main fuse board. No issues were identified and the PV system was generating electricity.
- Future schemes may benefit from the specification of micro-inverters since if problems arise with the single SB 2500 inverter then the whole array will cease to generate electricity.
- The ventilation consists of *System 1* services only. Greenwoods Unity CV100 single point extract fans were used in the downstairs toilet and bathroom. They were installed with a recommended clearance of 75mm on one side to allow removal of the internal grille. The factory setting of these fanes is 5 l/s but were set to extract a maximum 15 l/s. The measured extract rates confirmed this.
- The resident would benefit from having access to original product brochures as the ones provided in the *User Guide* are poorly copied and thus, unlikely to be read and understood.

8 Other technical issues

Technology Strategy Board guidance on section requirements:	This section should review the underlying issues relating to the performance of the building and its systems that have not been adequately captured elsewhere in this report. These could be technical issues detected through through testing, building use data and occupant issues etc. What technical issues have been discovered which could be leading to comfort or energy problems? Are the automated or manual controls being used effectively by the occupants or are they still becoming familiar with their operation? Did the commissioning process actually setup the systems correctly and, if not, what is this leading to? Are there design related technical issues, which are already becoming apparent and need to be highlighted for a future Phase 2 BPE study? Are there challenges being created through the dwelling usage or operation patterns? Summarise with conclusions and key findings.

8.1 Introduction

No other issues have been identified other than those listed elsewhere in the report.

8.2 Conclusions and key findings for this section

Not applicable

9 Key messages for the client, owner and occupier

Technology Strategy Board guidance on section requirements:	This section should investigate the main findings and draw out the key messages for communication to the client / developer and the building owner / occupier. Drawing from the findings of the rest of the report, specifically required are: a summary of points raised in discussion with team members; recommendations for improving pre and post handover processes; a summary of lessons learned: things to do, things to avoid, and things requiring further attention/study. Try to use layman's terms where possible so that the messages are understood correctly and so are more likely to be acted upon.

9.1 Introduction

This section highlights the key findings from this study and are summarised in Section 9.2.

9.2 Conclusions and key findings for this section

About the building: design and construction audit, drawings and SAP calculation review

- It is possible to set and deliver against high quality environmental targets if the scheme is well conceived and managed throughout.
- Specifying photovoltaics requires wider consultation at an earlier stage. Some partners (Distribution Network Operators) are not prepared to have discussions at the design stage, only at build stage when the project is advanced and this impacts on costs and delivery times.
- DNOs require more data on electricity flow to the grid as current understanding is based on a worst case scenario. In Summer, when all arrays are operating at peak, design of flow to the grid is based on little or no consumption in the property. This leads to the rash decision of insisting on a new sub-station to be built to cope with the capacity.

Fabric testing

- The study established the in-situ u values of the external walls. The design u values were 0.20 W/m^{2}K for the party wall and 0.13 W/m^{2}K for all others. The biggest difference between the as-designed and as-measured u value is for the north (party) wall (0.04 W/m^{2}K higher) followed by the south (0.01 W/m^{2}K higher). The east and west walls had lower u values compared to design (0.03 and 0.01 W/m^{2}K respectively). During testing, the adjacent property remained unheated.
- The east, south and west walls are all insulated with 190mm of mineral wool. Although building regulations stipulate that insulation is not required in party walls, 120mm of insulation was inserted for sound insulation. This is an area worthy of further

consideration, since eliminating the 75mm cavity and filling with insulation would give a total insulative thickness of 315mm, perhaps resulting in a better thermal performance. However, it is not clear what effect this would have on sound insulation and further research is required to confirm this.

- The design and measured u values were used in the SAP review. SAP version 9.90, NHER Plan Assessor version 5.4.1 was used. The y value was taken as 0.08 due to accredited construction processes being employed. There is a very good correlation between the design SAP values and the values obtained through the review. The in-situ heat loss coefficient is 103.12 W/K whereas the as-built SAP value is 108.58 W/K. The difference was mainly due to a slightly higher post-test air pressure tests - see Section 3.5. However, due to the strong correlation of the co-heating data presented in Figure 17, if it is assumed that the as-built heat loss coefficient of 103.12 W/K is the correct value then by a trial and error process, a y value of 0.05 in addition to using the in-situ u values would yield a SAP heat loss coefficient close to the measured value. However, the SAP rating would stay at 93. For comparison, if a default y value of 0.15 was used using measured u value data, the SAP heat loss coefficient would be 120.87 W/K with the SAP rating dropping one point to 92.
- When using this version of SAP (9.90, NHER Plan Assessor version 5.4.1), a u value of either 0.2 or 0.5 W/m^{2}K can only be selected for the party wall so 0.2 W/m^{2}K was chosen as this was the closest match to the measured u value of 0.24 W/m^{2}K.
- The thermography survey has highlighted that the roof design has an impact on heat retention. The design specifies that 400mm of loft roll should be inserted, but due to the reduced headroom at the rafter/joist interface (eaves), it is impossible to get 400mm in place. The thermography survey highlights colder spots in the ceiling as a result. Consideration should be given to increasing the headroom at these locations to enable 400mm of insulation to be installed.
- The air pressure testing highlighted areas which were permeated during the test - the external wall electrical sockets and the access hole for the valve to the external tap.

Key findings from the design and delivery team walkthrough

- Main issues arising were external as opposed to internal.
- Changing the detail between the head of the door frame and cladding for a sealed sloping batten would eliminate the water ingress problems encountered.

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

- The interviews revealed that residents were not provided with a formal verbal/face-to-face handover when they moved into their homes – they were simply provided with the keys and user manuals for their homes
- A month or so after moving into their homes, residents were visited by a representative of SYHA and provided with advice about how to be more energy efficient in their new homes
- Observation of the mock handover suggested that providing guidance and advice to residents can be challenging, particularly if they are not willing to listen to the advice or are sceptical of the information provided.
- Most of the guidance about the homes was provided in writing in the form of *Home User Guide* and *User Manual*. The *Home User Guide* was generally well written and structured, but the quality and clarity of information in the *User Manual* was very mixed, particularly as it was comprised of user manuals from manufacturers.
- Observation of the mock handover and review of the written documentation suggests that there is a need to strike a balance between overloading residents with information/guidance and leaving them to work out themselves how to use their houses (with support from written documentation).
- The handover process in this scheme clearly did not address most of the issues identified (Table 3) and residents will, therefore, be reliant on written documentation, some of which they may find difficult to interpret. Consideration needs to be given to communicating the information more effectively by ensuring the right information is in the right place at the right time.
- Our findings suggest that in future schemes SYHA should ensure that residents are provided with a formal handover, but should also consider delivering guidance and advice via other media, such as a website or DVD. This might enable guidance to be targeted more specifically and be more interactive.

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

Questionnaire Survey

- The main findings for the questionnaire survey refer to the air conditions in the summer which are humid and stuffy and winter when it is still. One possibility is that the residents have moved from draughty, poorly insulated properties, and the occupants are unaccustomed to the conditions in their new homes. Another possibility is that the ventilation rates in the homes are simply lower than occupant preferences. Residents should be made aware of the air tight nature of the building and stuffiness may result unless they manage ventilation into the building. However, this has to be managed in a way that maximises fresh air entering and minimises heat exiting i.e. it is not just a case of leaving windows open. Trickle vents in windows can be new to people if they have not had the experience of dealing with them in the past so this should be made clear in the handover process.

- Temperature fluctuations are evident in the winter. This may be due to losses as identified and described by the thermal survey in Section 3 or radiators not working correctly (identified in the interviews with residents).
- Overall, the properties relate very positively to other buildings in the benchmark dataset with relatively low running costs.

Interviews with residents

- The interviews revealed that residents were satisfied with their new homes, particularly since most had moved from very poor quality private rented accommodation. They were also satisfied with the information provided to them about their new homes. Residents reported a number of problems with their homes, such as water ingress through front doors and a leaking sink, however most of the problems had been resolved in a satisfactory manner. The interviewees also identified ways in which the houses could be improved, the most significant of which was to include a door between the kitchen and lounge and the others were:
    - the smallest bedroom could have been more spacious by making it the same size as the second bedroom
    - fences should be erected around the front gardens, so that people cannot walk across the lawns
    - street lighting could be improved
- The *Home User Guide* and handover process should provide more clarity on how to get the best from the heating system. For example, more clarity should be provided on the use of the TRVs and thermostat to better regulate indoor conditions during the winter

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

Rainwater harvesting

- Initial calculations for available rainwater must use correct rainfall data and actual footprint of the dwelling.
- RWH if specified, must be done so at the outset to reduce extra costs and to take advantage of the attenuation provide at each rainwater storage tank.
- The 16 houses three bed houses with a footprint of 42.5 m^2 can supply 22.8m^3 of rainfall a year. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £56 a year off their water bill.
- The 2 four bed houses with a footprint of 60 m^2 can supply 32.1m^3 of rainfall a year. At £2.47/m^3 (Yorkshire Water 2011-2012 prices) residents will save £79 a year off their water bill.
- With an average installed cost per system of £3,806, simple payback is 48 years for the larger houses and 68 years for the smaller dwellings.
- High standard of installation. Arrived at from using the system supplier's own installation team. We recommend that SYHA continue to use approved (and experienced) contractors in all future RWH system installations.
- Stored water very clear. No strain on electric cables inside the rainwater storage tank.
- Filters needed cleaning even though handover less than four months previously. SYHA need to set up a maintenance schedule to clean the filters at least twice a year.
- The actual specification on site was different to the original design specification.
- Actual Flow rates from taps and showers were greater than specified. However, the dwelling still met CfSH Levels 5 and 6 even with the measured flow rates
- The HA should prioritise writing a one page clear overview of the system. This information should also explain how to prevent the mains back-up coming on at night.
- The defects reporting works well in that the first visit is carried out promptly and it appears that the defect is usually sorted on the first visit as the report is not subsequently reported. However, one property had several problems all due to the same fault, which was not correctly rectified on the first visit.
- To build up a level of expertise about RWH within the HA, there needs to be a way to gather data from the plumber or electrician carrying out the repair, as they have to diagnose the fault to repair it.
- There are alternative ways to meet Code Levels 5 and 6 by slightly changing the appliance specification and these should be considered by SYHA in the future

Other services

- No issues were identified with the boiler. The condensate pipe is unblocked and free to discharge condensate. However, during the 'Interviews with Residents', a power surge/cut caused damage to a boiler in a different property which subsequently had to be repaired/reset.
- The central heating system did not exhibit any problems, all radiators heated evenly. Thermostatic radiator valves have been fitted and were set to mid-range (setting 3). The thermostat was also adjusted and the boiler reacted accordingly.
- The PV was checked by investigating the wiring of the system into the main fuse board. No issues were identified and the PV system was generating electricity.
- Future schemes may benefit from the specification of micro-inverters since if problems arise with the single SB 2500 inverter then the whole array will cease to generate electricity.
- The ventilation consists of *System 1* services only. Greenwoods Unity CV100 single point extract fans were used in the downstairs toilet and bathroom. They were installed with a recommended clearance of 75mm on one side to allow removal of the internal grille. The factory setting of these fanes is 5 l/s but were set to extract a maximum 15 l/s. The measured extract rates confirmed this.
- The resident would benefit from having access to original product brochures as the ones provided in the *User Guide* are poorly copied and thus, unlikely to be read and understood.

10 Wider Lessons

Technology Strategy Board guidance on section requirements:	This section should summarise the wider lessons for the industry, including, but not limited to clients, other developers, funders, insurance bodies, skills and training groups, construction team, designers and supply chain members to improve their future approaches to this kind of development. Provide a detailed insight in to the emerging lessons. What would you definitely do, not do, or do differently on a similar project. Include consideration of costs (what might you leave out and how would you make things cheaper); improvement of the design process (better informed design decisions, more professional input, etc.) and improvements of the construction process (reduce timescale, smooth operation, etc.). What lessons have been learned that will benefit the participants' businesses in terms of innovation, efficiency or increased opportunities? These lessons need to be disseminated through trade bodies, professional Institutions, representation on standards bodies, best practice clubs etc. Please detail how dissemination will be carried out for this project. As far as possible these lessons should be put in layman's terms to ensure effective communication with a broad industry audience.

10.1 Introduction

A summary of the wider lessons for the industry is summarised in Section 10.2.

10.2 Conclusions and key findings for this section

This study has not uncovered any serious issues but in fact, apart from minor irregularities, highlighted the design and build quality of the properties. The key messages are given in Section 9 but the two areas which induced challenges in the development were the installation and cost of the water harvesting and liaisons with the Distribution Network regarding sufficient capacity for the PV systems.

It was shown in Section 7 that a Code Level 5 or 6 property could be achieved with better specification of appliances and as a result, future development may choose to follow this route rather than install water harvesting. Following both routes may yield even better results but an incentive may be required to install water harvesting in a similar manner to the feed-in-tariff for PV to make it more viable.

The Building Performance Evaluation has yielded an abundance of information and with the permission of the stakeholders involved, the aim is to publish the information through recognised channels (conferences, channels, seminars) for the benefit of the wider community.

11 Appendices

Technology Strategy Board guidance on section requirements:	The appendices are likely to include the following documents: • Details on commissioning of systems and technologies through appending of the document *BPE_Domestic_commissioning sheets.doc* • Initial energy consumption data and analysis (including demand profiles where available) • Further detail or attachment of anonymised documents • Additional photographs, drawings, and relevant schematics • Background relevant papers

Image ref:	**Figure 52**	**Floor:**	-	**Room:**	-

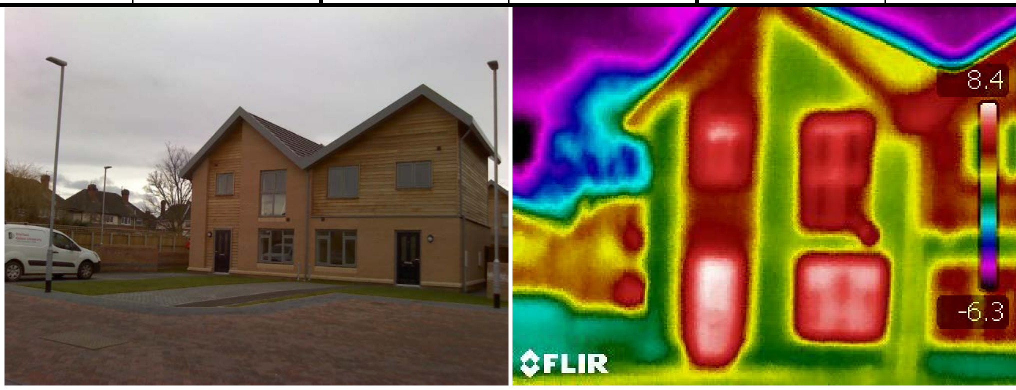


Photo and thermal image of front (east) of building

Image ref:	**Figure 53**	**Floor:**	-	**Room:**	-

Photo and thermal image of front (east) of building

Image ref:	Figure 54	Floor:		Room:	

Photo and thermal image of front (east) of building

Image ref:	Figure 55	Floor:	First	Room:	Bed 2

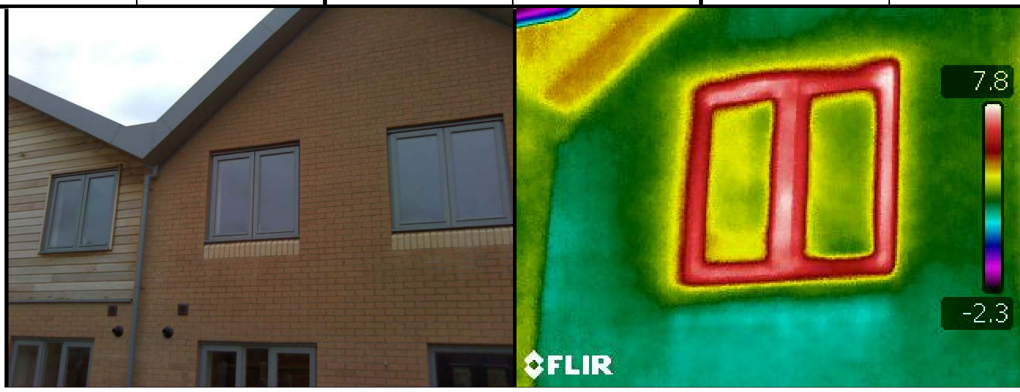


Photo and thermal image of bedroom 2 window (external, east)

Image ref:	Figure 56	Floor:	First	Room:	Living

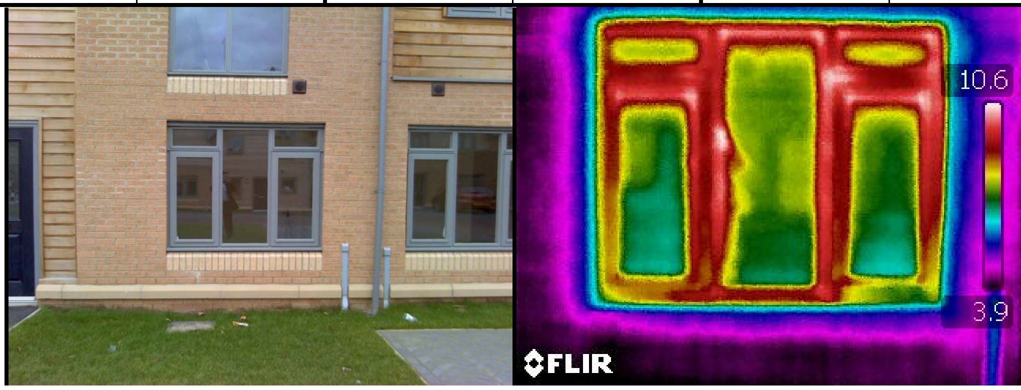


Photo and thermal image of living room window (east)

Image ref:	Figure 57	Floor:	First	Room:	Bed 1

Photo and thermal image of bedroom 1 window (east)

Image ref:	Figure 58	Floor:	First	Room:	Bathroom

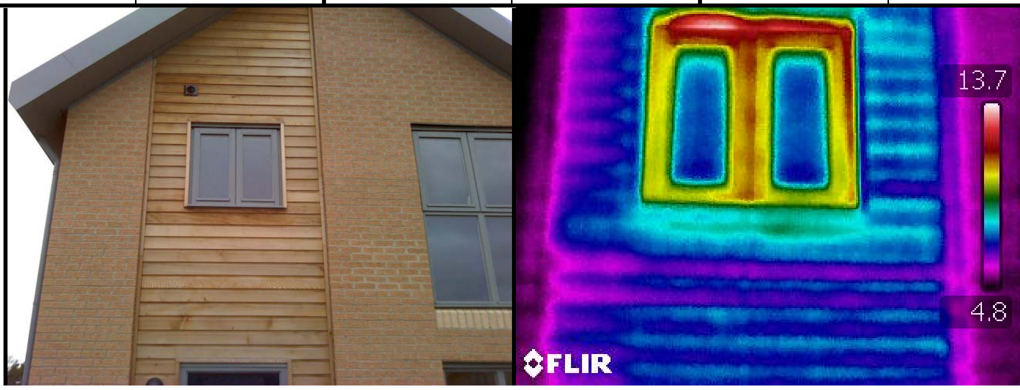



Photo and thermal image of bathroom window					

Image ref:	Figure 59	Floor:		Room:	

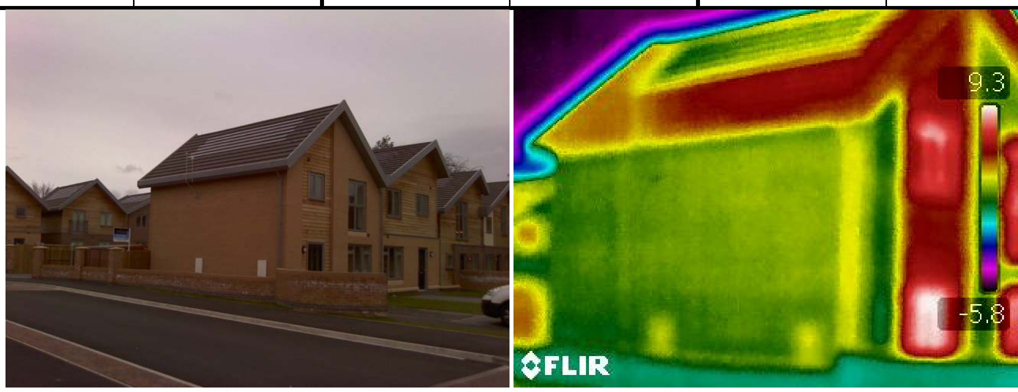



Photo and thermal image of side (south)/front of building					

Image ref:	**Figure 60**	**Floor:**		**Room:**	

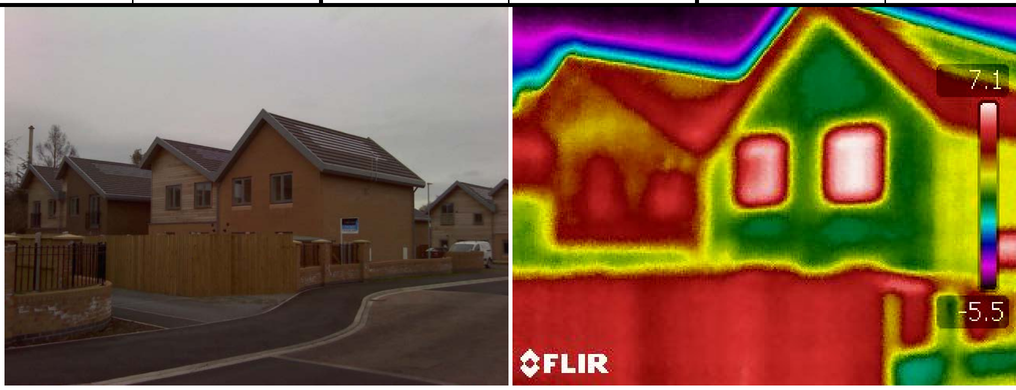


Photo and thermal image of back (west)/side (south) of building

Image ref:	**Figure 61**	**Floor:**	**First**	**Room:**	**Bed 3**

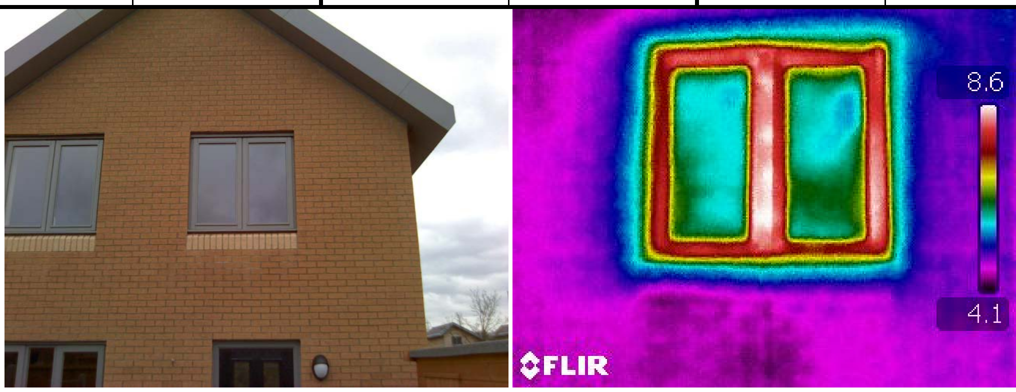


Photo and thermal image of bedroom 3 window (external, west)

Image ref:	Figure 62	Floor:	Ground	Room:	Kitchen

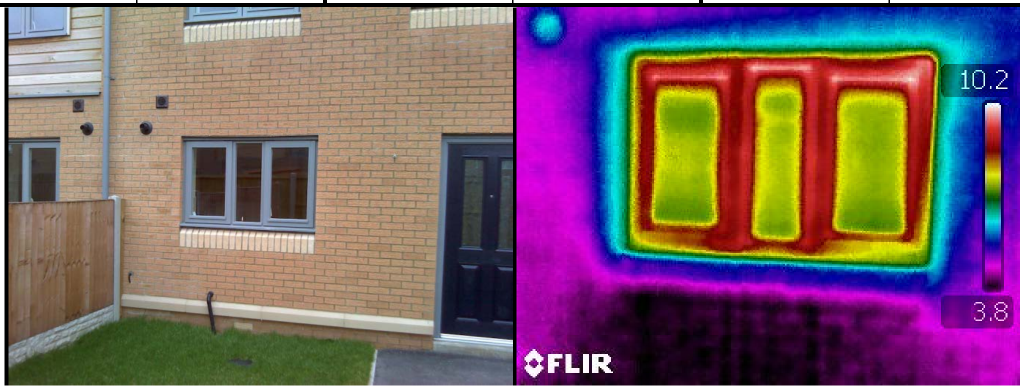


Photo and thermal image of kitchen window (west)

Image ref:	Figure 63	Floor:	Ground	Room:	Dining

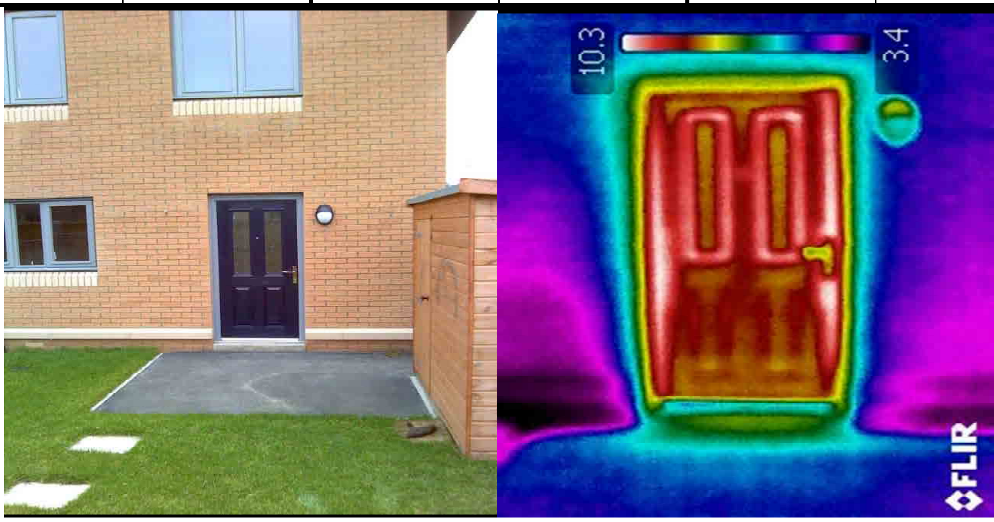


Photo and thermal image of dining room (external back)door

Image ref:	Figure 64	Floor:	Ground	Room:	Dining

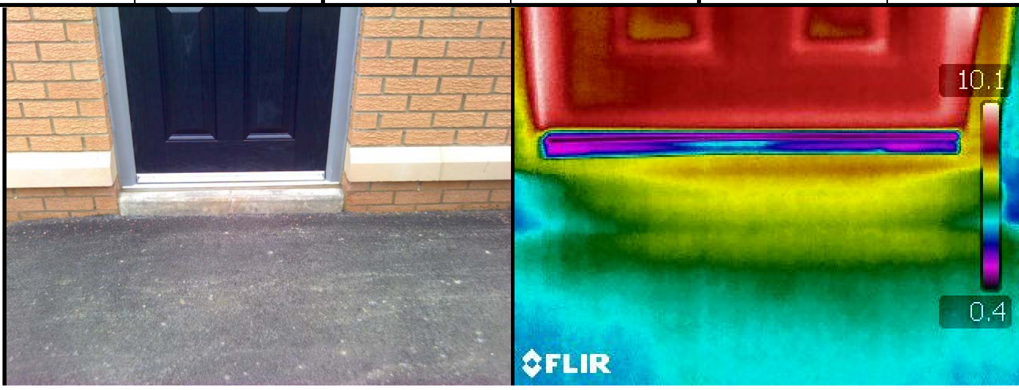



Photo and thermal image of threshold of dining room (external back)door					

Image ref:	Figure 65	Floor:	Ground	Room:	Dining
					
Photo and thermal image of threshold of dining room (internal back) door					

Image ref:	Figure 66	Floor:	Ground	Room:	Dining

Photo and thermal image of dining room door(internal)

Image ref:	Figure 67	Floor:	Ground	Room:	Hall

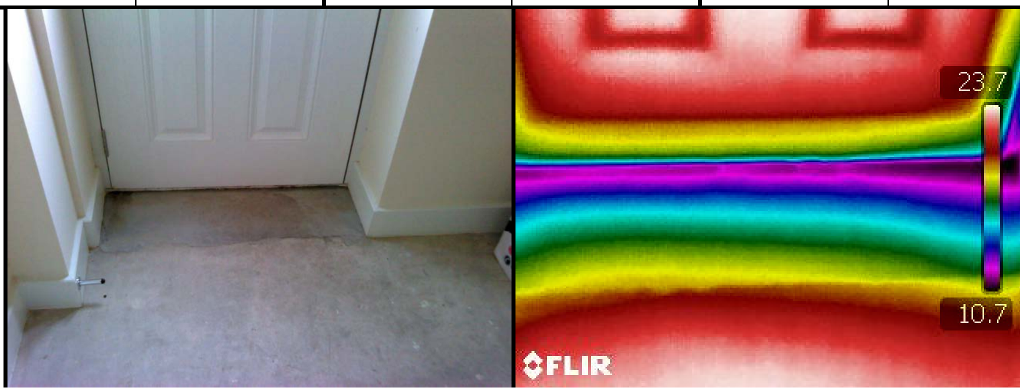


Photo and thermal image of threshold of front door (internal)

Image ref:	Figure 68	Floor:	Ground	Room:	-

Photo and thermal image of threshold of front door (external)

Image ref:	Figure 69	Floor:	Ground	Room:	Dining

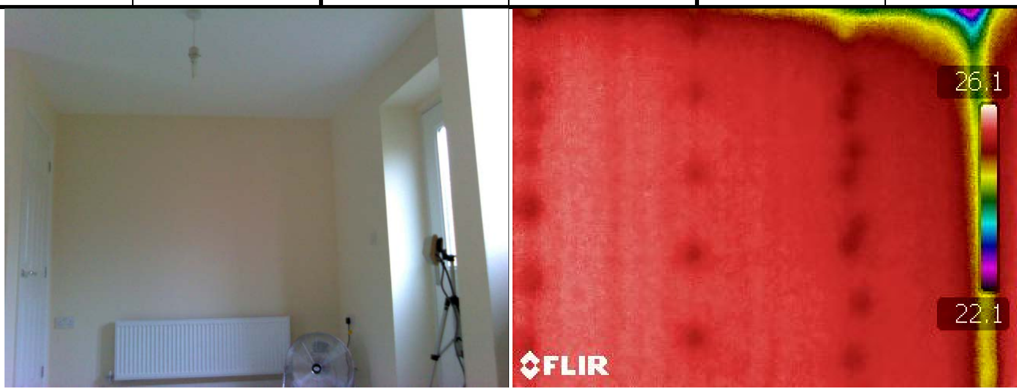


Photo and thermal image of dining room (south) wall

Image ref:	Figure 70	Floor:	Ground	Room:	Living
					
Photo and thermal image of living room party (north) wall					

Image ref:	Figure 71	Floor:	Ground	Room:	Hall
					
Photo and thermal image of front door (internal)					

Image ref:	Figure 72	Floor:	First	Room:	Bed 3

Photo and thermal image of bedroom 3 window (west)

Image ref:	Figure 73	Floor:	First	Room:	Bathroom

Photo and thermal image of bathroom(east & internal walls)

Image ref:	Figure 74	Floor:	First	Room:	Bathroom
					
Photo and thermal image of bathroom window (east)					

Image ref:	Figure 75	Floor:	First	Room:	Bed 1

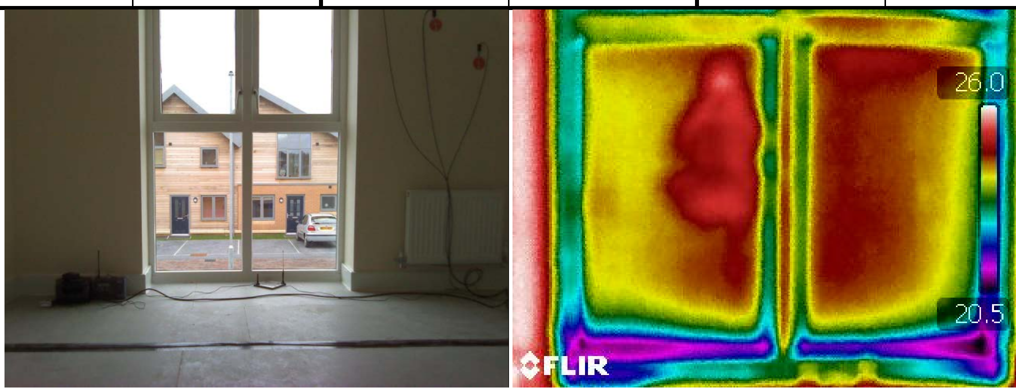



Photo and thermal image of bedroom 1 window lower (east)					

Image ref:	Figure 76	Floor:	First	Room:	Bed 1

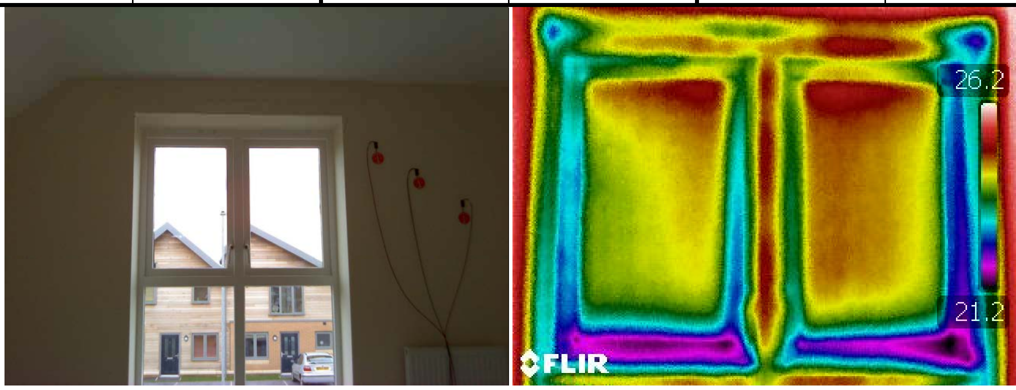


Photo and thermal image of bedroom 1 window upper (east)

Image ref:	Figure 77	Floor:	First	Room:	Bed 2

Photo and thermal image of bedroom 2 window (west)

Image ref:	Figure 78	Floor:	First	Room:	Bed 2

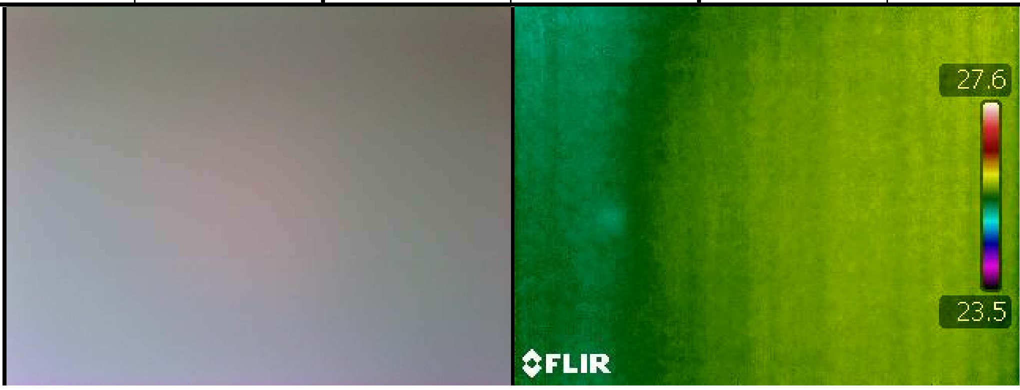


Photo and thermal image of bedroom 2 party wall (north)