Housing Innovation Showcase 2012
Building Performance Evaluation
Phase 1 – Part 1

HOUSING INNOVATION SHOWCASE 2012

affordable ^ sustainable ^ construction

kingdom housing association

Institute for Sustainable Construction

Construction technologies for tomorrow's communities

Edinburgh Napier UNIVERSITY

Misia Jack consultancy

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ABOUT THE AUTHORS

Kingdom Housing Association Ltd

Kingdom is a Fife based Housing Association and has developed over 4500 affordable new homes to meet a range of housing needs and tenures. Over the years, Kingdom has completed a number of sustainable housing projects, including the Housing Innovation Showcase which will not only contribute towards the Association's key objectives of sustainability and continuous improvement but will provide an ideal opportunity to share results and promote good practice within the affordable housing sector and the construction industry.

All Kingdom development staff were actively involved in the delivery of the HIS and the client lead officers for this evaluation were:

Bill Banks, Depute Chief Executive of Kingdom has been working in the affordable housing sector for over 28 years and has a track record of delivering innovated, collaborative and sustainable affordable housing projects. Bill undertook the Director role for the delivery of the HIS.

In addition to his role within Kingdom, Bill is also a Director with the Fife Construction Forum and Kingdom Initiatives.

Julie Watson, Development Officer has over 22 years housing experience. Since joining Kingdom in 2006, Julie has worked on a number of housing projects, including the award winning "Kingdom House" which was the first certified Passivhaus for Social Rent in the UK.

Part of Julie's role at Kingdom is to ensure sustainability principles and practices are incorporated into the affordable housing projects.

Housing Consultant **Misia Jack** was responsible for the evaluation of the Housing Innovation Showcase; Kingdom's Handover Procedure; User Satisfaction Surveys and for the co-ordination of this report.

Misia was educated both in Poland and in Scotland where she studied English Philology, Town and Country Planning and where she graduated at Heriot-Watt University with a post-graduate Diploma in Housing Studies. She works at the Scottish Housing Best Value Network as well as a housing consultant running her own practice. She has gained her practical experience of housing development while working for housing associations where she worked as a development manager, and later as a policy manager at the Scottish Federation of Housing Associations where she led on sustainable development. Her interest in housing quality and environmental sustainability goes right back to student times when user participation in design was the subject of her then ground breaking research and dissertation. She is passionately interested in performance improvement in housing, in ecological, user friendly design and in addressing climate change/fuel poverty through behavior change.

Technical Team – Building Performance Evaluation (BPE) Study Team

Led by Prof John Currie, the **Scottish Energy Centre (SEC) as part of the Institute for Sustainable Construction at Edinburgh Napier University** has a pre-eminent record in the development of renewable energy systems and sustainable design in construction. Founded in 1984 as a portal for research, knowledge transfer and expert services activity in the energy sector the portfolio of activities have expanded to help support commerce and industry in meeting the challenges of recent energy price increases and government initiatives and statutory requirements. The SEC has a unique position in the market for provision of commercial technical support services; with specific strengths in the field of energy diagnostics, modelling and integration of low carbon technologies.

Professor **John Currie** is Director of the Scottish Energy Centre at Edinburgh Napier University and Fellow and Chairman of the Energy Institute in Scotland. A Chartered Engineer with over 30 years' experience in teaching, research and practice John was formerly Chief Engineer with Carlsberg Tetley Brewing. Widely published, his research interests currently include improving building energy & environmental performance, monitoring and modelling pollution in the urban environment, and the development of novel low carbon technologies. He presently Co-Chairs the Scotland 2020 Climate Group, recently launching 'Retrofit Scotland', and sits on the Engineering Accreditation Board of the Engineering Council.

Julio Bros Williamson is an Energy and Building consultant with the Scottish Energy Centre (SEC). He is an Architect from the Marista University in Mexico City and holds an MSc in Energy Efficient Building from Oxford Brookes University. He has been a Chartered Mexican Architect since 2003. At SEC he has been a firm contributor to the renewable, energy efficiency and the sustainability sectors & involved in BPE of domestic buildings for both new build and refurbishment of buildings. Julio is the Treasurer and Director at the Scottish Ecological Design Association (SEDA) and an active member of Scotland 2020 Climate Group as an advisor to the Scottish Government.

Jon Stinson graduated from Edinburgh Napier University in 2007 with an honours degree in Architectural Technology. He joined Scottish Energy Centre at Edinburgh Napier University as a research assistant after completing a research degree in low carbon strategies and SMART technology. During this time he was involved with monitoring the impact of energy awareness technology on the social and behavioural aspects of domestic energy use, addressing fuel poverty and the carbon reduction agenda. Jon currently works in the field of thermal performance of historic buildings and performance evaluation of newly built low and zero carbon homes.

ACKNOWLEDGEMENTS

The Housing Innovation Showcase would not have been possible without the support and dedication of many people. The authors would therefore like to thank all those involved.

Particular thanks are extended to the residents of the Dunlin Drive Phase 1A development for all their co-operation with this study.

The authors would also like to take this opportunity to thank all staff at Kingdom who have assisted with the project and the study, the Main Framework Contractor, the Framework Project Design Team, the Preferred Partners and their Teams and the System Providers for making the project a reality and a great place to live.

Main Framework Contractor:	Campion Homes Ltd
Framework Project Design Team:	Hardies, Employers Agent and CDM Co-ordinator Oliver and Robb, Architects Scott Bennett Associates, Engineers
Preferred Partners:	Powerwall, Campion Homes, Stewart Milne Construction, CUBE RE:Treat, Future Affordable, Lomond Homes, Campbell Construction Group (CCG) and Bobin Developments
System Providers:	Powerwall Volumetric Space Frame, Scotframe Val-U-Therm, Stewart Milne Sigma II, Weinerberger Porotherm Insulated Clay Block, CUBE RE:treat SIPS, Springfield Properties: K2 and eCore, Energyflo Breathing Wall, CCG iQ System, Beco Wallform

The project was managed by Kingdom Housing Association and delivered as a partnership between Kingdom, Fife Council, Fife Construction Forum and Green Business Fife. Funding support for the project was provided by the Scottish Government, Fife Council and Kingdom Housing Association.

EXECUTIVE SUMMARY

This Executive Summary provides an overview of the findings, observations and recommendations resulting from Kingdom's Housing Innovation Showcase (HIS) project. This is based on post construction testing of twenty seven new build homes built using a range of Modern Methods of Construction (MMC).

The HIS comprised of twelve flats with communal gardens and fifteen houses with their own private gardens. All of the tested homes varied in terms of size, form and construction technique.

New technologies were installed and included Solar Hot Water (SHW), Solar Photovoltaic Panels (PV), Combined Solar Hot Water & Electric Panel PVT Collector, Voltage Optimisation, Air Source Heat Pumps (ASHP) as well as Gas-fuelled Micro Combined Heat & Power Boilers (mCHP). In addition, ventilation strategies were incorporated including Mechanical Ventilation with Heat Recovery (MVHR) and Mechanical Extract Ventilation (MEV) systems. All homes were fitted with an In-home Energy Display monitor.

This report provides:

1. An evaluation of the 'as-designed' and 'as-built' fabric energy performance of 10 system-built, low-energy dwellings against a 'control dwelling' which were monitored over a six month post-construction period. The report reveals whether there is a gap between design and actual performance in the studied systems in order to learn from the findings.

2. An evaluation of 'value for money' for each of the systems; informed by analysis of construction time, cost, and quality as defined by resident levels of satisfaction.

3. An evaluation of the Housing Innovation Showcase Exhibition held in May 2012.

4. An assessment on the effectiveness of Kingdom's procedures for raising resident energy awareness and understanding of the operation of the installed new technologies.

5. Lessons for the development of system-built and low-energy housing and the implications for the wider audience.

The HIS provided a unique opportunity to undertake post-construction evaluation testing and monitoring in order to understand and evidence the relationship between MMC, the effectiveness of new technologies and resident satisfaction levels.

Kingdom's Housing Innovation Showcase has been a bold attempt to deliver and explore ways in which high levels of energy efficiency can be implemented into affordable housing. The design intent was to deliver homes that are healthy, comfortable and environmentally sustainable. Based on the level of resident satisfaction with their new homes it is clear that this intent has been fully achieved. Satisfaction levels scored highly on most metrics of all the dwellings evaluated, which is an excellent achievement by all parties involved.

During the early occupation stages of the project some fabric deficiencies and reduced system efficiencies were identified however none were too great to overcome and remediate**.** The study shows that in reality, it is possible to design, construct and deliver low carbon and low cost homes whilst achieving high levels of satisfaction.

Kingdom has demonstrated how environmentally conscious designs integrated into various modern methods of construction can create homes for the future while delivering a valued place and energy efficient homes which are much appreciated by residents.

It should be borne in mind that specifications between the various MMC systems differed making some direct comparisons difficult. With reference to **construction period and costs,** while all systems were built within timescales substantially better than traditional methods, there were significant differences in construction time (superstructure) ranging from 49 days to 126 days. The build **cost per square meter (£/m^2)** varied largely between each system, with the average cost amounting to £907 per m^2.

The least expensive build cost were the flats procured via Volumetric Space Frame by Powerwall at £711 per m^2, closely followed by the Control House by Campion Homes at £743 per m^2 and houses procured via Energyflo Breathing Wall Timber Frame System by Lomond Homes at £768 per m^2.

When considering **value for money** for each of the systems three indicators were analysed. These were time, cost and quality as perceived by the residents.

The Control House by Campion Homes was the only system which delivered a better than average construction time and cost of 65 days and £743 per m^2 respectively whilst scoring 10/10 for levels of satisfaction.

Another system which scored highly on the grounds of cost and satisfaction was the Volumetric Space Frame System by Powerwall. It was procured at a better than average cost of £711 per m^2, achieved 10/10 satisfaction levels, but took 91 days to construct, which was slightly longer than the average.

The iQ Closed Panel Timber Frame System by CCG had the shortest construction time of 49 days, achieved 9/10 for satisfaction and cost slightly more than the average at £903 per $m^{2.}$

The Energyflo Breathing Wall Timber Frame System by Lomond Homes scored 10/10 for satisfaction, cost more than the average at £768 per $m^{2,}$ but took 90 days to construct.

It was crucial to the success of the project to evaluate whether anticipated energy efficiency and carbon performance have been achieved in reality, to find out from the residents what works best for them in their new homes and to establish cost effectiveness of the various solutions.

The technical analysis revealed that:

1. The tested systems achieved as-built measured **heat loss performance** at various levels with results ranging from 4% - 39% above the predicted thermal transmittance values. Equally some dwellings demonstrated improved air tightness ranging from 2% - 39% better than predicted and significantly better than the contemporary Building Standards requirements.

   The majority of the measured values oscillated around the $3m^3/(h.m^2)$@50Pa permeability which is considered a highly airtight dwelling limiting ventilation heat loss substantially. Some properties reached closer to the 5 $m^3/(h.m^2)$@50Pa whilst some dwellings reached as low as 0.6 $m^3/(h.m^2)$@50Pa. At these low air tightness levels, consideration of indoor air quality is essential, hence the introduction of varied ventilation strategies throughout the dwellings.

2. With reference to **new technologies**, for most of the installed Solar PV systems, there was a 10% - 15% deficiency in measured output, attributed mainly to losses in the system and inverters. Evaluation of **solar hot water** systems showed little discrepancy between predicted and actual efficiency.

3. While **ventilation** systems were fully operational in a number of homes, some of the ducting was poorly installed demonstrating early signs of underperformance. Most homes achieved installed efficiency figures between 82% - 87% compared with manufacturer's stated efficiencies of >90%.

4. With reference to **in-use energy consumption** – all homes used more energy than predicted, delivering 10% - 30% of an increase compared to predicted levels. This information will be further reviewed following a twelve-month energy monitoring period in Part 2 of this study.

Within the above context it is important to point out that while some people still think that the HIS was a competition, it was never the intention to say 'and the winner is...'. In Kingdom's view all systems selected are 'winners' in their own right as they all met Kingdom's selection criteria. With the information about each system's performance and the feedback on their relative value for money, any of them could be used by Kingdom again, depending on planning/site specific constraints.

The HIS project created excellent conditions for residents to save energy and carbon while stimulating behaviour change in favour of energy conservation. The next step in this process is for Kingdom to support residents on their behaviour change journey.

Despite all of Kingdom's efforts in holding a pre-handover workshop briefing during the handover and the detailed supportive information within a bespoke Resident Handbook, this did not meet some of the resident's needs. Some still reported not knowing how to program their heating systems, not being advised about MVHR and/or not knowing that they should pay attention to their energy monitors; when interviewed they requested further training. Based on other studies, this is not an unusual outcome. These findings have wider implications for the housing sector and for our society overall.

Kingdom is aware that its' housing staff need to be fully briefed on energy efficiency and that the provision of technical and energy advice is not an exclusive domain of technical staff / energy advisors. Supporting residents on their behaviour change journey is part and parcel of providing homes which are safe, secure and energy efficient; looking at what information should be provided through handover procedures, follow up visits and other feedback mechanisms and in what format this information should be provided, is essential.

As identified in this study as well as events on **What Works in Behaviour Change** [1] and research such as **Scottish Environmental Attitudes and Behaviours**[2] there is an increased likelihood of people adopting energy efficiency behaviours if:

- they view energy efficiency as being a benefit to themselves rather than a curtailment; this is particularly true in terms of increased thermal comfort and health
- energy use and savings are visible and so provide goals and motives
- others around them are engaged in similar behaviours or trying to meet similar goals
- information is provided in a vivid, salient and a personal manner

There is a pressing need to find effective ways of influencing resident interaction with their new homes, instilling in our society a greater sense of responsibility for the environment and to make an impact on energy use while also protecting resident comfort and satisfaction.

RECOMMENDATIONS

As the commissioning client, Kingdom's role is to make sure that their investment delivers the desired results. The prediction of a building's performance must be done accurately at design stage and execution must be to a high standard. The supply chain must be capable of delivering low carbon buildings free of defects. Once the building has been completed building performance evaluation (BPE) needs to be performed to verify the predicted parameters and to identify what, if any, improvements need to be made.

This study identified a set of recommendations for achieving truly low carbon buildings. They are grouped into three sections as follows:

1. Design & Construction
2. Kingdom Housing Association
3. Wider Audience

[1] http://www.scotland.gov.uk/Topics/Research/by-topic/environment/social-research/Remit/events/Behaviour-Change
[2] http://www.scotland.gov.uk/Resource/Doc/280711/0084578.pdf

Recommendations for Design & Construction

The study demonstrated that the prediction of a building's performance must be done accurately at the design stage and once the building has been completed a second evaluation should be performed to verify the predicted parameters and identify where improvements need to be made. Building performance evaluation needs to be incorporated into Building Control and Architectural Plan of Work (RIBA) so that the gap between design predictions and operational performance across the process of creating low carbon buildings narrows as quickly as possible. This will be essential as we reach new and more demanding 2016 Building Standards and beyond.

The following recommendations relate to the areas that have affected the performance of the new build homes:

1. Design Stage

- **Design development –** construction professionals and energy specialists need to work alongside the design team and be involved in the process as early as possible. Early design must be informed by findings from relevant completed BPE's through continuous feedback and communication between stakeholders.

- **Design calculation –** in addition to SAP prediction tools a more accurate and defined energy tool should be used, preferably a dynamic type which considers occupation patterns and weather data in combination with the design, e.g. IES-VE, EDSL-TAS, Autodesk Ecotect. This will pave the way to the use of future tools such as Building Information Modelling (BIM) in this scale of project.

- **Technical on-site supervision –** it is important that the main contractor and trades are supervised and aware of onsite construction changes. The building industry in Britain often fails to adapt to new technologies and ways of installing them. A "this-is-the-way-I-install-it" approach hinders performance improvement.

2. Building fabric

- **Wall-floor junction –**attention to detail is necessary particularly at the skirting level where insulation wraps round the junction between wall and floor and that thermal bridging is kept to a minimum. Air infiltration is prevalent in these areas therefore an airtight connection has to be achieved.

- **Services & ducts –** seek professional advice on methods to avoid and repair the penetration of services through building fabric which compromises the envelope performance. This should include detailed advice how to repair and adequately seal round services. Universal use of gaskets or special seals that minimise impact to the air tight envelope is recommended.

- **Eaves level & ceilings –** ensure that in practice insulation covers awkward access areas close to the eaves and without perturbating any roof ventilation grills or vents. The use of a different insulation product at eaves level might help to minimise air infiltration and heat loss. Supervision is essential at this stage.

- **Thermal bridging –** detailed design including calculation of all connections/ junctions for thermal bridging should be performed in seeking to achieve lower Psi (ψ) value levels than the Building Standards threshold of 0.15 W/mK. Thermal bridging Psi values between 0.01 and 0.08 W/mK should now be common practice in detailing and below 0.01W/mK is greatly encouraged.

- **Air tightness –** airtight layers should be kept integral and penetrations through this minimised. Service zones and cavities should be implemented where services are kept outside the airtight barrier to minimise interference with the designed airtight barrier.

3. Construction

- **Offsite vs. onsite –** offsite assembly design should be followed as prescribed in order for subsequent onsite trades to follow with the remaining building work (finishes and services). If changes or assembly faults are encountered they have to be communicated to the manufacturer and alternatives suggested.

- **Technology performance –** it should be borne in mind that performance at design stage is subject to inefficiencies which are dependent on the level of on-site control, quality of installation, quality of commissioning and operating hours, as well as maintenance. Quoted efficiencies are often higher than the actual installed efficiencies.

- **Commissioning –** in addition to pre-handover checks a post occupational commissioning of services should be conducted and recorded at the end of the first month of occupancy.

- **Contracting sequence of work –** it is essential that the main contractor has a core site team that is adequately trained on current thermal detailing best practice and that they supervise sub-contractors to achieve quality defect free outcomes.

Recommendations to Kingdom Housing Association

1. Kingdom should formalise existing good practice exercised by its staff, by producing a comprehensive written Energy Awareness procedure to preserve consistency in its implementation and to raise standards.

   This procedure should involve re-visiting new residents after they have settled into their new homes to provide further guidance on how to:

   - Operate central heating programmers
   - Operate new technologies
   - Monitor information provided by the in-home energy display systems
   - Be energy efficient
   - Understand information contained in their Energy Performance Certificate (EPC) and use this information as a tool in raising awareness about energy performance

2. Kingdom should mainstream application of the Energy Awareness procedure in the course of letting their existing housing to maximise its' impact.

3. Kingdom is well aware that its' housing management staff need to be fully briefed in energy efficiency and that provision of technical and energy advice is not an exclusive domain of technical staff / energy advisors. During interviews with housing staff they expressed interest in being trained in this area so that they too can provide basic advice if needed not only at handover stage but to ensure that this advice can be provided as part of their day to day services and at re-letting stage.

4. Staff training should include a basic overview of EPCs and how to operate central heating programmers and other new technologies, including MVHR and in-home energy display systems.

5. There is evidence that regularly repeated face-to-face interaction, reinforced with technology to monitor usage and pledges to a long-term commitment to reduce energy consumption can work.

6. It is recommended that the housing sector develops 'real life' instructions presented on YouTube or in DVD format and recommend application of energy efficiency saving Apps on mobile phones. Relevant information could also be presented on Kingdom's own website for reference as required. To be most effective information provided to residents needs to be personalised, visually appealing and continuously reinforced until established as a routine.

7. It is also recommended that Kingdom review the specification for MVHR systems in line with NHBC Standards 2014[3] and make sure that the amount of heat that is capable of being recovered is compatible with the amount of heat which is generated by the installed appliances e.g. in the kitchen and bathroom. Otherwise there may not be sufficient ventilation and cooling in well insulated dwellings, rendering the MVHR systems less effective. It is recommended that future specification for MVHR controls should:

   - Be fitted with visual and audible indicators that show they are working
   - Clearly illustrate whether they are in normal or boost and/or bypass mode
   - Be fitted with visual and audible indicators when maintenance is required

8. Kingdom should regularly update and monitor the quality and effectiveness of the Resident Handbook, and promote its use by the residents.

Recommendations to the Wider Audience

1. Using MMC rather than more established techniques can reduce construction time and cost without compromising quality. The Scottish Government should continue promoting wider application of MMC in line with the *Sustainable Housing New Build Market Transformation Strategy* which needs to be continually updated by findings from this evaluation and other studies such as *Greener Homes Innovation Scheme.*

2. Consideration should be given to the wider funding of BPEs with the objective that the results of post construction testing inform the development of Building Standards: as built performance of dwellings must be evaluated as standard and the results fed back to the development teams and the supply chains to ensure continuous improvement.

3. Modelling predictions for fabric thermal performance, energy efficiency and carbon emission performance need to be improved to more closely reflect the 'as built' performance. This can be done by at least making sure that lessons from post construction testing are fed into regulatory modelling tools such as SAP.

4. Based on evidence from the post construction testing compliance, agencies should seek to develop performance standards for new technologies, with the priority attached to low carbon technologies and ventilation strategies (MVHR[4] & MEV).

5. With specific reference to MVHR systems, a message for the regulatory bodies and software developers is that the next revision of SAP software should include actual or measured efficiencies rather than default values.

6. There is a pressing need for finding effective ways of influencing resident interaction with new technologies and instilling in our society a sense of greater responsibility for the environment. This is particularly challenging amongst particular client groups, including older people who may have specific culture or varying needs. It is recommended that the Scottish Government or its Agent works with experienced clients such as Kingdom and other agencies to capitalise on lessons learned so far and develops innovative ways of customer engagement to influence people's behaviours to reduce CO_2 emissions and costs more effectively than has been the case to date.

7. Production of a 'standard' Resident Handbook for adopting and adapting, including versions for groups with specific requirements such as the elderly would be beneficial. Such Resident Handbooks could be developed in partnership with the interest groups such as Consumer Futures to ensure that they meet all types of resident needs.

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[3] NHBC Standards 2014 Chapter 3.2

[4] **http://nhbcnews.co.uk/go.asp?/bNHB001/mADQBG2F/qLMQTG2F/u12UCD2F/xWTDOG2F/cutf%2D8**

8. With reference to post-construction testing, the Scottish Government and external agencies should develop easy to perform standard methodologies for wider application that can be used for post construction testing at any time of the year.

9. The housing industry should be encouraged and incentivised to develop a feedback mechanism to ensure that the results of their post construction testing inform the future design and construction decisions for designers, house builders and their supply chains by setting up a portal for logging and benchmarking results.

10. Consideration should be given to funding the development of a training programme about key findings from Building Performance Evaluations (BPE). Such a programme could be delivered through training providers such as CIH, SHARE, EVH, SFHA and/or GWoSF and could utilise Asset Skills grants which may subsidise the cost of training in energy efficiency. This programme should include information for housing staff on educating and influencing behaviour change and about operating new technologies and their effectiveness.

11. The Scottish Government needs to recognise and respond to the real pressures social housing providers are under. The extra £4000 funding through the Affordable Housing Supply Programme for every home meeting the 'silver' sustainability standard for emissions and energy use within section 7 (Sustainability) of building regulations is helpful but not sufficient to optimise the quality standards.

12. Affordable housing subsidies must be aligned to a level that truly recognises the increasing quality standards to reduce carbon emissions but also the pressing need to tackle fuel poverty to improve health and well-being.

Figure 1 - Dwelling context overlooking play area *photo Misia Jack*

EVALUATION OF RESULTS

Figure 2 – Housing Innovation Showcase *photo: Misia Jack*

Introduction

Driven by concerns about the ability to develop affordable housing with decreasing subsidy levels and determined to encourage sustainability, innovation and energy awareness, Kingdom Housing Association (Kingdom) developed the Housing Innovation Showcase (HIS) at Dunlin Drive in Dunfermline, Fife, Scotland.

Kingdom set out to achieve a step-change in the selection of low carbon MMC systems and public aspirations for new affordable housing. Working in partnership with its stakeholders, Kingdom took the lead in showcasing this unique project.

The main objectives of the HIS were to build a varied and highly specified set of low-carbon, energy efficient homes with selected system providers to determine how MMC and various new technologies can be adopted and/ or adapted to better serve the procurement of affordable housing within tight cost constraints and to establish their impact on the everyday lives of residents.

The HIS is the 1st phase of a larger affordable housing development designed to provide a total of 125 new homes. The remaining 4 phases are being developed by Kingdom to provide mixed tenure affordable housing. This 1st phase consists of 27 new social rented homes split into10 blocks using different MMC systems.

Although the building fabric of the various MMC systems may on the surface appear similar the construction methodologies and their performance due to the installation of different new technologies, differ. In addition, each block has been built using a different construction process with the use of similar roof and floor systems but different wall types. To allow some level of comparability of performance all homes were built to the same design brief and general specification.

The HIS was delivered at a cost of approx £3.5M.

The MMC systems used were:

- Powerwall - Volumetric Space Frame System (now known as Ene-wall)
- Campion Homes - Scotframe Val-U-Therm System
- Stewart Milne Construction - Sigma II System
- Campion Homes – Weinerberger Porotherm Insulated Clay Block System
- CUBE RE:Treat - SIPS Panel System
- Campion Homes - Passivhaus Standard and Control House
- Future: Affordable - K2 Closed Panel Timber System with e.Core Bathroom Pod
- Lomond Homes – Eneryflo Breathing Wall System
- CCG - Timber Close Panel iQ System
- Bobin Developments - Beco Wallform Insulated Concrete Formwork

The new technologies include Solar Hot Water (SHW), Solar Photovoltaic Panels (PV), Combined Solar Hot Water & Electric Panel PVT Collector, Voltage Optimisation, Air Source Heat Pumps (ASHP) as well as Gas-fuelled Micro Combined Heat & Power Boilers (mCHP). Mechanical Ventilation & Heat Recovery (MVHR) systems were installed in some of the dwellings and all homes were fitted with an In-home Energy Display monitor.

Research Focus

The research for this study commenced during spring 2012.

Following the occupation of the newly completed homes during early summer 2012 the Building Performance Evaluation (BPE) Study Team were able to begin monitoring the in-use energy consumption and performance of the MMC and new technologies.

The main focus of this research was to evaluate the extent to which the as-built performance met the prescribed design. Alongside this was the need to understand the relationship between building performance and the resident levels of satisfaction with their homes.

Within the context of measuring building performance, the research primarily focused on the measurement and evaluation of energy demand, using the recognised Standard Assessment Procedure (SAP) which provides an evaluation of energy consumption parameters and the design outputs.

Study Objectives

The study objectives were as follows:

At a technical level:

1. Evaluate and monitor the homes over an early-occupation period (first six months)
2. Compare the performance of 13 different systems (built using a varied set of energy performance outputs against a typical Kingdom dwelling)
3. Undertake post-construction performance tests and early-occupation assessment of the use of new technologies
4. Conduct an energy assessment of early-occupation

At a social level:

1. Evaluate levels of resident satisfaction with their homes
2. Assess the effectiveness of Kingdom's handover procedure
3. Assess the impact of the HIS project
4. Analyse feedback from the HIS Exhibition

The achievement of the objectives at the **technical level** was addressed through a review of the as-designed data produced by each system provider. The data was compared with the measurement and monitoring of actual energy use, the occupiers' comfort levels and their interaction with the technology in their home.

The research involved conducting interviews, surveys and field tests during the prescribed evaluation period. This included the processing of downloaded data and calculating results while adopting industry-led standards. Methodology for assessing and monitoring performance was adopted from the CIBSE TM22 accepted method[5]**.** For more detailed information see TM22 Energy Assessment and Reporting Methodology (inc. CD-ROM), 2nd Edition or follow this link.[6]

The achievement of the objectives at the **social level** was addressed through structured, face to face interviews with the residents. The interviews focused on levels of satisfaction with all aspects of design as well as the effectiveness of the technologies installed and their effect on thermal comfort. A review of Kingdom's handover procedure and observing the implementation of this during the allocation process was carried out along with surveys with the project partners and the visitors to the HIS Exhibition.

Report Structure

This first part of the report details the outcomes of the research which took place after handover during the summer and autumn of 2012.

The second part involves post construction monitoring of the same homes for a full year of occupation to include a full heating season. The outcomes from this will be published separately.

[5] http://www.usablebuildings.co.uk/fp/OutputFiles/FR2MainText.html
[6] https://www.cibseknowledgeportal.co.uk/component/dynamicdatabase/?layout=publication&revision_id=103

Part 1

This first part covers the HIS, the HIS Exhibition, key information about project procurement as well as the assessment of value for money of the various systems. It also contains **Case Studies** for each house system.

Each case study reports on:

- Field study results which evaluated the as-built thermal performance of walls, ceilings & floors
- Design and Construction audit to all dwellings, including a comparison of the design outputs against the as built outputs and full review of SAP worksheets
- System performance evaluation of low carbon technologies
- Infra-Red Thermography of all blocks
- Air tightness evaluation of all blocks
- Acoustic performance evaluation of all blocks
- An as-designed and as-built comparison of predicted energy usage against actual energy usage
- Resident satisfaction levels with various aspects of design, including comfort levels

Appendices to Part 1 contain a description of the witnessed handover as well as the technical appendices which expand on the research findings and explain the evaluation in more detail.

Part 2

This will report on the energy consumption during the first full year of occupation, in particular comparing the performance of each of the MMC systems against the performance of the Control House and will be published later in 2014.

Figure 2 - Central play area of the HIS

HOUSING INNOVATION SHOWCASE

The Housing Innovation Showcase (HIS) is a partnership between Kingdom Housing Association & Fife Council, with support from Fife Construction Forum & Green Business Fife. The development of the HIS was managed and procured by Kingdom who is the lead developer for the Fife Housing Association Alliance.

The HIS project is located at Dunlin Drive in Dunfermline and consists of 27 new houses built using different construction methods.

The HIS aimed to:

- Showcase different house systems
- Test the cost, energy performance and flexibility of the new systems
- Trial and promote new technologies
- Deliver Community Benefits across the project
- Promote mainstreaming of different MMC systems across a wider affordable housing programme
- Promote affordable housing in Fife

The strengths and unique features of the HIS at UK level were:

1. The site infrastructure was developed by Kingdom's Framework Contractor in line with a master plan for the whole site.

2. Kingdom's Preferred Partners were selected to showcase their house construction systems and their choice of low carbon technologies.

3. All houses meet the identified housing needs and demonstrate mainstreaming capabilities.

4. Testing several different house construction systems against a control dwelling to evaluate their individual performance against key criteria: thermal performance, interaction with new technologies, cost and speed of construction as well as resident satisfaction levels.

5. Testing the effectiveness of handover procedures as a vehicle to influence residents' environmental behaviour. This included a review of the Resident Handbook and the use of the in-home energy display systems.

6. Implementation of a Community Benefits Charter by addressing employability, encouraging energy awareness and construction methods in local schools. Delivery of the Community Benefits Charter was facilitated through Kingdom's Fife Works project. Further details are within the Community Benefits chapter.

7. To increase awareness about low carbon buildings and MMC. Similar to the Finnish Housing Fairs, the completed homes were open to the public for three weeks prior to allocation. This involved a public Exhibition of new technologies and sustainable products at various associated events. Further details are within the HIS Exhibition chapter.

Strengths of the Housing Innovation Showcase

Through successful management of a wide number of partners all working together, Kingdom facilitated collaborative partnership between ten different system providers. This involved team working with a number of external agencies and was led by the Project Board which managed various sub-groups.

To be effective, this structure required and relied upon efficient and effective communication. All of the partners who were interviewed following the showcase stated that it was the excellent communication which was the key to delivering the project on time and within budget.

The HIS provided a unique opportunity to carry out post-construction evaluation testing and monitoring in order to evaluate and evidence the relationship between MMC, the effectiveness of new technologies and resident satisfaction levels with the end product.

It was crucial to the success of the project to evaluate whether anticipated energy efficiency and carbon performance have been achieved in reality, to find out from the residents what works best for them in their new low carbon homes and to establish cost effectiveness of the various systems.

Achievements of the Housing Innovation Showcase

Figure 3 - Award winners - Kingdom HA & Project Partners

The HIS gained recognition after being shortlisted for two prizes in the Homes For Scotland 2013 awards in two categories: **Best Green Initiative** and **Best Partnership In Affordable Housing Delivery**. The project went on to win a **Scottish Green Apple Award for environmental best practice** as well as a **VIBES award** for its environmental vision while also being recognised in the **Fife Partnership Excellence Awards.**

In summary the HIS participated in and was awarded the following:

<u>Awards Won</u>
Green Apple Award 2012

VIBES Collaboration Award 2012
RICS Design & Innovation Award 2013 – Represented Scotland in Global RICS Awards Final
Green Business Fife Energy Award 2013
<u>Commendation</u>
Homes for Scotland, Best Green Initiative 2013

<u>Shortlisted</u>
Fife Partnership Excellence Award 2012
Renewables Award 2012
Homes for Scotland Best Partnership 2013
RICS Scotland Awards 2013 – Residential

<u>Finalist</u>
GO Awards Scotland 2013 – Sustainability and CSR Initiative Category

While the HIS was a great achievement at a national and local level, one of the key weaknesses of the showcase, clearly recognised by Kingdom's staff, was the limited success of integrating the supply chains. The key reason for this was the tight programme which needed to be followed.

> ***"Time was the main constraint. If we had more time we would have achieved better integration of the supply chain." Housing Professional***

The reason for bringing different partners together was to bring as much experience and expertise to the development as possible. While many different parties collaborated effectively towards a common goal this took a tremendous effort by Kingdom to co-ordinate. Recognising this, one of the partners suggested that if one contractor was responsible for all the systems, numerous meetings would have been avoided and the whole process of invoicing, cost control, design control and snagging would have been simplified. However, Kingdom decided that the benefits to the inclusive approach taken far outweighed the negatives and that the close involvement of the team of contractors was necessary to ensure that the project was delivered successfully. This is a very important lesson for the future.

Achievements of the HIS arise from:

1. Providing the highest possible quality of housing to residents
2. Delivering high quality housing within tight financial benchmarks in partnership with key stakeholders
3. Developing a non-standard product as part of a standard development and meeting challenging objectives
4. Improving Kingdom's understanding about what is involved to increase resident awareness about low carbon housing and low energy consumption
5. Successfully managing a project as complex as the HIS
6. Trialling new construction methods and different new technologies
7. Collaborative working and how it can work successfully by sharing knowledge and expertise
8. Celebrating diversity and competitiveness as important features of collaboration
9. Meeting ambitious timescales
10. Embracing innovation
11. Identifying systems and solutions which work best in an attempt to mainstream their application

One of the participants commented that:

> ***'HIS provided unique opportunities for networking and collaboration with local and national partners, the supply chains, Fife Council, local schools, universities and colleges – right across Fife – to the wider business community - all to make Fife an easier place to do business'. Housing Professional***

HOUSING INNOVATION SHOWCASE EXHIBITION

An integral part of the HIS was an Exhibition of the completed development where all of the participating system providers showcased their products to the public. The Exhibition took place in May 2012 – just ten months after the first workshop of preferred partners was held.

The newly completed homes were open to the public for three weeks. During this time all partners ran workshops, tours, seminars and meetings. The key objective of the Exhibition was to raise industry and public interest in energy awareness, MMC and new technologies.

The Exhibition attracted over 3000 visitors from all parts of Scotland, the rest of the UK and abroad, confirming considerable interest in MMC and new technologies. Five hundred local people also attended a family fun day which was a great success.

A survey was undertaken to assess the Exhibition's impact. Based on feedback it is clear that it has been a tangible success for visitors who took part.

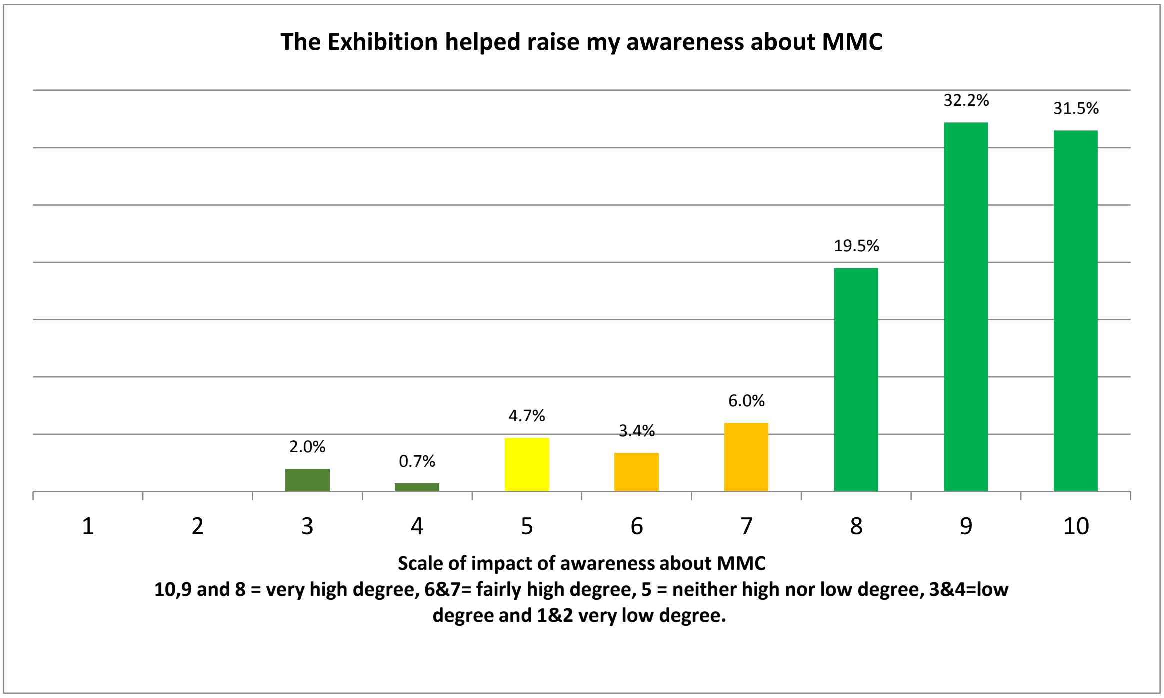
Impact of the Housing Innovation Showcase Exhibition

Most of the respondents visited the Exhibition because of their professional interest. Others included prospective residents, the general public and the local community.

The Exhibition was excellently advertised, with 93% of the respondents saying that they had been aware of the objectives of the HIS prior to their visit.

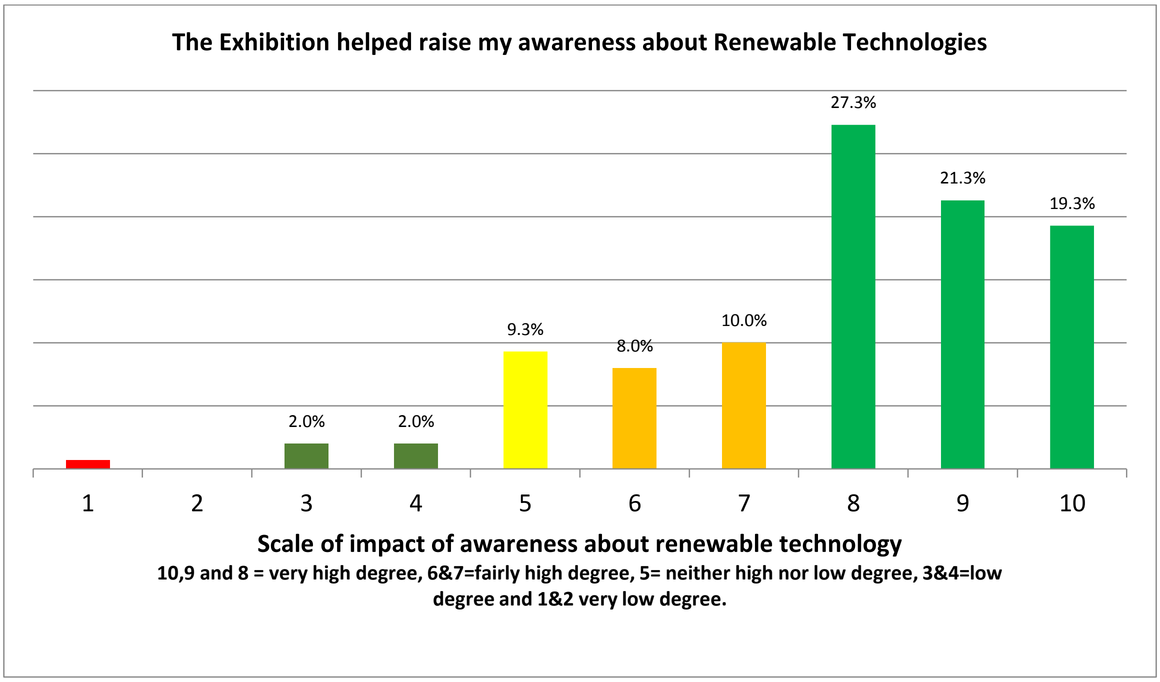
Respondents greatly valued being able to physically visit the houses constructed using MMC, being able to view various new technology systems in situ and in particular being able to experience how various new technologies operate 'for real' in demonstration houses. Some commented that they found the Exhibition to be a good educational tool.

83% of the respondents stated that they had learnt more about MMC to a very high degree.   Equally high proportions stated that they had learnt more about details of specific systems.



Graph 1:   Exhibition impact on MMC awareness

75% of respondents stated that they had learnt more about energy use. Some 68% stated that they had learnt more about renewable technologies to a very high degree.



Graph 2 – Exhibition impact on renewable technologies awareness

98% of respondents stated that the Exhibition met their expectations. The main quoted reason for this was that the Exhibition provided an opportunity to see first-hand the new building techniques and technologies as opposed to just reading about them.

Visitors stated that the Exhibition provided:

- a ‘working experience of different methods of modern construction’
- an opportunity to ‘develop working relationships with a variety of other professionals’
- a chance to ‘gain a better understanding of new technologies’

Equally, visitors’ feedback demonstrated a widespread endorsement of the Exhibition’s success.

Examples of feedback are below.

1. Visitors valued having the opportunity to see the range of construction types and various new technologies in one place and to talk to the experts / exhibitors about their products.

2. Many visitors liked the fact that the HIS focused more on demonstrating how a standard house type could be delivered in different ways not on architectural qualities of the built form.

3. Respondents liked the fact that all dwellings were of a similar style and that the overall appearance of the development was coherent, despite the very different construction techniques and forms of construction in use and that the standard house designs were fitted with different types of low carbon technologies.

4. Respondents liked the fact that all the systems are concentrated in one scheme and that the dwellings are all ‘genuine affordable dwellings’.

5. Many visitors commented on the value of the planned performance monitoring of the systems and technologies, praising this as very useful to the housing sector and the construction industry.

> ***I liked the idea that a variety of construction methods were showcased and that they can be compared for efficiency and cost effectiveness across time. This allows new technologies to be compared in a controlled way, creating confidence across the construction sector and highlighting pitfalls and allowing lessons to be learned within a relatively new sector."*** **Architect**

Another strength of the HIS Exhibition, strongly commented on by the visitors, was that the HIS was supported by "*very clear technical information and very helpful and well informed staff*". Kingdom staff who manned the Exhibition received lots of praise for their knowledge, helpfulness, and enthusiasm: visitors valued the guided tours conducted by "*extremely friendly"* Kingdom staff who "*talked them through the project background and the whole process"* and praised the fact that in each block they had '*further opportunities to speak with experts able to provide further technical information'*.

Professional visitors in particular greatly valued '*summary sheets'* and the '*comparison cards'* which allowed them to see direct comparisons between the systems, their cost, size, design performance as well as the different building standards to which they were built.

Fundamentally, the Exhibition improved understanding of the work of Kingdom and the importance of social house building within the local communities.

Community Benefits

Kingdom was able to incorporate a number of Community Benefits into the HIS, bringing added value and achieving one of the key aims and objectives of the project.

Employment and Training Opportunities

Training opportunities for the HIS were progressed through Fife Works and Opportunities Fife. Eleven training placements worked on the project. Various site visits also took place with College students to give them first-hand experience with the different MMC and new technologies.

Schools and Colleges

Educational activities were progressed with local Primary Schools, Carnegie, Adam Smith and Elmwood Colleges and St Andrews and Edinburgh Napier Universities. Examples of the activities taken forward are detailed below:

- **Primary Schools**

  Pupils from Duloch, Carnegie, Touch, St Mary's and Tanshall Primary Schools participated in a Construction Challenge where they worked together in groups to complete various tasks.

Figure 4 – Winning poster at the Family Day

- **Play Area**

  The initial design for the play area was made by the Play Practice. Architectural Students from Adam Smith College reviewed the proposals and recommended different finishes for the Play Area (recycled play surfacing and porous pathways).

  Carnegie Primary School chose the play sculpture which is on display in the play area.

- **Photography and Filming**

  Technicians from Adam Smith College provided photography and filming services for the project. This work was used during the Exhibition, incorporated into various PR publications including this Building Performance Evaluation (BPE) Report and can be seen on the HIS Website – www.housinginnovationshowcase.co.uk

- **Artwork**

  Art Students from Adam Smith College visited the site and have produced art work based on their interpretation of the project and the materials used during the construction process. This work was displayed during the HIS Exhibition and is now on show in Kingdom's offices.

- **Edinburgh Napier University**

  The Low Carbon Business Technology Gateway (LCBTG) produced animations showing how each system was assembled and built. This animation work is a useful educational tool and can be viewed on : https://www.youtube.com/watch?v=R5asnnA8cPQ

- **Family Day**

  Almost 500 people from across Fife and beyond visited the HIS on the Family Fun Day, which was held on Saturday 19 May 2012.

  The family fun day was organised to raise awareness of environmental issues and to give local people the chance to see the project and learn about the new technologies that have been installed. There were a range of fun activities for kids. Among the most popular was a special stone carving workshop, the chance to make their own bird box and storytelling sessions.

  Local radio station Kingdom FM provided entertainment with its road show and there was even an appearance from Dunfermline FC's famous mascot, Sammy the Tammy.

Figure 5 – Carnegie Primary structures experiment 01
Figure 6 – Carnegie Primary structures experiment 02

PROCUREMENT

Framework Consultants/Contractor

Framework Consultants and a Framework Contractor were appointed to work on the HIS project. Designs were developed up to Planning Stage prior to the House System Providers being appointed.

The Design Team consisted of the following partners:

- Hardies – Employers Agent and CDM Co-ordinator
- Oliver and Robb- Architects
- Scott Bennett Associates – Engineers
- Campion Homes, appointed to carry out the main infrastructure works on the site, installing services and providing serviced plots for the House System Providers.

House System Providers

Selection Process

The House System selection process consisted of four stages. An Assessment Panel, made up of representatives from Kingdom, Framework Consultants and Fife Council was set up to assess all of the applications received.

Over 150 registrations of interest were received and as a result of the four stage assessment process covering both quality and pricing, ten different House Systems where chosen for the project. Key selection criteria included; Sustainability; Value for Money, Compliance with Kingdom Housing Associations Design Standards, Housing for Varying Needs and Secured by Design.

Procurement

The Association procured separate Design and Build contracts with each successful House System Provider. Estimated and actual superstructure costs for each system are detailed in table 02, page 37.

Programme Delivery

The first House System started on site in November 2011 and all the House System providers were on site by 29 February 2012. The HIS was completed in April 2012. Programme and actual construction periods for each system are detailed in the Appendices and in the Time & Costs section.

Funding

Funding assistance for the project was provided by the Scottish Government and Fife Council with the remainder being funded by Kingdom:

FUNDING	AMOUNT
Scottish Government Grant (55.48%)	£1,974,484.00
Fife Council Funding (7.69%)	£273,544.00
Kingdom Private Finance (36.83%)	£1,310,942.00
TOTAL	**£3,558,970.00**

Table 1 - Breakdown of sources of funding

Value for Money: Time, Cost and Housing Quality

When comparing value for money, three indicators have been taken into account: construction period, cost and housing quality. Each of these indicators is discussed in turn, with housing quality assessment informed by resident feedback and the levels of satisfaction with their homes.

Time and Costs

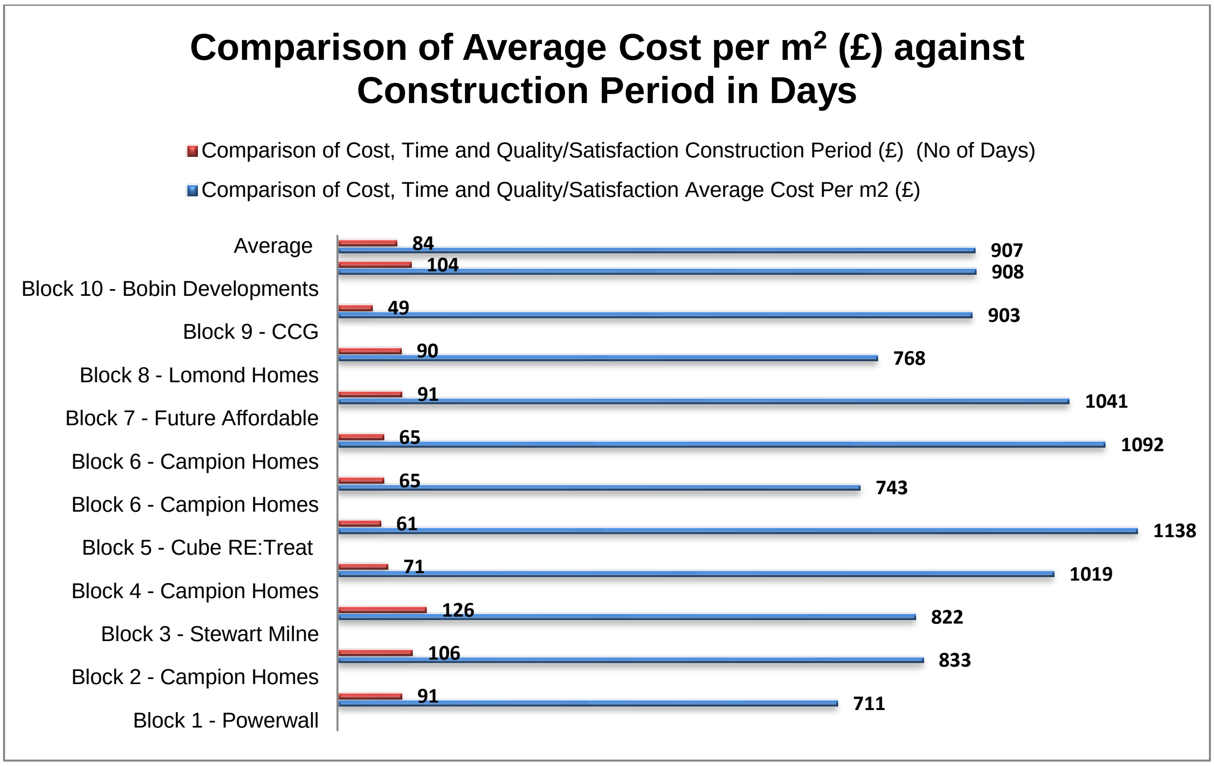
The **construction period** for each system covers the superstructure works only. This was measured in days and varied between each of the systems. When comparing the results, it should be borne in mind that the average construction period cannot be compared like for like as the specifications vary between the blocks.

The **average construction period** was 84 days. Timber Close Panel iQ System by CCG was constructed in the shortest time of 49 days, closely followed by SIPS Panel system by Cube RE:treat of 61 days and the Control House / Passivhaus by Campion Homes at 65 days.

The SIGMA II Closed Panel timber frame by Stewart Milne system had the longest construction period of 126 days.

With reference to **costs**, the cost per m^2 varied largely between the various systems. Again, when comparing the costs, it should be borne in mind that the average costs cannot be compared like for like as the specifications vary.

The **average cost** per m^2 across all the systems was £907 per m^2. The least expensive were flats procured via Volumetric Space Frame System by Powerwall at £711 per $m^{2,}$ closely followed by Control House by Campion Homes at £743 per m^2 and by houses procured using Energyflo Breathing Wall Timber Frame System by Lomond Homes at £768 per m^2.



Graph 3 - Detailed breakdown of costs per unit against average. Breakdown of floor areas can be found in the appendices.

Housing Quality: Feedback from the Residents

Methodology

A resident satisfaction survey was carried out between July and October 2012, just a few months after the handover. In total 24 out of 27 households participated in the survey which involved 22 face-to-face interviews, 1 telephone interview and 1 self-completed questionnaire. This resulted in a 89% response, which is well above the industry average of 50% as identified by domestic building performance evaluations funded by Technology Strategy Board[7].

The process in achieving this high return involved:

1. Meeting with the new residents to encourage them to participate in an independent satisfaction survey with all feedback informing future house design.

2. Kingdom wrote to all residents advising them that a housing consultant would be contacting them direct to arrange a mutually convenient time to carry out an interview.

3. The housing consultant approached each household to arrange an appointment, outlining what would be involved in the interview, namely the nature of the questions and the anticipated duration of the meeting.

Questionnaire and the Interviews

All interviews were based on a questionnaire which was designed to meet Kingdom's requirements and incorporated many questions from the Association's standard satisfaction questionnaire. The questionnaire can be accessed by following this link: Kingdom Housing Association Dunlin Drive User Satisfaction Questionnaire .

A ten scale rating (10 = very satisfied and 1 = very dissatisfied) was used to provide an accurate measure of user satisfaction levels. Subsequently, the Scottish Housing Regulator published guidance favouring a five response scale which can be translated into the ten-scale as follows:

Very Satisfied	8, 9 or 10
Fairly satisfied	7 or 6
Neither satisfied nor dissatisfied	5
Dissatisfied	3 or 4
Very dissatisfied	1 or 2

The reported results convey both rating scales.

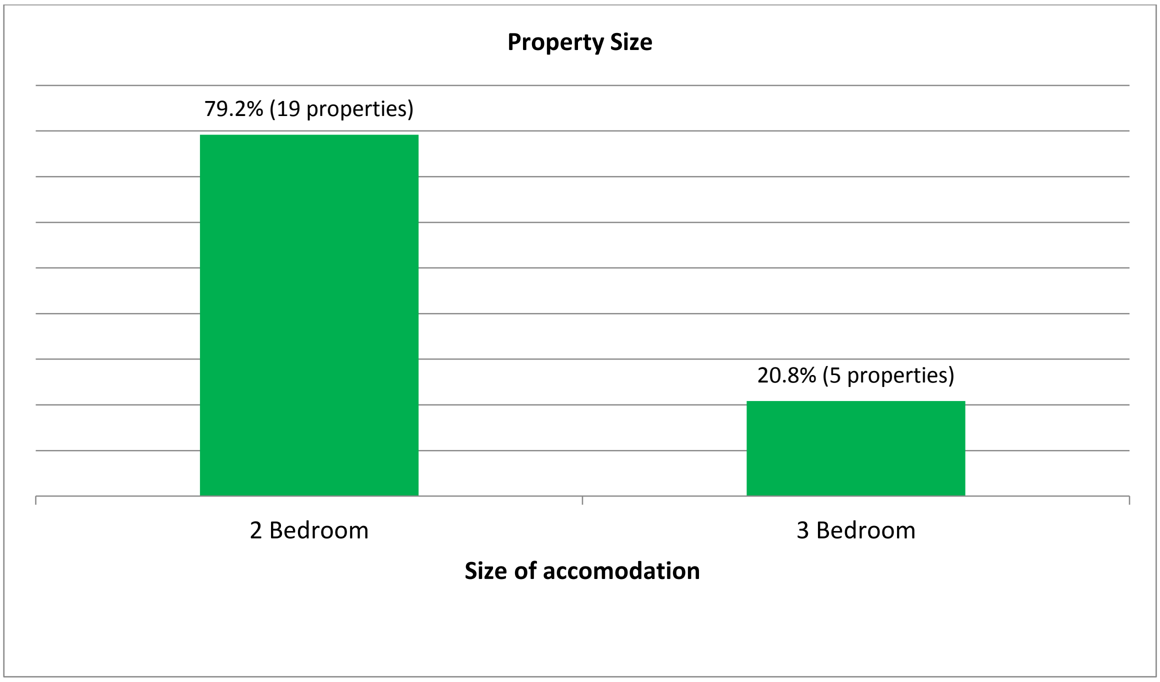
Each interview involved asking over fifty questions of the residents. To make the process as efficient as possible, most involved live transcription of answers on line. On average, each interview lasted about one hour and fifteen minutes, with the shortest interview lasting forty five minutes and the longest about two hours.

All residents interviewed gave their feedback readily and as such contributed a great deal of interesting and valuable information which can be readily used by Kingdom and the housing sector in the future.

[7] https://connect.innovateuk.org/web/building-performance-evaluation

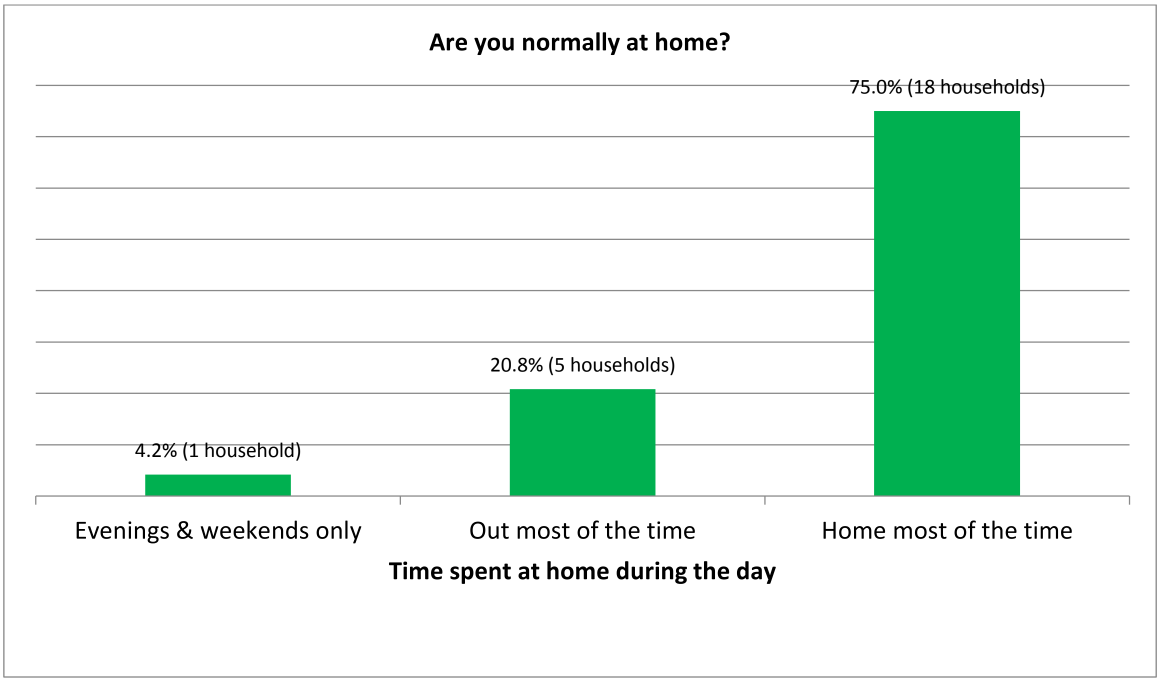
House types and Profile of Respondents

Approximately 60% of respondents live in houses with the remainder living in cottage flats. The property sizes are shown below.



Graph 4 - Chart showing **size of accommodation**, HIS.

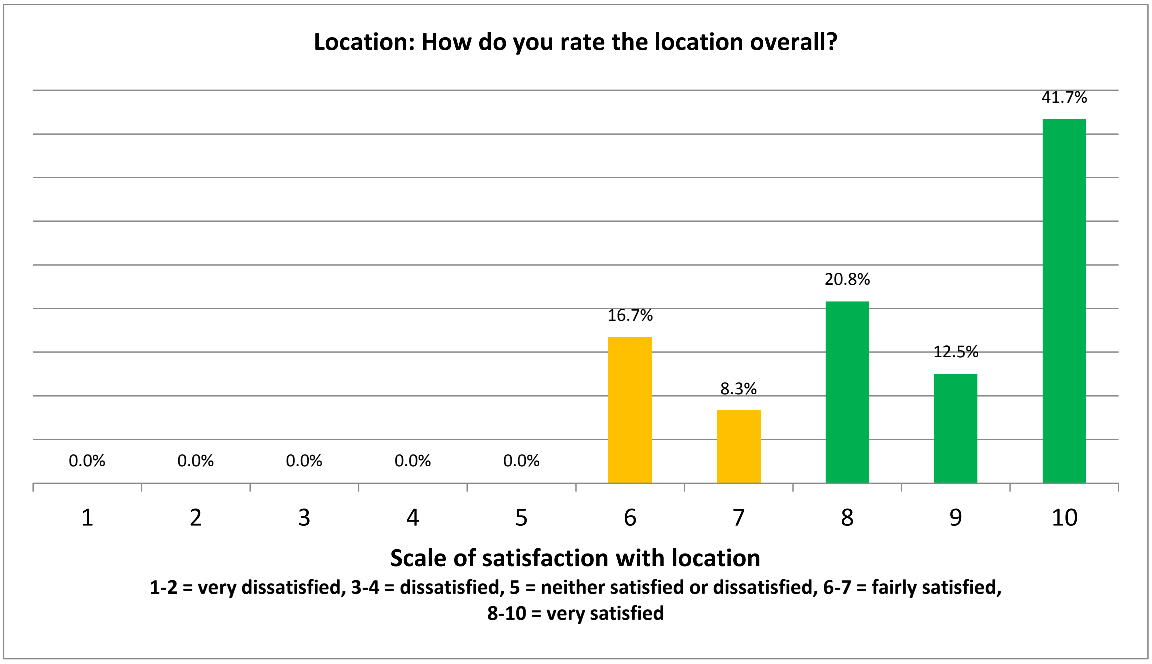
75% of respondents spent most of their time at home. Well over three quarters were over thirty years of age, with almost a third living with two or three children. Around 40% of respondents had no children.



Graph 5 - Chart showing relative proportion of **time spent at home** during the day

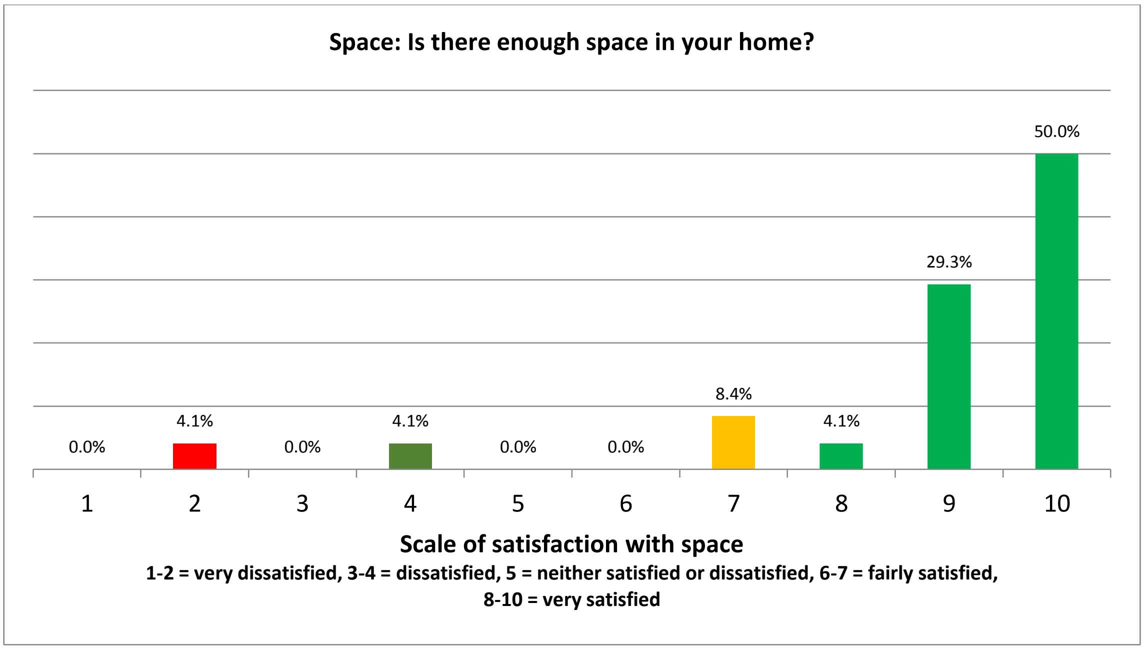
Trends in Satisfaction with Home, Location, Facilities and Services

A high proportion of the respondents (75%) were very satisfied with the location of their home. The remaining 25% indicated lower levels of satisfaction in this area. Typically, residents belonging to this group were less likely to own a car.



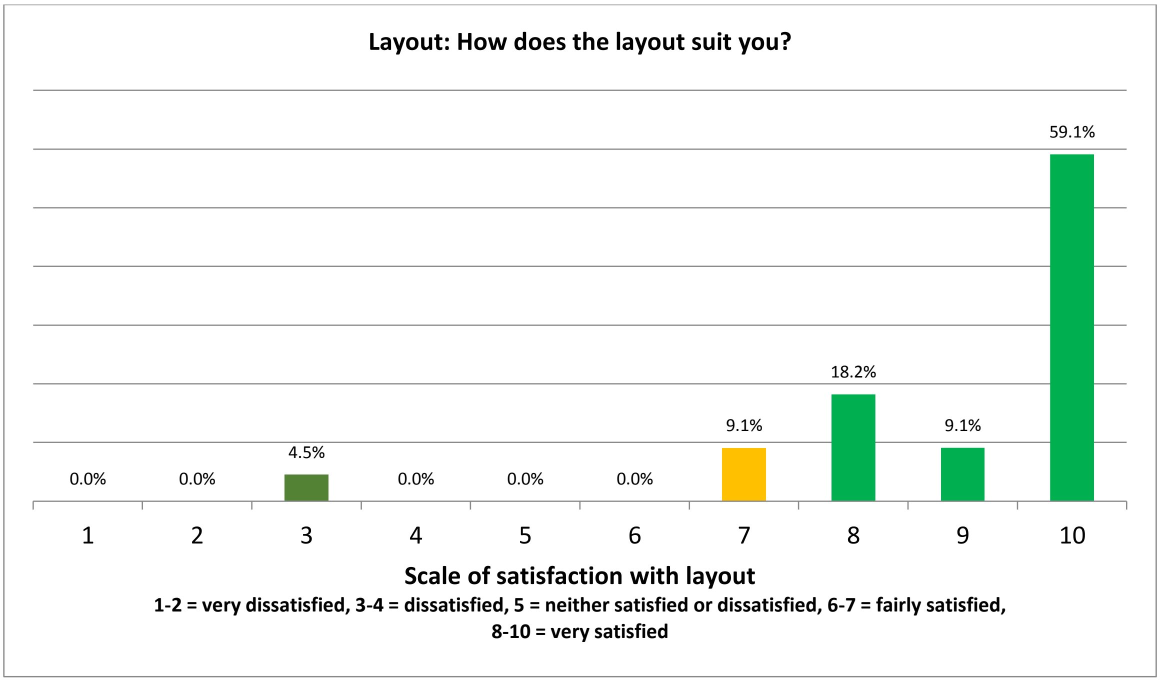
Graph 6 - Satisfaction levels with **Location**

Satisfaction levels relating to the **amount of space** in their home were again very high with 92% of respondents being either fairly satisfied or very satisfied. Two respondents were dissatisfied with the amount of space in their home and this was mainly due to the size of their living rooms.



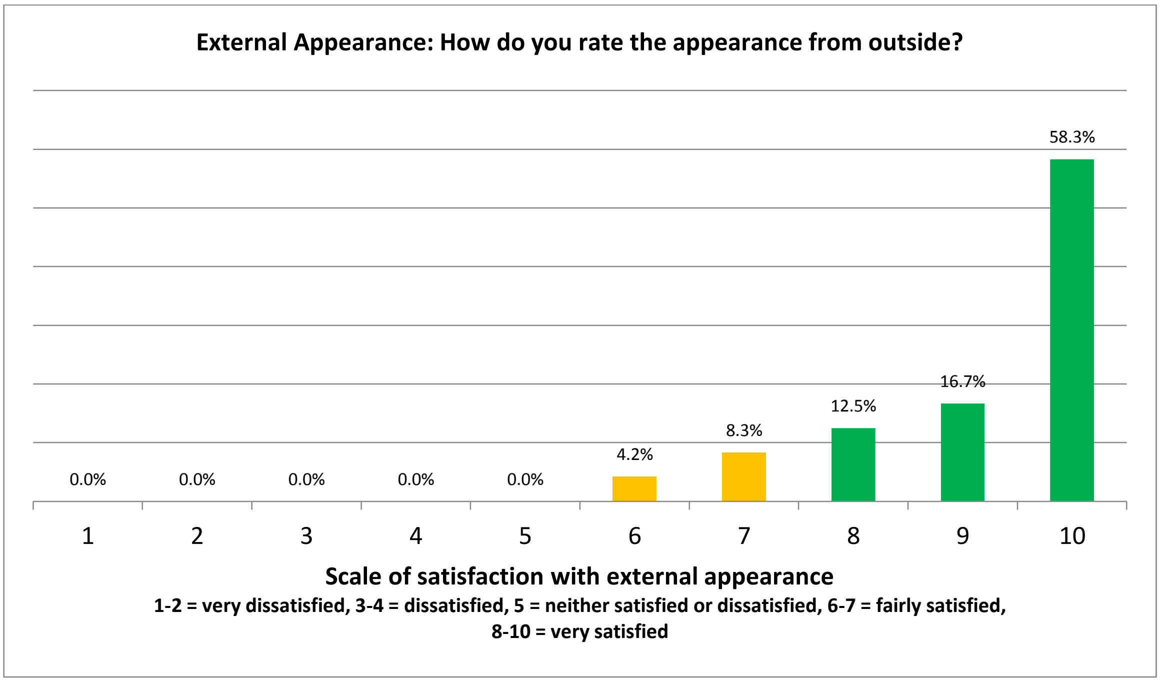
Graph 7 - Rating of overall satisfaction with space within home

Levels of satisfaction with the **layou**t were high with 96% of the respondents either fairly satisfied or very satisfied. Negative feedback about the layout was attributed to a living room which was considered to be too small and too difficult to arrange furniture.



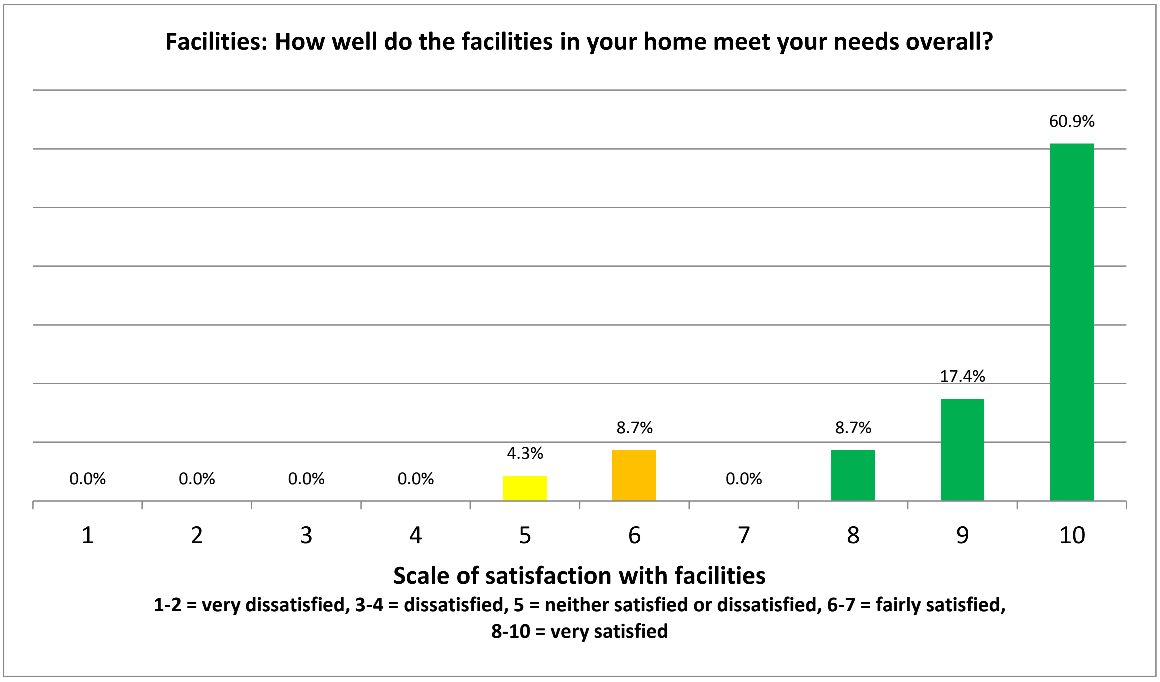
Graph 8 - Rating of overall satisfaction with internal layout design

All respondents were either satisfied or very satisfied with their home's external **appearance,** which is truly an excellent result.



Graph 9 - Rating external appearance

Similarly, satisfaction levels with **in home facilities** were extremely high with 96% of respondents either fairly satisfied or very satisfied with only one neither satisfied nor dissatisfied. This lower 5/10 score was attributed to problems with not enough worktop space in the kitchen and difficulties with hanging shelving/fixtures on plasterboard walls.

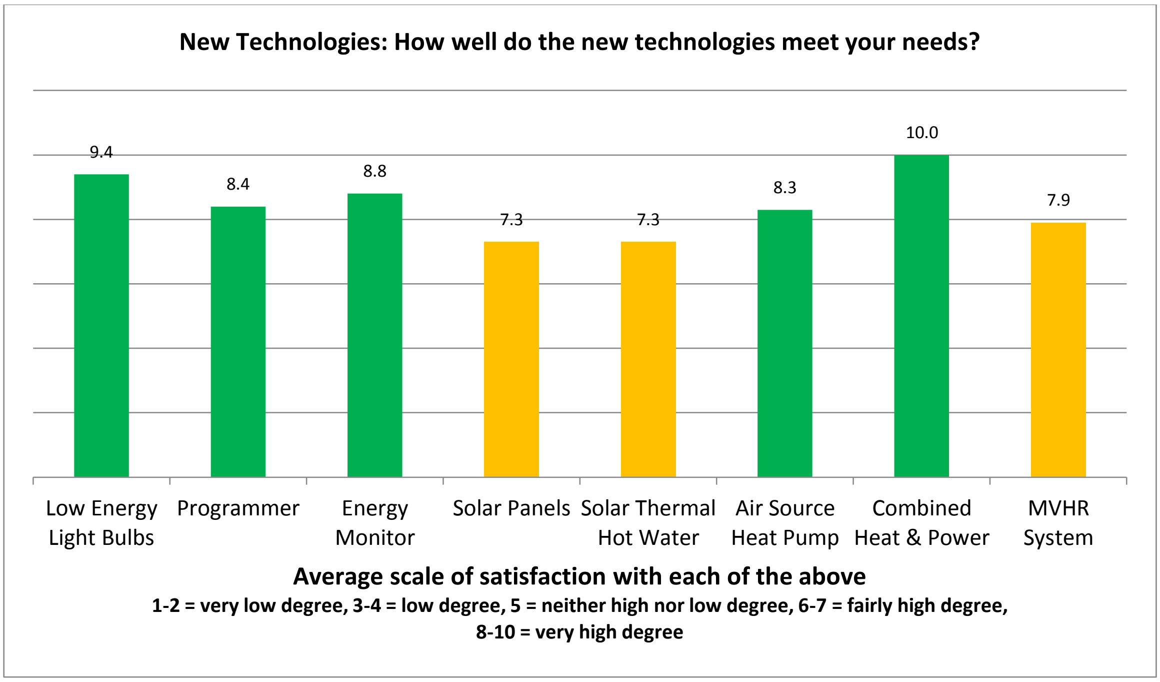


Graph 10 - Rating of how well facilities in the home meet needs

Satisfaction levels with new **technologies** were established at an early stage after occupation and as such is only indicative of an *initial reaction* by the residents. These will need to be verified following at least one heating season. It is however worth reporting the initial findings.

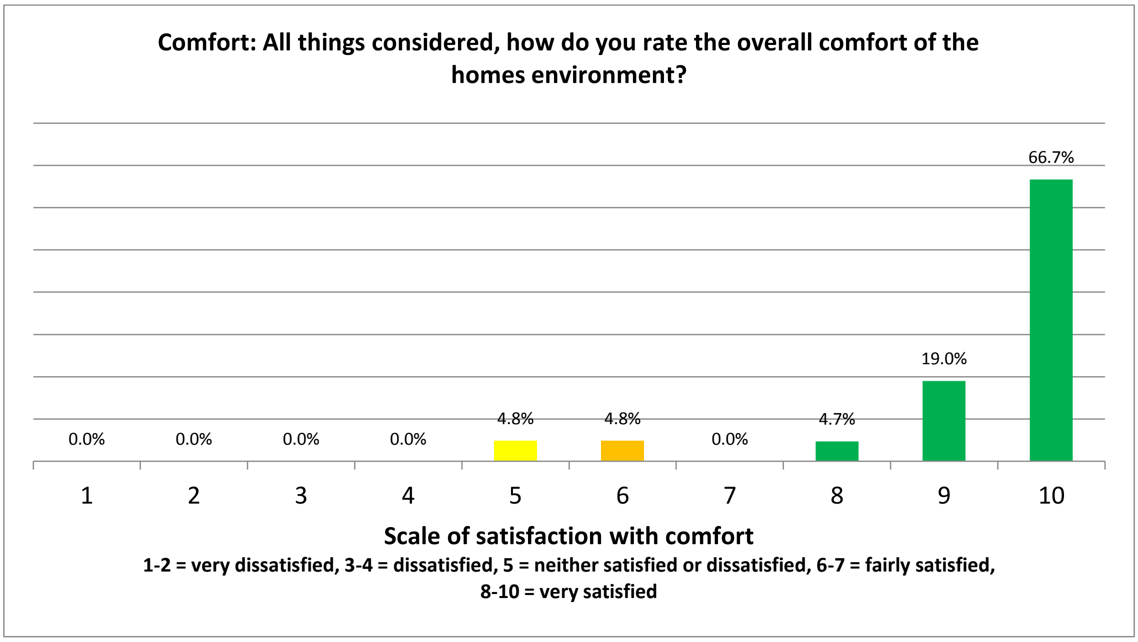
Overall, it was positive, with either high or very high levels of satisfaction with low energy light bulbs, programmers, in-home energy display monitors, MVHR and PV panels. In cases where new technologies such as a programmer, MVHR or In-home energy display monitors were affected by defects, the scores went down to 1, 2 or 3/10.

Typically, the remaining 'middle scores' could perhaps be improved by further raising awareness about operating programmers and In-home energy monitors – an issue which Kingdom staff have been actively addressing since obtaining survey results.



Graph 11 – Expectations of new technologies

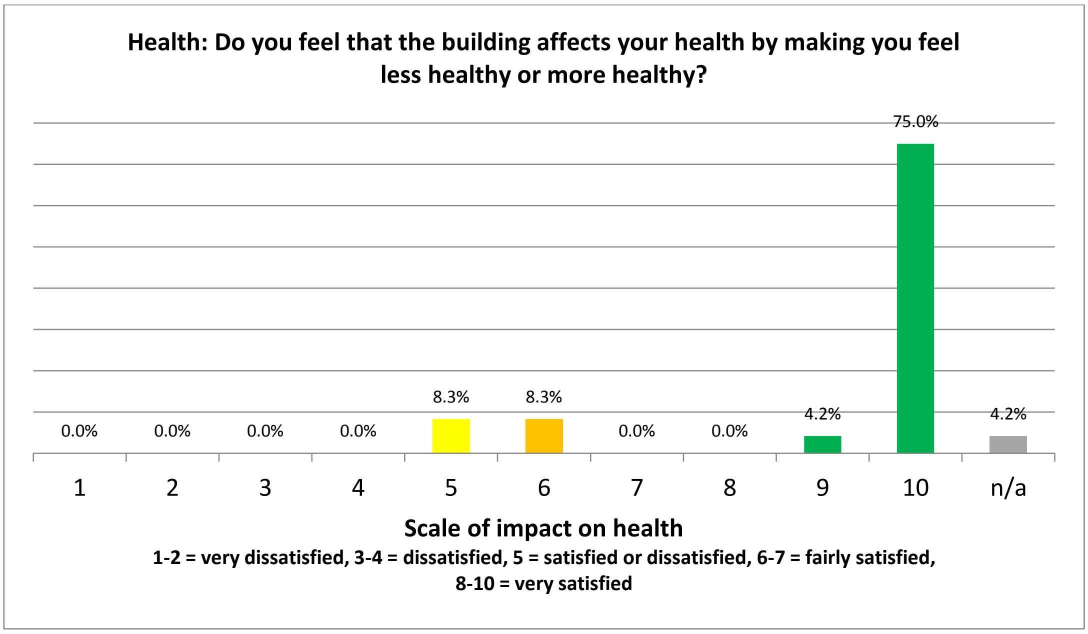
Feedback about **comfort levels** at this early stage of occupation was scored highly or very highly by all but one of the respondents.



Graph 12 - Rating of overall comfort of homes

Again, **impact of new homes on health** is also positive, with three quarters of residents awarding a 10/10 score believing that their health has improved since moving into their new home.

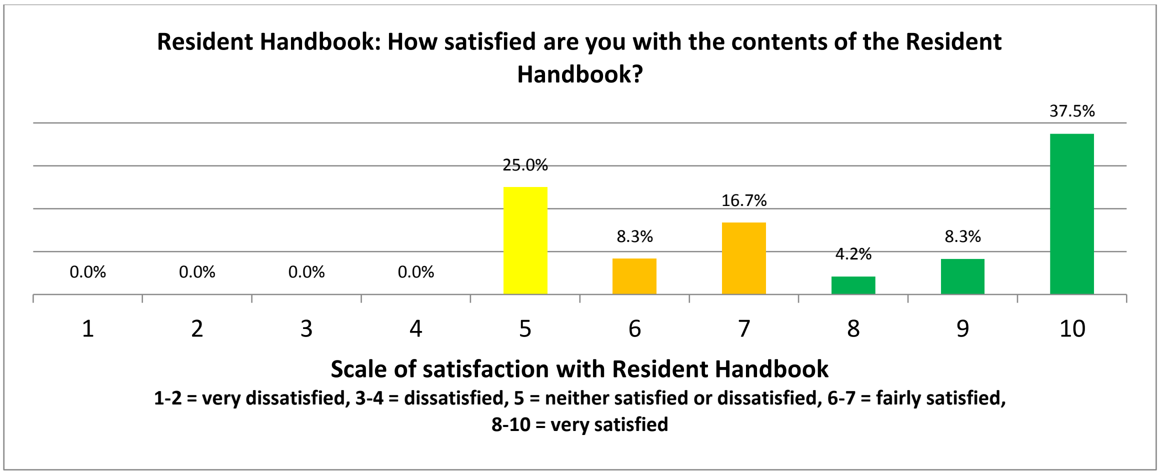
While the impact of moving into a brand new, high profile, modern, energy efficient home cannot be underestimated, it should also be borne in mind that a high proportion of residents previously lived in unsuitable housing, including overcrowding, having to climb stairs (while also experiencing mobility problems), fuel poverty and serious antisocial behaviour which caused them stress and feelings of insecurity. It should be noted that during the interviews there was some indication that MVHR had positively impacted on the health of some residents with breathing difficulties. This is an issue which will require further study.



Graph 13 - Impact on health

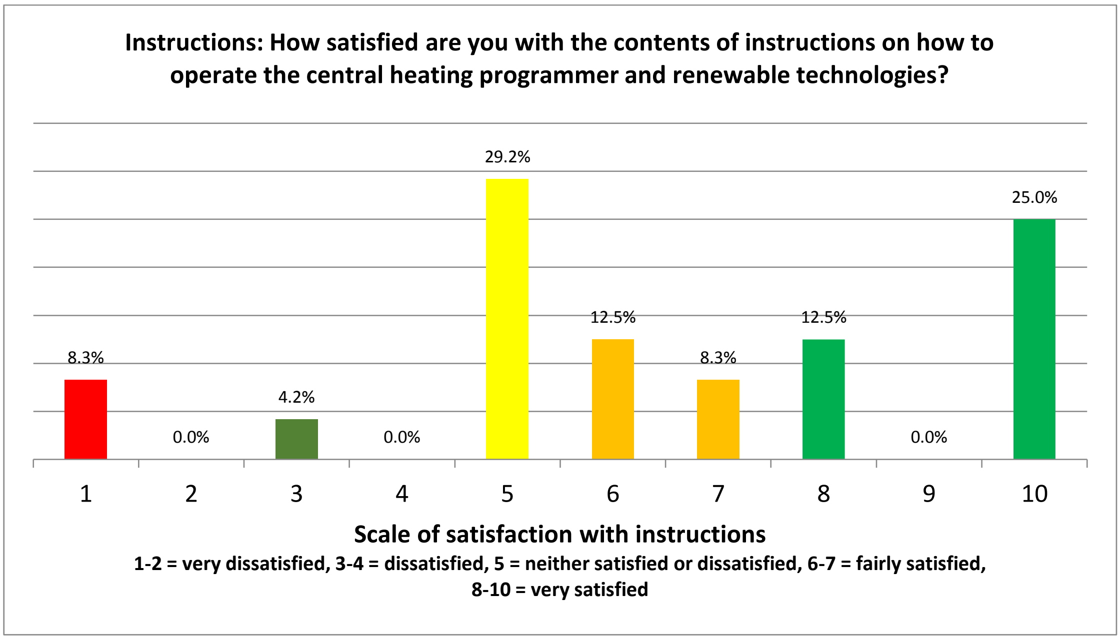
Feedback relating to the usefulness or otherwise of the **Resident Handbook** is a little contradictory. While a significant number of respondents admitted to not having referred to the handbook, they still rated it highly. A quarter of respondents were neither satisfied nor dissatisfied with its contents.

The handbook contains a lot of useful, well researched and attractively presented information for each of the systems and residents would be well advised to use it more effectively.



Graph 14 - Satisfaction levels with 'Resident Handbook

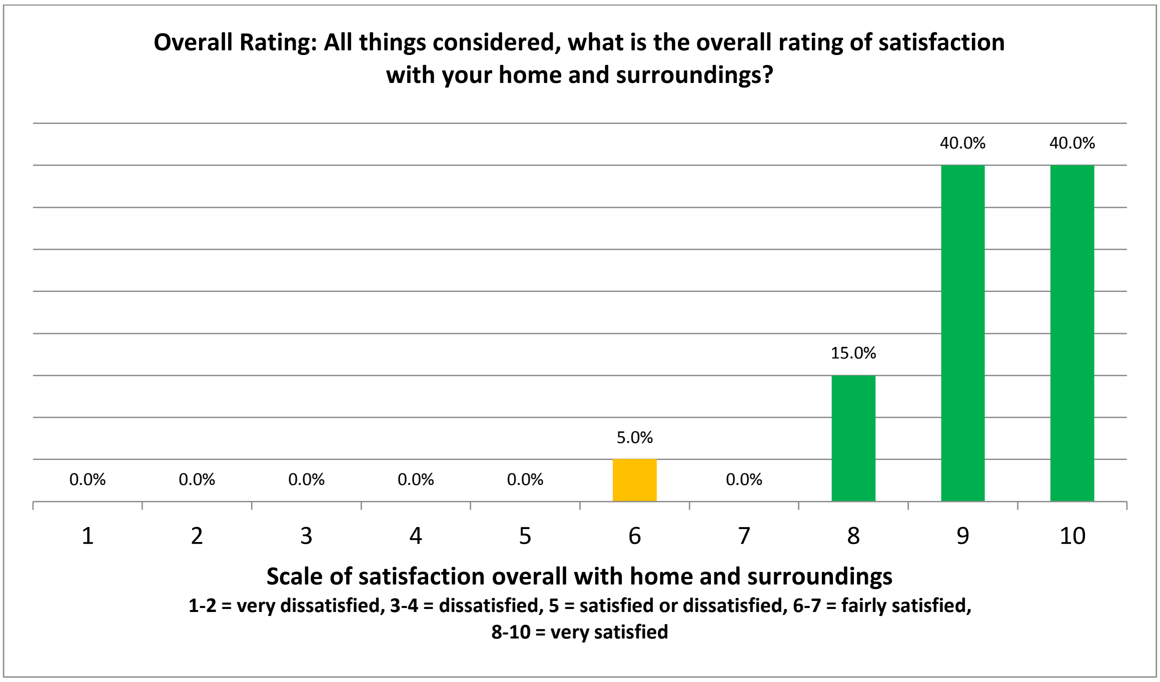
Feedback regarding the **instructions on how to operate the programmer and new technologies** showed relatively lower levels of satisfaction. While 58.3% of respondents were either fairly satisfied or very satisfied, three residents were very dissatisfied or dissatisfied with the quality of instruction at handover stage. About a third of respondents were neither satisfied nor dissatisfied. Concerned with these results, Kingdom staff have since been actively involved in training residents on how to use their programmers, In-home energy display monitors, MVHR etc.



Graph 15 - Satisfaction with instructions how to operate controls and new technologies at handover stage

Feedback with the **area outside home** revealed that generally levels of satisfaction with landscaping, play area, parking, clothes drying overall were very high. Lower levels of satisfaction were due to the positioning of bin stores and lack of enclosure of bin stores in backcourts, issues which have since been addressed by Kingdom. The lack of defensible space in front of the houses as well as the size of the front gardens was also disliked by a significant number of residents although it should be noted that the design of the external layout meets the Designing for Streets planning requirements.

The residents were asked to summarise their thoughts about all aspects of the design. Without exception 100% of the respondents were very satisfied or satisfied, rating design mostly at 10 out of 10. This is truly excellent feedback.



Graph 16 - Satisfaction with home and surroundings

Overall levels of satisfaction with their home, area, services and facilities were also high **with** 95% of respondents being very satisfied. This **overall score is excellent** and confirms that the HIS is a highly successful housing development.

Conclusions

Some people still think that the HIS was a competition. It was never the intention to say 'and the winner is...' In Kingdom's view all systems trialled are 'winners' in their own right as they all met Kingdom's selection criteria. With the information about each system's performance and the feedback on their relative value for money, each one of them could be used in a future Kingdom project depending on planning/site constraints.

The HIS provided homes highly valued by the residents. Satisfaction levels with various aspects of design, scoring highest results on most metrics of all the properties evaluated. Residents greatly valued their new well designed, innovative and highly energy efficient homes.

Design features which afforded particularly high ratings were spacious dining kitchens, downstairs shower rooms, utility rooms, In-home energy display monitors, triple glazing and the play area.

Where ratings were lower, this was mainly due to living rooms which in a couple of house types were found to be too small, some problems with the location of monitors/sockets and problems with fixing fixtures to plasterboard walls.

When considering value for money for each of the systems three indicators were analysed. These were time, cost and quality as perceived by the residents. It should be borne in mind that the average superstructure construction times and costs cannot be compared like for like, as the specifications vary between the blocks.

The Control House by Campion Homes was the only system which delivered a better than average construction time and cost of 65 days and £743 per $m^{2)}$ respectively whilst scoring 10/10 for levels of satisfaction.

Another system which scored highly on the grounds of cost and satisfaction was the Volumetric Space Frame System by Powerwall. It was procured at a better than average cost of £711 per m^2, achieved 10/10 satisfaction levels, but took longer to construct, giving a poorer than average construction time of 91 days.

The iQ System Closed Panel Timber Frame by CCG had the shortest construction time of 49 days, achieved 9/10 for satisfaction and cost slightly better than the average at £903 per $m^{2.}$

The Energyflo Breathing Wall Timber Frame System scored 10/10 for satisfaction, cost better than average at £768 per m^2 but took 90 days to construct.

Please see the table overleaf for details. Note: For details of how scores have been derived please refer to CASE STUDIES Summary of Results, individual sections on User Satisfaction with each of the studied systems.

Comparison of Cost, Time and Housing Quality					
Contractor & Construction Type	New technologies	Average Cost Per m^2 £ (superstructure only)	Construction Period No of Days (superstructure only)	Quality/ Satisfaction	Translated into SHR's Standard Rating
Block 1 - Powerwall Volumetric Space Frame System	ASHP, Solar water heating, In-home energy display	711	91	10/10	Very satisfied
Block 2 - Campion Homes Scotframe Val-U-Therm Closed Panel Timber Frame	ASHP, MVHR, In-home energy display Solar water heating	833	106	9/10	Very satisfied
Block 3 - Stewart Milne SIGMA II Closed Panel Timber Frame	MVHR Gas micro CHP In-home energy display	822	126	9.5/10	Very satisfied
Block 4 - Campion Homes Weinerberger Porotherm Insulated Clay Block System	Photovoltaics MVHR In-home energy display Solar water heating	1019	71	9/10	Very satisfied
Block 5 - Cube SIPS Panel System RE:Treat	Photovoltaics MVHR In-home energy display	1138	61	8/10	Very satisfied
Block 6 - Campion Homes Control House - Open Panel Timber Frame	In-home energy display	743	65	10/10	Very satisfied
Block 6 - Campion Homes Passivhaus	Passivhaus design standards, MVHR In-home energy display	1092	65	10/10	Very satisfied
Block 7 - Future Affordable K2 Closed Panel Timber System	SBS 2013 & SBS 2016 PVs, ASHP, MVHR, In-home energy display	1041	91	8.6/10	Very satisfied
Block 8 - Lomond Homes Eneryflo Breathing Wall Timber Frame System	PVs, voltage optimiser, CMEV, In- home energy display	768	90	10/10	Very satisfied
Block 9 - CCG iQ System Closed Panel Timber Frame System	Hybrid PV & HW panel MVHR In-home energy display	903	49	9/10	Very satisfied
Block 10 - Bobin Developments Beco Wallform Insulated Concrete Formwork	MVHR In-home energy display	908	104	9.5/10	Very satisfied
AVERAGE		**907**	**84**	**9.3/10**	**Very satisfied**

Table 2 – Comparison of Cost, Time and User Satisfaction Levels

GUIDANCE OFFERED TO THE RESIDENTS AT HANDOVER STAGE

Organising environmental awareness sessions with prospective residents of highly energy efficient housing is still rare in the UK - it is generally assumed that to save carbon it is enough to build highly energy efficient buildings. Indeed policy in this area is based on this assumption.

Research reveals that all too often the provision of highly insulated homes with energy saving technologies results in unintended consequences - or so called 'rebound effect' – whereby in such circumstances consumers tend to increase their energy demand rather than reduce it (see **http://www.ukerc.ac.uk/support/ReboundEffect**)

Although a level of environmental awareness is not a strong predictor of environmental behaviour[8], it is considered that it is a good starting point to achieving behaviour change and should be included in any awareness raising programmes. In doing so it should always be kept in mind that economic factors are more influential than environmental considerations, for this reason monitoring of actual energy use and sharing information should be part and parcel of a behaviour change programme.

Kingdom were proactive in this area by involving the new residents in an energy efficiency workshop, prior to them moving in to their new homes. During the handover process, residents were given further information and were shown how to operate the new technologies. Recent post occupancy evaluations assumed that the best time for raising resident awareness about operating controls and about energy efficiency is during the handover. However this study demonstrates that to achieve results, the point when the house is being handed over is not necessarily the best time.

Kingdom's handover procedure was evaluated in June 2012. When assessing the handover procedure various factors were taken into account, including:

- Outcomes for residents
- How far good practice is followed
- The organisation's level of self-awareness
- Track record and commitment to improvement

What is Kingdom's Standard Handover Procedure?

Kingdom's Housing staff described the following procedure as typical at handover stage.

Successful applicants would be met on the day by a Housing Officer/Assistant. They would initially be shown around the property. Staff would then demonstrate:

- How to work the windows
- How to work the heating in the property
- Where electric/gas meters are and take readings

Staff would then go through the tenancy paperwork with the new residents and discuss their rental payments.

Staff would normally only carry out follow up visits if they felt residents were vulnerable. As rule of thumb, follow up visits would only be carried out to most of the residents from homeless category, those who are taking on their first tenancy, and those who may have disabilities which might affect their ability to sustain a tenancy. A detailed description **of a witnessed handover is contained in the Appendix to this Report.**

[8] **http://www.scotland.gov.uk/Topics/Research/by-topic/environment/social-research**

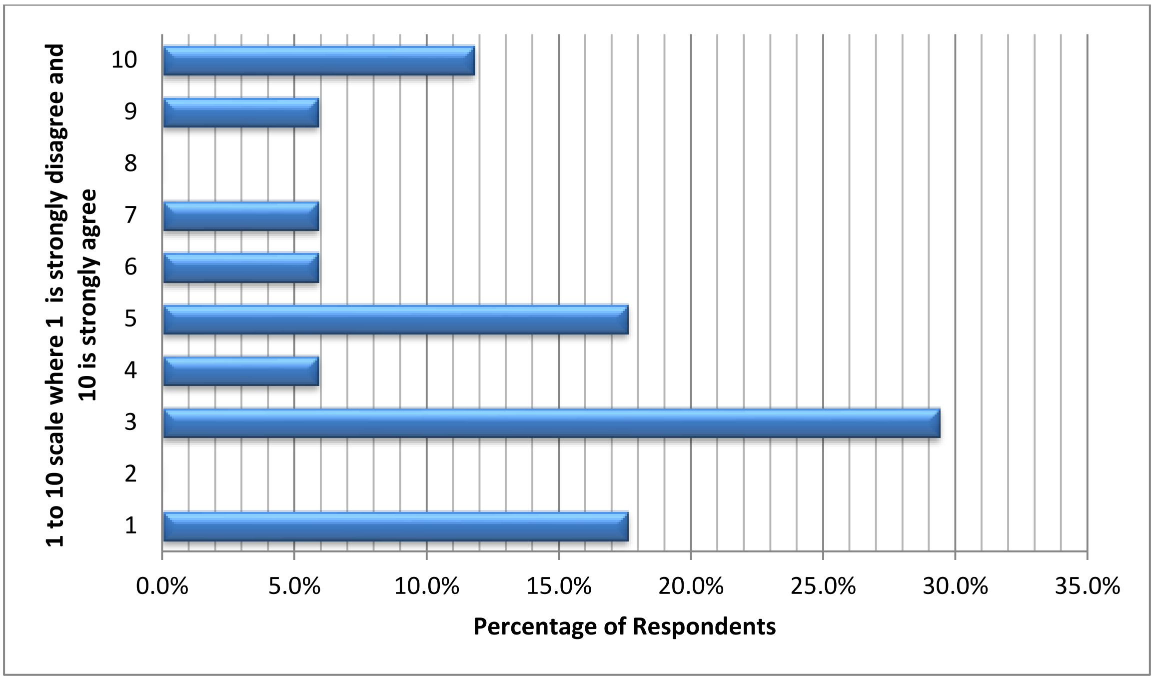
HIS Handover Procedure

From the outset it was known that the HIS was different - a more engaging approach would be required.

The first step in this process involved issuing residents with information leaflets followed by holding a workshop session. The objective of this workshop was to raise resident awareness about energy efficiency, low carbon technologies and to talk about the In-home Energy Display monitors as well as discussing waste reduction and recycling. This workshop was held on site and was run by Development staff with Housing Management staff in attendance. Kingdom's objectives were to:

1. Enable awareness through provision of highly energy efficient dwellings fitted not only with new technologies, but also with In-home Energy Display monitors
2. Educate through instructions how to operate the systems
3. Engage, mostly through encouraging discussion about energy efficiency and through provision of an on-going support whenever residents seek help

Questionnaires were completed by the residents who attended the workshop session. These revealed that most of the prospective residents were supportive of being energy efficient. Their attitudes towards saving the environment were mostly positive; slightly higher proportion of residents saw environment as a high priority. Almost 50% disagreed with the statement that the environment was a low priority in their life when compared with other priorities. A similar proportion of respondents believed that their behaviour did contribute towards climate change. However, about 30% of the respondents agreed with the statement that environment was a lower priority for them with the remaining 20% being undecided.



Graph 17 - Question on whether the environment is a low priority

A few months after the workshop, most of those who had attended commented that the workshop was very interesting and helpful and they remembered that it was about energy efficiency, low carbon technologies and about reducing waste. Generally, the residents exhibited positive attitudes towards energy efficiency, waste reduction and new technologies and it seems that the workshop made a positive impact on their attitudes. However, recollection of the technical information covered was limited.

While the workshop appears to have increased prospective residents' energy awareness, as yet there is no clear evidence that it impacted on the residents in terms of their energy efficiency leading to reductions in energy use.

Influencing human behaviour is a complex issue: as well as understanding the factors that influence behaviour, it is important to understand how behaviour changes. The consumer change ladder below illustrates this complexity and demonstrates that there is a wide distance between knowing about the need to change behaviour and actually changing it. As such customer engagement strategies and handover procedures need to reflect this complexity and come up with flexible ways of addressing this issue. Kingdom's energy efficiency workshop was a good starting point in the quest of educating and influencing resident environmental behaviour.

Figure 7 - Steps in Behaviour Change

How well was Kingdom's Handover procedure implemented?

It was found that Kingdom's standard approach to handing over new homes was practical, simple, straight forward and in line with the key requirements set out by the Scottish Housing Regulator. It was:

- inclusive
- clear and well presented
- used plain language
- reflected positive and welcoming attitude towards new residents

Information communicated during the handover of these properties exceeded the information described by staff as typically communicated at a standard handover. It included helpful and practical advice, not only about the residents' and landlord's responsibilities, but also information about recycling issues and sustainability.

With reference to demonstrations, again the witnessed handover confirmed that in practice, staff communicated to residents information about house systems at a much more detailed level than indicated as 'standard: it covered not only information about sockets, windows, showers, central heating and meters, but it conveyed, in detail how to operate the new technologies and the In-home energy display. In this sense, the handover procedure applied during the evaluation was very comprehensive and was executed professionally, using clear, plain language in a friendly and informal manner by all demonstrators involved.

Kingdom's Sustainability Policy commits to raising awareness about environmental issues and by:

- Encouraging the co-operation of all Kingdom's staff;
- Advising Kingdom's residents and clients on environmental benefits;
- Promoting and adopt good practice;
- Encouraging all consultants, contractors and suppliers appointed by the Association to adopt sound environmental and sustainable practices and policies, when possible.

The HIS is an exceptional example of a housing development procured by Kingdom which in physical terms successfully delivers on the above objectives.

Conclusions and Recommendations

The HIS created an ideal opportunity to raise awareness and encourage residents to save energy and carbon and to stimulate behaviour change. The next step in this process is for Kingdom to support people on their behaviour change journey.

Kingdom's approach to influencing Dunlin Drive resident environmental behaviour is exemplary and it would be recommended that lessons learned from it should be taken account of when devising an Engagement Strategy. However, we know that we cannot rely on people to make rational decisions based on the information provided, and we cannot assume that changing attitudes will lead to a change in behaviour. Research consistently reports that most people are unaware of how much energy they use, what tariff they are on (82% do not know this)[9] and how they can reduce their personal carbon footprint.

In Dunlin Drive, despite all Kingdom's efforts – the pre-handover workshop, the briefing during the handover and detailed supportive information by way of a bespoke Resident Handbook for each of the systems - some residents still reported not knowing how to programme their heating systems, not to have been advised about MVHR and/or did not pay attention to their In-home Energy Display and when interviewed, requested further training.

In response, Kingdom followed up requests for further support by assisting residents during face to face sessions, in their homes, free from pressure of the handover process, when not distracted by other tenancy related issues covered at handover.

Kingdom should formalise existing good practice exercised by its staff, by producing a comprehensive written Energy Awareness procedure to preserve consistency in implementation and to raise standards.

This procedure should involve re-visiting new residents after they have settled into their new homes to train and to reinforce training on how to:

- Operate CH Programmers
- Operate new technologies
- Monitor information provided by the In-home Energy Display monitors
- Be energy efficient
- Understand information contained in their EPC and use this information as a tool in raising awareness about energy performance.

Kingdom should mainstream application of this procedure in the course of letting their existing housing to maximise its' impact.

Kingdom is well aware that its' Housing Management staff need to be trained in energy efficiency and that provision of technical and energy advice is not an exclusive domain of technical staff / energy advisors. During interviews with housing staff they expressed interest in being trained in this area so that they too can provide basic advice if needed not only at handover stage but to ensure that this advice can be provided as part of their day to day services and at re-letting stage.

This training should include a basic overview of EPCs and how to operate central heating programmers and other new installed technologies, including MVHR and In-home Energy Display monitors.

Kingdom should regularly monitor the quality and effectiveness of the Resident Handbook, promote its use by the residents and keep it up to date.

[9] EST, Green Barometer 4, March 2008

CASE STUDIES: SUMMARY OF RESULTS

Figure 8 - Housing Innovation Showcase Site Plan

Disclaimer: *While every care has been taken to ensure that the information contained within this technical document is correct, the authors give no warranty and make no representation as to its accuracy and accept no liability for any errors or omissions.*

SYSTEM OVERVIEW

BLOCK 01 – PLOTS 1,2,3 & 4

VOLUMETRIC SPACE FRAME SYSTEM

Powerwall
Space Frame Systems Ltd

Figure A01 – Front elevation block 01

www.powerwall.co.uk

PROPERTY DESCRIPTION	2 x 2 Bedroom Cottage Flats – G/Floor Amenity 2 x 2 Bedroom Cottage Flats – F/Floor General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Volumetric space frame system - Plot 1 – Air Source Heat Pump, In-home energy display - Plot 2 - Solar Water Heating, In-home energy display - Plot 3 - In-home energy display - Plot 4 - In-home energy display
MAIN CONTRACTOR	Powerwall
SYSTEM PROVIDER	Powerwall – Space frame Systems Ltd
ARCHITECT	Assist Design Architects

Figure A02 – Wall make up for block 01

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 01 – PLOTS 1,2,3 & 4

VOLUMETRIC SPACE FRAME SYSTEM

Powerwall
Space Frame Systems Ltd

	PLOT 1 GF FLAT		PLOT 2 FF FLAT		PLOT 3 FF FLAT		PLOT 4 GF FLAT	
	Design	As-built	Design	As-built	Design	As-built	Design	As-built
AIR PERMEABILITY $m^3/(h.m^2)$ @ 50Pa	2.18	3.19	2.18	3.59	2.18	3.28	2.18	3.07
SAP RATING	84B	82B	85B	85B	84B	83B	83B	82B
EI (CO_2) RATING	84B	83B	89B	88B	87B	86B	86B	85B
DWELLING EMISSION RATE – DER (Kg/yr)	18.2	19.86	12.72	13.27	15.77	16.49	16.24	17.79
TOTAL PRIMARY ENERGY - DER ($kWh/m^2/yr$)	98.73	107.8	65.82	68.64	74.39	82.97	82.57	90.26
ENERGY USE								
Space heating (kWh/year)	639	880	1811	2054	1816	2094	1935	2536
Water heating (kWh/year)	1387	1387	1728	1723	2621	2613	2702	2687
Lighting (kWh/year)	454	454	454	454	376	376	389	389
Pumps and fans (kWh/year)	130	130	250	250	175	175	175	175
Total (kWh/year)	2610	2851	4242	4481	4987	5257	5201	5786
ENERGY COST								
Space heating (£/year)	£73	£101	£56	£64	£56	£65	£60	£79
Water heating (£/year)	£159	£159	£54	£53	£81	£81	£84	£83
Lighting (£/year)	£52	£52	£52	£52	£43	£43	£45	£45
Pumps and fans (£/year)	£15	£15	£29	£29	£20	£20	£20	£20
Total energy cost (£/year) excluding saving from energy generated	£299	£327	£190	£198	£201	£209	£208	£227

Table A01 – Comparison of SAP outputs between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. These design calculations were analysed for their consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team explained that the Powerwall system now called Ene-Wall, was easy to adapt to various performance levels. One of the changes that took place was related to the buildings geometry and the modular nature of the system. Ground floor and upper floor modules created a 'double' construction arrangement to the separating floor between ground and upper floor flats creating a floor zone greater than the design plans. The design team had to add risers and associated space for the stairs, which modified the floor-to-floor height. Although providing for a quick on-site assembly, the system was slow to fabricate at source which created problems with the Housing Associations schedule and delivery times.

The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission rates (TER) were reviewed to identify any anomalies and possible misinterpretation of the design; some were incorrect, for example the front elevation orientation is stated as being north when in fact it is west. It was also identified that the window dimensions included in the SAP calculator were not as-indicated in the buildings drawings; thus providing incorrect building data. In addition to that, it was identified that in all of the plots the SAP worksheet had no floor U-value and there were inconsistencies in the wall U-value used in all plots. Another incorrect specification was that the air source heat pump (ASHP) make and model used in the SAP calculations was different from the device installed. Secondary heating was originally modelled but in the survey this was not identified.

The changes to the building form and technology installed were documented by the monitoring team after the dwelling was handed over to Kingdom. Any alteration observed by the monitoring team which impacts on the buildings thermal performance has been accounted for within the 'as-designed' SAP calculations conducted by the BPE Study Team.

Figure A03 – Front elevation block 1

Figure A04 – Block 1 under construction

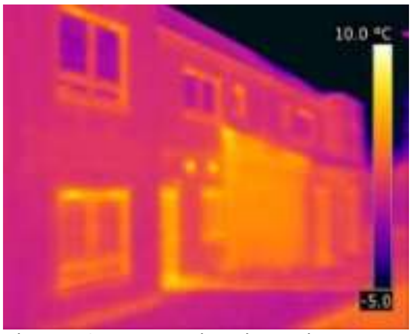


Figure A05 – Front elevation IR image

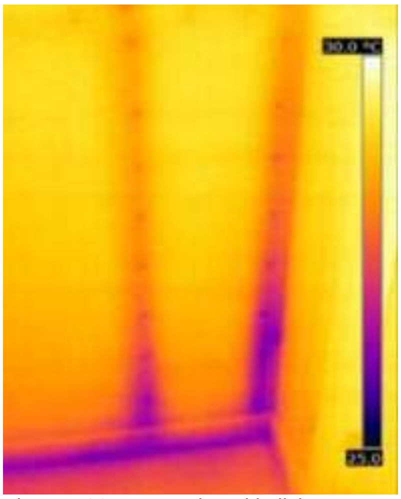


Figure A06 – Internal stud in living room

- **Fabric Performance Audit**

The thermal performance of the building fabric of selected plots was assessed during the BPE and would later be used to explain differences in predicted energy demand. Air permeability tests on all 4 plots were performed by an external evaluator at post-construction and pre-occupation stage. Full reviews of this appear in page 137 of the technical appendix, undertaken using ATTMA and BSRIA specification as guidance. For the purposes of the initial SAP calculation, the design team used 2.18m³/(h.m²) @ 50Pa as a baseline figure while the actual measured for the 4 plots varied from 3.07 to 3.59m³/(h.m²) @ 50Pa. The lower permeability was used at design stage as it was the system supplier's intention to install MVHR; however this ventilation system was changed to intermittent extract fans. As-built results show higher than 3.0 m³/(h.m²) @ 50Pa which permits the use of conventional extract fans.

Infrared thermographic surveys were performed under the BPE methodology and guidance explained later in page 134 of the technical appendix. Internal images were taken from plots 3 & 4, ground and first floor respectively. These concentrated on junctions, skirting, ceilings and external walls. The internal images identified thermal bridging and cold surfaces under skirting; and more noticeably where the internal lining studs were located (Figure A06). Other images showed heat-loss where service ducts were located and where electrical sockets are close to the floor. Externally the surface temperatures of the walls show an even distribution of temperatures with some wall junctions showing some surface temperature increases which could translate as cold bridging (Figure A05). The first floor entry lobbies showed higher surface temperatures where heat losses appeared to be greater in comparison with other areas of the envelope. Field study results were used to create an as-constructed SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

Figure A07 – Air source heat pump at rear of block 1, used in plot 1

Figure A08 - Water tank in cupboard - plot 1

Figure A09 – Pipe work from ASHP and water tank installed in plot 1

- **Services Performance Audit**

An audit on performance was conducted on the flats installed with low carbon technologies in conjunction with any other space heating systems. The tests were conducted after the first month of occupation.

Included in the performance testing was the air source heat pump (ASHP); which was reviewed for its operation and energy consumption. The system is an air-to-water device which is connected to the radiators and hot water. The system also has an immersion heater for back up in cold winter periods. The resident was benefiting from the use of the equipment but the heat meter probe used to establish the net benefits of this system was located outside the hot water pipework when it should have been inside; thus not recording adequately the actual consumption values. In terms of its commissioning and operation, the technology at the time of testing appeared to be operating according to design intent.

The upper flat (plot 2) in this block benefited from a Solar water heating device which was not tested for its efficiency as the same device was evaluated in another dwelling in the development and is reported elsewhere. Finally, for purposes of system performance, hot water temperatures delivered to the kitchen and bathrooms was recorded. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. In this case a recorded temperature of 44˚C was obtained which is below the threshold. KHA will carry out programmed testing of these temperatures. All light fittings were identified as having low energy light bulbs as described in the SAP and EPC calculations.

- **SAP re-calculation**

The SAP value for each dwelling was re-calculated using as-built in-situ data (U-values, as-built air permeability and actual window dimensions, orientation). Differences between the predicted and the as-built SAP values could thus be compared, as well as the DER values for each dwelling. The ground floor flat, plot 1 DER value of 19.86kg/m^2/yr with a score of 82B compared with a predicted value of 18.2 kg/m^2/yr and a score of 84B. The first floor flat, plot 2, has a revised DER value of 13.27 kg/m^2/yr and a SAP score of 85B compared with the predicted of 12.72kg/m^2/yr and a score of 85B.

- **Energy Consumption Audit**

The monitored property, plot 1, is occupied by two adults; one occupier who works at home whilst the other is out during the day. Mixed dwelling use is experienced where energy is consumed throughout the day. Electrical and gas readings were taken from the 1st to the 31th of August 2012 from the energy display monitors and also from the utility meters. Total yearly primary energy consumption was predicted to be 98.73kWh/m^2/yr for plot 1 and 65.82kWh/m^2/yr for plot 2. As-built figures show an increase to 107.8kWh/m^2/yr for plot 1 and 68.64kWh/m^2/yr for plot 2. Please refer to table of comparison above for other plots. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation especially for lighting and pumps and fans. A more realistic energy consumption projection will be available on - completion of the longer-term BPE study which will be published later in 2014.

Figure A10 – Control systems within the dwelling

Figure A11 – Heat flow mats and thermocouples connected to data logger installed in plot 4, North facing wall

Technical Key findings

- Higher energy use was identified by the ASHP consuming more electricity during this period compared to SAP predicted values.
- Air permeability compared with the predicted increased ventilation heat loss identified in the SAP as-built
- IR thermograms show heat loss between entrance lobbies and main fabric – at wall junctions

User Satisfaction - Volumetric Space Frame System by Powerwall

New technologies: Vokera Air Source Heat Pump (ASHP)

Overall this house was rated 10 out of 10 = Very Satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m^2 £711 = better than average construction cost
Period of construction 91 days = poorer than average construction period

Generally the residents consider there to be **enough space** in their homes, however one householder commented that a 4 person apartment is perfect for two people. Given the choice, residents would like to have more space in the main bedroom and a double storage cupboard rather than a single one.

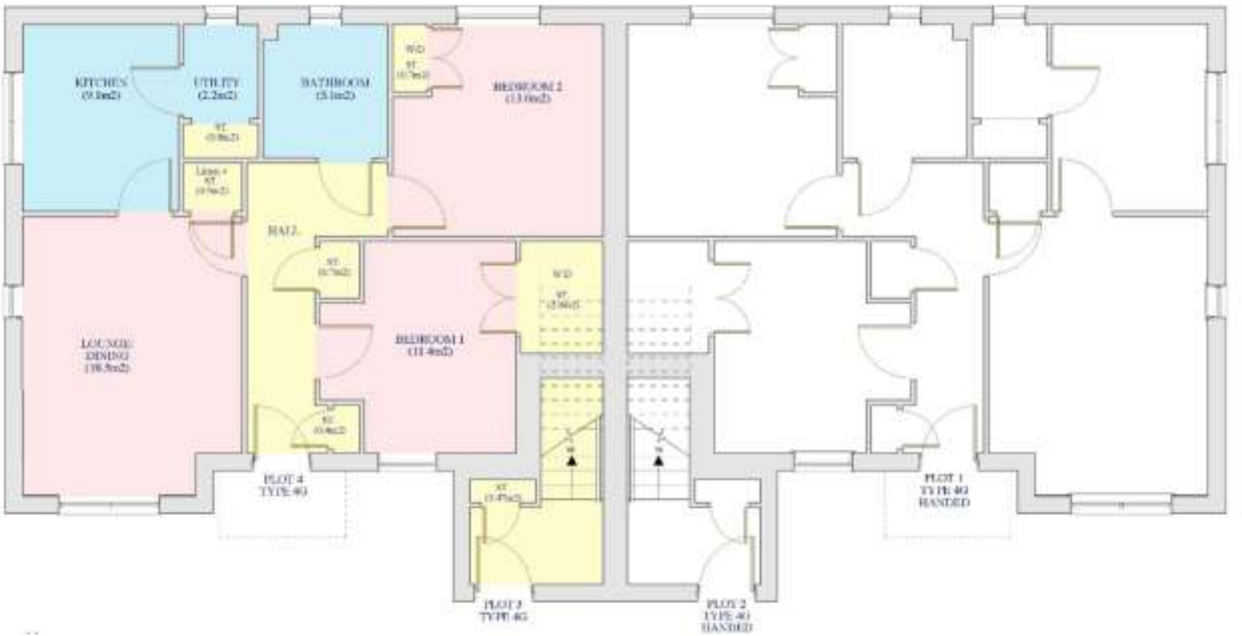
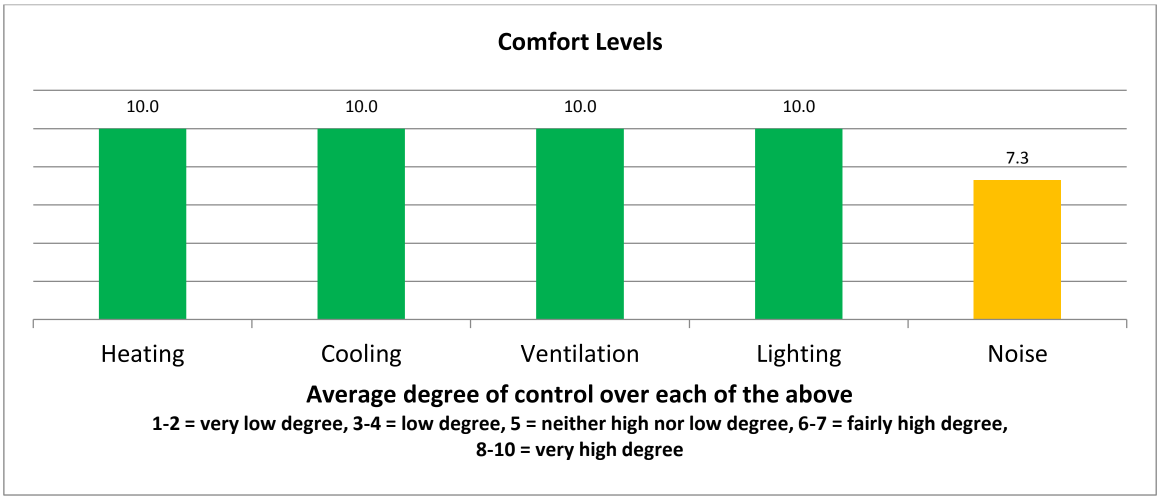


Figure A12 – Ground floor plan of block 01 plots 1 & 4

With reference to **new technologies** air source heat pump (ASHP) and in-home energy display systems were perceived as working well, however initially the ASHP programmer was thought to be too complicated and was rated poorly. In light of user feedback the programmer was replaced and residents trained on how to use it.

With reference to comfort relating to temperature, air quality and noise from the outside very high levels of satisfaction were noted, with residents feeling in control of their internal environment and feeling decidedly healthier in their new homes.



Graph A01 - User feedback relating to comfort levels where 1 is low and 10 is very high

One problem related to noise, reflected in the above table was caused by 'creaky floorboards' in an adjacent property, an issue which has since been rectified.

Utilities costs were substantially reduced for all residents. "*In my previous home I used to pay £200 per month for heating and electricity. My bill was £75.00 for 6 weeks!"*

Residents were happy with instructions contained in the **'Resident Handbook'**, *"except for instructions about setting the air source heat pump".* With reference to an offer of further training – residents generally stated that *"It is far too complicated for them".* Kingdom confirmed that they would continue to encourage increasing resident awareness about operating new technologies.

Features which were particularly LIKED:	**Features which were particularly DISLIKED:**
• Layout • Reduced fuel bills • Lack of noise from the outside (linked with high levels of sound insulation in triple glazed windows) • Spacious kitchens • Utility room- residents noted that they were not expecting it in a house of this size • Good quality finishes • External appearance: landscaping, garden, drying facilities and the playground	• ASHP programmer is too complicated • The buzz from the air source heat pump can be a little annoying at the beginning • Poor quality internal walls as residents find it impossible to fix any shelves or fixtures; even using purpose designed fixings.

Table A02 - Liked & disliked feature

Social Key Findings from User Feedback

- High levels of satisfaction with outlook, layout and quality of internal environment
- Initial problems with air source heat pump but high levels of satisfaction with lower energy costs when comparing with previous accommodation
- Programmer for Vokera ASHP was found to be too complicated for residents to understand and operate

SYSTEM OVERVIEW

Block 02 – PLOTS 5,6,7 & 8

SCOTFRAME VAL-U-THERM SYSTEM

Figure B01 – Front elevation block 02

www.scotframe.co.uk

PROPERTY	2 x 2 Bedroom Cottage Flats – G/Floor Amenity 2 x 2 Bedroom Cottage Flats – F/Floor General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Scotframe - Val-U-Therm System - Plot 5 - ASHP, MVHR, In-home energy display - Plot 6 - Solar Thermal, MVHR, In-home energy display - Plot 7 - MVHR, In-home energy display - Plot 8 - MVHR, In-home energy display
MAIN CONTRACTOR	Campion Homes
SYSTEM PROVIDER	Scotframe
ARCHITECT	Oliver & Robb Architects

Figure B02 – Wall makeup of block 02

DESIGNED & MEASURED SAP OUTPUTS

Block 02 – PLOTS 5,6,7,8

SCOTFRAME VAL-U-THERM SYSTEM

	PLOT 5 GF FLAT		PLOT 6 FF FLAT		PLOT 7 FF FLAT		PLOT 8 GF FLAT	
	Design	As-built	Design	As-built	Design	As-built	Design	As-built
AIR PERMEABILITY $m^3/(h.m^2)$ @ 50Pa	2.5	2.5	2.5	2.45	2.5	2.45	2.0	2.36
SAP RATING	85B	83B	86B	81B	85B	80C	85B	83B
EI (CO_2) RATING	86B	84B	90B	84B	88B	82B	89B	86B
DWELLING EMISSION RATE – DER (Kg/yr)	17.40	20.13	12.54	19.41	14.75	21.56	14.67	16.77
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	89.92	104.48	60.99	95.24	72.13	106.07	72.40	82.53
ENERGY USE								
Space heating (kWh/year)	571	960	1422	4393	1423	4393	1034	1842
Water heating (kWh/year)	1213	1213	1447	1408	2665	2600	2602	2570
Lighting (kWh/year)	383	383	406	406	406	406	383	383
Pumps and Fans (kWh/year)	240	240	415	415	322	322	285	285
Total (kWh/year)	2406	2796	3690	6622	4817	7722	4303	5079
ENERGY COST								
Space heating (£/year)	£65	£110	£44	£136	£44	£136	£32	£57
Water heating (£/year)	£139	£139	£45	£44	£83	£81	£81	£80
Lighting (£/year)	£44	£44	£47	£47	£43*	£47*	£41*	£41*
Pumps and fans (£/year)	£27	£27	£48	£48	£33*	£33*	£29*	£29*
Total energy cost (£/year) excluding saving from energy generated	£276	£320	£183	£274	£302	£296	£183	£207

Table B01 – Comparison of SAP between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh, *10 hour electricity tariff used for plots 7 and 8. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to Re-calculated SAP.

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. These design calculations were analysed for their consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team answered highlighting some changes. The design team explained that the system can be easily adapted with various insulation depths to achieve required U-value standards. One of the elements highlighted by the team was that it was difficult to integrate the MVHR system into a common space (cupboard). Also pipes and some ducting were exposed which are unsightly and at risk of damage.

The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission rates (TER) were reviewed to identify any anomalies and possible misinterpretation of the design. Most of the elements included in the SAP calculation were as stated in the design. The windows were not specified independently and apparently were included as bulk areas instead of window by window. Plot 6, first floor, is stated as having a party ceiling, when in fact it is a party floor. The SHW panel data is not as specified by the manufacturer. The changes to the building form and technology installed were documented by the monitoring team after the dwelling was handed over to Kingdom. Any alteration observed by the monitoring team which impacts on the buildings thermal performance has been accounted for within the 'as-designed' SAP calculations conducted by the monitoring team.

- **Fabric Performance Audit**

The thermal performance of the building fabric was assessed during the BPE and would later be used to explain differences in predicted energy demand. Plot 6 was the chosen flat to be analysed in detail and all aspects of its performance were obtained from this plot.

The air permeability tests on all 4 plots were performed by an external evaluator at post-construction and pre-occupation stage. A full review of this appears in page 137

Figure B03 – Front elevation of block 2

Figure B04 – Block 2 under construction

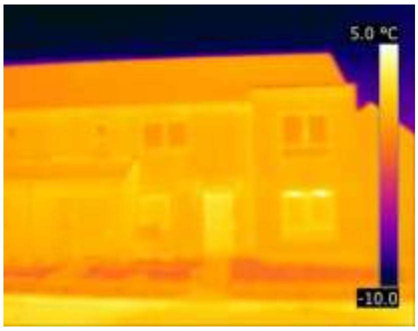


Figure B05 – Front elevation IR image of plot 5 and 6

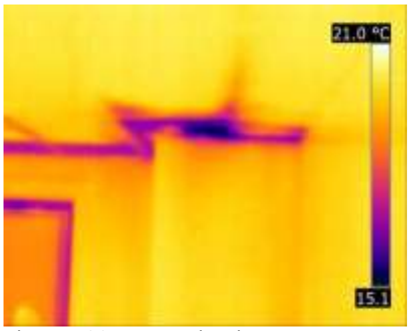


Figure B06 – Internal IR image, ceiling/wall junction in plot 6 of the technical appendix and it was undertaken using ATTMA and BSRIA specification as guidance. For the purposes of the initial SAP calculation, the design team used 2.5 $m^3/(h.m^2)$ @ 50Pa in plots 5, 6 & 7 and 2.0 $m^3/(h.m^2)$ @ 50Pa for plot 8 as a baseline while the actual measured figure was 2.5 $m^3/(h.m^2)$ @ 50Pa for plot 5, 2.45 $m^3/(h.m^2)$ @ 50Pa for plots 6 & 7 and finally 2.36 $m^3/(h.m^2)$ @ 50Pa for plot 8. All plots except plot 8 surpassed the predicted figure. This will impact the re-calculated SAP.

Infrared thermography surveys were performed during the BPE methodology and guidance explained later in page 134 of this Report. Internal and External images focus on ground floor plot 5 and first floor plot 6 (Figure B05). Front elevation images show an even distribution of surface temperatures on wall and roof. Some higher heat loss patches around windows and plot 5 doors in comparison to plot 6, but these may be due to reflection and the fact that the ground floor may have been heated more than first floor. The back elevation IR study indicates that walls show even surface temperatures but with heat loss evident below the suspended ground floor. Back garden has a lower level than the front of the block thus this can be appreciated see Figure B07. Internally more images with heat loss were identified in first floor plot at the ceiling edges near the roof eaves where insulation is missing (Figure B06). Ground floor images identified heat loss at skirting levels and near service ducts and kitchen areas. Field study results were used to create an as-constructed SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

- **Services Performance Audit**

An audit on performance was conducted on plot 6 where a Solar Hot Water panel (SHW) system was installed. Plot 5 is installed with an ASHP of equal size and brand to plot 01 in block 01, for this reason it wasn't re-tested. The MVHR system, a Nuaire MRXBOX95-WH1 was not tested in this property but the efficiency calculated in other plots gave 81%.

Evaluation of the Solar thermal panels was conducted after the first month of occupation. The Solar Hot Water system is a Clearline Viridian Solar model V20 with two panels orientated to the south and connected to a Power Flow Indirect dual coil 180Lt water tank. Additional to this, the tank was fitted with a 3kW immersion heater controlled by a timer on twice-a-day setting to provide top-up heating. The calculated efficiency using heat meter data for the month of August was of 77% compared to a system manufacturer's efficiency of 81%. In terms of all the technology and heating systems, they were found to be in working order. Insulation


Figure B07 – Air source heat pump at rear ground level of plot 5 and solar water heater on roof used in plot 6


Figure B08 – Water tank in cupboard - plot 6


Figure B09 – SHW distribution system

around pipe work is tightly fitted from the tank to the Viridian controller and to the solar panel; however exposed valves and flanges could be further insulated.

Finally, for purposes of system performance, testing of the hot water temperatures delivered to the kitchen and bath rooms was recorded. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing took one minute interval reading of water in the hot water taps and an average temperature of 45˚C was obtained which is below the threshold. KHA will carry out programmed testing of these temperatures.

The majority of the light fittings were identified as being low energy light bulbs against a specified minimum of 75% present in the dwelling.

- **SAP re-calculation**

The SAP values for plots 5 & 6 were re-calculated based on findings from measured fabric performance (U-values, as built air permeability) resulting in new SAP values obtained. Plot 5 obtained a new DER value of 20.13kg/m^2/yr with a score of 83B compared with the predicted 17.4kg/m^2/yr with a score of 85B. Plot 6 obtained a new DER value of 19.41kg/m^2/yr and a score of 81B above the buildings TER thus not achieving the SAP predictions. Total yearly primary energy consumption was predicted to be 89.92kWh/m^2/yr for plot 5 and 60.99kWh/m^2/yr for plot 6. As-built figures show an increase to 104.48kWh/m^2/yr for plot 5 and 95.24kWh/m^2/yr for plot 6.

- **Energy Consumption Audit**

Plot 6 is occupied by a single parent with a small child. The adult has occasional work throughout the week and therefore can be at home all-day. Electrical and gas use is consumed periodically and space heating and appliances are used throughout the day. Electrical and gas readings were taken from the energy display monitors and from utility meters. Readings were taken from the 1st to the 31th of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data.

Technical Key findings

- Ground floor flats have performed better than first floor flats because roof recorded a poor thermal transmission value which affected fabric heat loss.
- As-built air tightness levels were close to the predicted but U-values impacted new SAP values.
- Internal infra-red thermography images show concerns, especially in first floor roofs/ceiling where heat loss prevails around ceiling/wall junctions.
- SHW panels show benefits but resident (plot 6) has indicated that water temperatures are not hot enough and a backup immersion heater is often used.

User Satisfaction - VAL-U-THERM SYSTEM, Scotframe by Campion Homes

New Technology: Clearline Solar Hot Water, Vokera Air Source Heat Pump and Nuaire Mechanical Ventilation Heat Recovery Unit

Overall this house was rated at 9/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 £833 = better than average construction cost
Period of construction 106 days = poorer than average construction period

With a dining kitchen and a spacious living room at over 18m^2, the residents considered that there was enough space overall in this property.

Figure B10 – Ground Floor plan – block 02

The level of satisfaction with storage space was rated as relatively poor because both storage cupboards contained services such as water storage tank and ventilation equipment. The services encroached on the amount of space left over for storage and this was disliked, particularly given that storage cupboards were not fitted with shelves.

Figure B11- Not enough storage space in a storage cupboard which houses services and lack of shelving in the storage cupboard

With reference to **new technologies** residents reported that:

- Instructions on how to use the programmer during the handover were hard to follow. In the resident's opinion instructions should have been delivered more slowly and to physically demonstrate its operation.
- Residents did not feel in control regarding cooling and ventilation and they felt that there was not enough information given at handover about the Mechanical Ventilation and Heat Recovery system (MVHR): *"Once I get the internet, I will find out about MVHR. We have not been made aware of this system to understand its benefits. There is no information about it other than in the handbook – which does not say to keep the windows closed to enable the system to work efficiently."*

There were high levels of satisfaction relating to overall comfort levels with temperature, air quality and noise.

Residents were happy with instructions contained in the **'Resident Handbook'.** However, with reference to training on new technologies during the handover some commented that *"it was too much to take in in the space of the short time"* and wanted someone *"to talk them slowly over how to use the system".*

Rating of **Satisfaction with Area Outside** was affected by dissatisfaction with the position of the bin area which was in close proximity to flats but this has since been reviewed and the bin stores relocated to a more suitable position.

Features which were particularly LIKED	Features which were particularly DISLIKED
• The flat is more energy efficient with lower energy costs by at least 50% when compared with previous accommodation • Having utility room • The size of the flat is perfect	• Having to walk all the way round the green area which is adjacent to the car park, rather than stepping straight over it to get into the front door

Table B02 – Likes and Dislikes

Key Findings from User Feedback

- High Levels of satisfaction with layout design and thermal efficiency
- There is a need to better educate residents in operating MVHR
- SHW panels show benefits but resident has indicated that water temperatures are not hot enough and a back-up immersion heater is often used

SYSTEM OVERVIEW

Block 03 – PLOTS 9,10,11,12

SIGMA II BUILD SYSTEM

www.stewartmilne.co.uk

Figure C01 – Front elevation block 03

PROPERTY	2 x 2 Bedroom Cottage Flats – G/Floor Amenity 2 x 2 Bedroom Cottage Flats – F/Floor General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Sigma II Build System: Close Panel Timber Frame - Plot 9 - MVHR, In-home energy display - Plot 10 - MVHR, In-home energy display - Plot 11 – Gas Micro CHP, MVHR, In-home energy display - Plot 12 - Gas Micro CHP, MVHR, In-home energy display
MAIN CONTRACTOR	Stewart Milne Construction
SYSTEM PROVIDER	Stewart Milne Timber Systems
ARCHITECT	Stewart Milne Group

Figure C02 – Wall Makeup of block 03

SYSTEM OVERVIEW

Block 03 – PLOTS 9,10,11,12

SIGMA II BUILD SYSTEM

	PLOT 9 GF FLAT		PLOT 10 FF FLAT		PLOT 11* FF FLAT		PLOT 12* GF FLAT	
	Design	As-built	Design	As-built	Design	As-built	Design	As-built
AIR PERMEABILITY $m^3/(h.m^2)$@50Pa	2	2.35	3	2.7	2	2.8	3	2.2
SAP RATING	86B	85B	87B	83B	88B	84B	86B	86B
EI (CO_2) RATING	88B	87B	88B	83B	89B	84B	88B	88B
DWELLING EMISSION RATE – DER (Kg/yr)	15.20	16.87	14.58	20.60	12.89	19.34	14.63	15.78
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	76.19	83.86	71.54	100.01	64.26	93.25	73.17	78.39
ENERGY USE								
Space heating (kWh/year)	811	1430	810	3285	367	2925	809	1231
Water heating (kWh/year)	3000	2967	3068	2980	2870	2762	2770	2748
Lighting (kWh/year)	358	358	381	381	391	391	358	358
Pumps and fans (kWh/year)	343	343	360	360	360	360	343	343
Total (kWh/year)	4512	5098	4618	7005	3988	6439	4281	4680
ENERGY COST								
Space heating (£/year)	£25	£44	£25	£102	£11	£91	£25	£38
Water heating (£/year)	£93	£92	£95	£92	£89	£86	£86	£85
Lighting (£/year)	£20	£20	£21	£21	£22	£22	£20	£20
Pumps and fans (£/year)	£19	£19	£20	£20	£20	£20	£19	£19
Total energy cost (£/year) excluding saving from energy generated	£158	£176	£162	£236	£143	£219	£151	£163

Table C01 - Comparison table between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, 24 hour electricity tariff: 5.64p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 03 - PLOTS 9, 10, 11,& 12

SIGMA II BUILD SYSTEM

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. These design calculations were analysed for their consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team explained that no changes were made that would impact the buildings thermal behaviour. The design team did explain that it was moderately difficult to achieve the clients set energy requirements; The system requiring an in-depth insulation analysis to fit into the wall panel which created some limitations. Despite this, once-achieved the system was regarded as being "well thought of and effective" One of the elements highlighted by the team was that it was difficult to integrate the mini Combined Heat & Power (mCHP) specifications into the SAP software, as it is not flexible enough to accommodate such new technology.

The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission Rates (TER) were analysed to identify any anomalies and possible misinterpretation of the design. During the re-evaluation, the monitoring team identified that the original design SAP output of the primary heating system, originally specified for plots 9 and 12, was oversized. As a result the monitoring team were unable to generate and verify the SAP output provided by the design team. In this instance the values and specifications have been modified to replace the as-designed Baxi Ecogen mCHP heating system (230L, 50mm insulation) with the Baxi Potterton boiler (180L, >75mm insulation) as per plot 10 & 11.

Another anomaly that was identified was the inconsistency in floor U-values where plot 09 had 0.12W/m^{2}K and the rest of the plots had 0.15W/m^{2}K.

An error was highlighted where the factory insulated tank is stated as having 50mm thick insulation when it should be >75mm. Also tanks were modelled as being 230Lts when in fact they were 180Lts. All the changes above have been included within the design stage SAP outputs and are reflected within the Table C01 on page 58 of this case study. The rest of the SAP details were entered appropriately.

Figure C03 – Front elevation of block 3

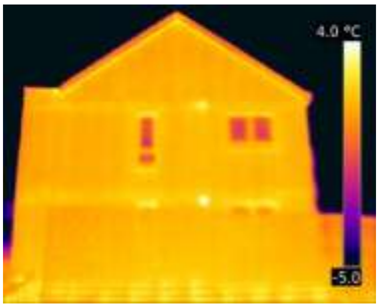


Figure C04 – IR image West elevation plots 9 and 10

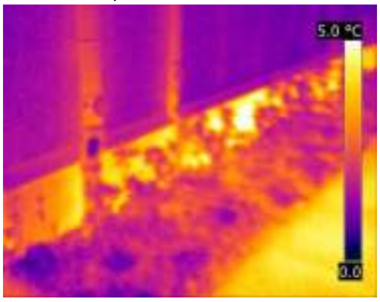


Figure C05 – IR image external wall and ground level in plot 9

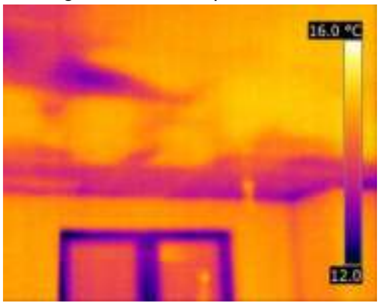


Figure C06 – IR image internal wall and ceiling junction plot 10

- **Fabric Performance Audit**

The thermal performance of the building fabric was assessed during the BPE and would later be used to explain differences in predicted energy demand. Plots 9, 10 & 12 were chosen to conduct the in situ U-value evaluation; plots 9 & 10 were chosen to conduct the IR thermography survey.

Air permeability tests were performed by an external evaluator at post-construction and pre-occupation stage. See page 137 of the technical appendix. After a review, all results comply with the ATTMA and BSRIA specification as guidance. For purposes of the SAP calculation, the design team used 2.0m^3/(h.m^2) @ 50Pa in plots 9 & 11 and 3.0 m^3/(h.m^2) @ 50Pa in plots 10 & 12 as a baseline, while the actual measured figure was 2.35 m^3/(h.m^2) @ 50Pa for plot 9, 2.7 m^3/(h.m^2) @ 50Pa for plot 10, 2.8 m^3/(h.m^2) @ 50Pa for 11 and 2.2 m^3/(h.m^2) @ 50Pa or plot 12. Plots 9 & 11 are above the predicted, while plots 10 & 12 were below the predicted figure. This will impact the re-calculated SAP.

Infrared thermographic surveys were performed under the BPE methodology and guidance later explained in page 134 of this Report. Both internal and external images concentrate on plot 9 ground floor & plot 10 first floor. Front elevations showed differences in surface temperatures and heat loss at the junctions. Heat loss was noticeable below the floor level where the brick facing shows temperature differences (Figure C05). Internally, heat loss was identified around skirting's and floor joists (Figure C07). In the first floor flat, insulation appeared to be missing in the ceilings; particularly near roof eaves (Figure C06). This is repeated throughout. Field study results were used to create an as-constructed SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

- **Services Performance Audit**

All plots were installed with an MVHR Nuaire MRXBOX95-WH1 system. The audit was conducted on plot 12 to measure the services performance. The MVHR system was not tested in this property but the efficiency calculated in other plots gave 81% compared with the 92% efficiency stated by the manufacturer. The installed mCHP system is a Baxi Ecogen powered by mains gas. It is a dual energy system, and provides efficient central heating and hot water and also generates up to 1kW of electricity. The heated water is stored in a Powerflow unvented hot water system which has a 3kW immersion heater installed for back up.
During the second visit to test system performance, the occupier complained that water temperatures were very high and that this was highlighted to the Housing Association, it

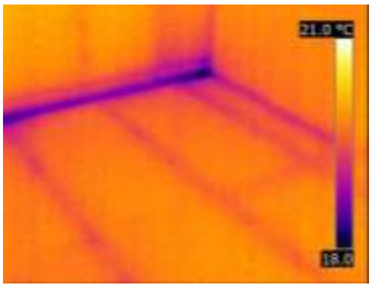


Figure C07 – IR image internal wall corner and floor junction plot 09

Figure C08 – Boiler installed at plot 12

Figure C09 – Pipe configuration at plot 12

was later confirmed that the immersion heater was on override and was constantly on, instead of a timed control as expected. This would increase electricity use throughout this period.
The mCHP was operational while conducting the survey. Some installation issues were spotted; for example a lack of insulation around pipe work and holes or badly patched up gaps appeared beneath the mCHP which may present air infiltration as these pipes penetrate or are close to the external building fabric. During the inspection, all pipe work was un-insulated

Finally, for purposes of system performance, testing of the hot water temperatures delivered to the kitchen and bath rooms was performed. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. In-situ testing of one minute intervals gave an average temperature of 57˚C which is considerably higher than the threshold and could cause some scalding. This may be due to the immersion heater on constantly with the mCHP heating water. KHA will carry out programmed testing of these temperatures.

All light fittings were equipped with energy efficient light bulbs which fulfils SAP minimum score of 75% of low consumption light bulbs.

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 11 & 12 with as-built in situ data (U-values, air permeability). Differences between the predicted and the as-built SAP values could thus be compared, as well as the DER values of each dwelling. Plot 12 obtained a new DER value of 15.78kg/m^2/yr with a score of 86B compared with the predicted value of 14.63 kg/m^2/yr and a score of 86B. Plot 11 obtained a new DER value of 19.34kg/m^2/yr and a score of 84B compared with the predicted value of 12.89kg/m^2/yr and a score of 88B. Although underperformance is experienced, it is important to highlight that air permeability improved in plot 12. The main culprit could be the differences in U-values. Total yearly primary energy consumption was predicted to be 64.26kWh/m^2/yr for plot 11 and 73.17kWh/m^2/yr for plot 12. As-built figures show an increase of 93.25kWh/m^2/yr for plot 11 and 78.39kWh/m^2/yr for plot 12.

- **Energy Consumption Audit**

Plot 12 is occupied by a single adult who occupies the dwelling during most of the day. Space heating and hot water is used periodically and appliances are used throughout the day. Readings were taken from the 1st to the 31th of August 2012. Re-calculations for the month of August were not possible as they were deemed inaccurate.

Figure C10 – Hot water tank installed at plot 12

Technical Key findings

- As-built space heating requirements doubles the design predictions.
- Flats recorded higher than predicted values which increased fabric **heat loss.**
- Some flats had air permeability levels below predicted and others had above.
- Infra-red thermography images show distinct heat loss at ceiling level.

User Satisfaction - SIGMA II BUILD SYSTEM by Stewart Milne Homes

New Technology: Baxi micro Combined Heat & Power and Nuaire MVHR system

Overall this house was rated at 9.5/10= very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m^2 £822 = better than average construction cost
Construction period 126 days = poorer than average construction period

While generally the residents consider that there is **enough space** in their homes and the size of the flats was rated very highly (9 and 10/10), given a choice residents would have preferred it if there was more space in the living room for table and chairs. A young mum with a toddler also expressed preference for more storage as she "*has nowhere to store a vacuum cleaner and a pushchair".*

Figure C11 – Ground floor plan block 3

While the flat layout was rated highly (between 7 and 10 out of 10), ground floor residents expressed strong preference for direct access from the utility room to the backcourt.

Detailed features liked by the residents included excellent use of space under the stairs to create a walk-in wardrobe

Detailed features disliked by the residents included:

- Kitchen power points are considered to be in inconvenient places – they were spaced out in such a way that they were blocked by the microwave which was situated in the only area large enough to accommodate it.
- Ventilation switch would have been better placed next to the light switch.
- The position of the sockets in bedrooms assumes only one arrangement for the bed and this blocked access to the fitted

Figures C12 & C13 - Sockets blocked by microwave which according to the tenant, cannot be placed in another location wardrobe. Because of this the resident's preferred position for the bed necessitates running an extension cable from the socket by the door to the opposite corner where there is a bedside table.

- The position of the aerial socket suggests that the TV set would need to sit in front of the radiator.


Figures C14 & C15 - The position of the sockets in bedrooms assumes only one arrangement for the bed and this blocks access to the fitted wardrobe. Resident's preferred position for the bed necessitates running an extension cable from the socket by the door to the opposite corner where there is a bedside table.

With reference to **new technologies** one of the residents was enthused by observing the **In-home energy display system**– they were pleased with it and remarked that it was "*amazing how much power is used by phone chargers*! "However, another resident in this block was unaware of 'what is what' in the in home energy display system and did not pay attention to it.

Two of the flats are fitted with gas **micro combined heat and power boilers however** both residents appeared unaware of the type of system they had in their flats despite the fact that details are featured in the Resident Handbook and were referred to during the handover demonstration. When asked about new technologies, residents' comments focused on the programmer, which was rated relatively low in terms of user satisfaction levels: while the residents confirmed that they were shown how to use the programmer, they also stated, that they have forgotten how to use. This resulted in the residents not taking advantage of the programmer and turning the heating on and off manually as required.

Figure C16 – In-home Energy Display System

Figure C17 - It would have been better if there were some slabs every now and then to be able to cross over from the car to the pavement in front of the house.

Based on a short time in occupation, the cost of heating was thought to be much lower than in previous accommodation. Their level of satisfaction with training how to use it were rated relatively low – mostly between 5 and 6, namely they were ‘neither satisfied nor dissatisfied’ or ‘fairly satisfied’ with training received.

Residents were neither happy nor unhappy with instructions contained in the ‘**Resident Handbook’** and confirmed that they needed further training about operating heating and ventilation**.**

With reference to satisfaction with the **Area Outside** residents praised the play area and landscaping, however they do not like having to walk around the landscaped area between the car park and their front door - it would have been better if there were some slabs every now and then to be able to cross over from the car to the pavement in front of the house.

Another issue identified by ground floor residents was in their view - poor access to backcourt as they do not like having to walk all the way round the back of the house, as they found it slightly restrictive– “*it makes me choose not to use the backcourt green to hang out the washing. It would have so much better to have a door at the back of the utility room”.*

Features which were particularly LIKED	**Features which were particularly DISLIKED**
• In-home Energy Display system monitors! Pleased that the monitors are part and parcel of everyday life. • Eco aspect • This place helps with being environmentally friendly • Having a utility room and storage • Handles in the shower and toilet with grab rail	• Having to walk around the landscaped area between the car park and the front door • Not having direct access to backcourt via the utility room

Table C02 - Likes and Dislikes

Key Findings from User Feedback

- High levels of satisfaction with layout and Eco friendly design
- Better quality training in micro CHP would have been welcome at early stages of occupation
- More attention needed in detailed design of socket distribution to secure flexibility in arranging furniture and in the kitchen to ensure there is adequate space for food preparation

SYSTEM OVERVIEW

BLOCK 04 – PLOTS 13 & 14

INSULATED CLAY BLOCK

Figure 01 – Front elevation block 03 – plot 14

www.porothermuk.co.uk

PROPERTY	2 x 2 Bedroom Cottages – Amenity
TECHNOLOGY & SYSTEMS SUMMARY	Weinerberger Porotherm insulated clay block - Plot 13 – Photovoltaic panels, MVHR, In-home energy display - Plot 14 – Solar water heater, MVHR, In-home energy display
MAIN CONTRACTOR	Campion homes Ltd
SYSTEM PROVIDER	Weinerberger
ARCHITECT	Oliver & Robb Architects

Figure D02 – Wall makeup for block 04

DESIGNED & MEASURED SAP OUTPUTS

Block 04 – PLOTS 13 & 14

INSULATED CLAY BLOCK

CAMPION HOMES LTD

POROTHERM

	PLOT 13		PLOT 14	
	Design	**As-built**	**Design**	**As-built**
AIR PERMEABILITY $m^3/(h.m^2)$@50Pa	2.5	2.32	2.5	2.38
SAP RATING	88B	84B	85B	82B
EI (CO_2) RATING	90B	85B	87B	82B
DWELLING EMISSION RATE – DER (Kg/yr)	13.27	18.28	16.44	21.39
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	62.70	88.09	81.29	106.39
ENERGY USE				
Space heating (kWh/year)	2357	4353	2334	4294
Water heating (kWh/year)	2717	2682	1598	1576
Lighting (kWh/year)	367	367	369	369
Pumps and fans (kWh/year)	377	377	452	452
Total (kWh/year)	5817	7779	4752	6691
ENERGY COST				
Space heating (£/year)	£73	£135	£72	£133
Water heating (£/year)	£84	£83	£50	£49
Lighting (£/year)	£21	£21	£21	£21
Pumps and fans (£/year)	£21	£21	£25	£25
Total energy cost (£/year) excluding saving from energy generated	£199	£260	£168	£228

Table D01 – Comparison of SAP between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, 24 hour electricity tariff: 5.64p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 4 – PLOTS 13 & 14

INSULATED CLAY BLOCK

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. These design calculations were analysed for consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team explained that no changes were made that would impact the buildings thermal behaviour. The design team did explain that the system had to be installed with insulation on both sides of the walls to meet client's energy efficiency expectations; by doing so thermal inertia benefits are negated. On-site construction benefited from the use of special adhesives because of its honeycomb hollow extrusion and for use during colder weather conditions (mortar would freeze and work would have to stop) but the system was not suitable for developments with tight time-restrictions, due to drying times. The design team also felt that the system, as installed, was less flexible for future adaptation to the external envelope. Further detailing considerations are required when using the system for a two storey unit. Another observation was that changes had to be made to reinforce the gable ends by using steel wind posts which required extra detailing to minimise any thermal bridging.

The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission rates (TER) were reviewed to identify any anomalies and possible misinterpretation of the design. An error occurred where the factory insulated DHW tank was wrongly specified as having 50mm deep insulation when it should be >75mm. It was also highlighted that the dwelling was modelled with a 1.5kWp solar PV system when in fact the as-built system was 0.96kWp. These changes have been factored in to the re-calculation of SAP.

- **Fabric Performance Audit**

The thermal performance of the building fabric was assessed during the BPE and would later be used to explain differences in predicted energy demand. In-situ U-value evaluation was conducted in both plots while the internal and external IR thermography survey was performed on plot 14.

Air permeability tests were performed by an external evaluator at post-construction and pre-occupation stage. A full review of this appears in page 137 of the technical appendix. After a review, all results comply with the

Figure D03 – Front of plot 14 during construction, before rendering showing the clay building blocks

Figure D04 – IR image front elevation of plot 14

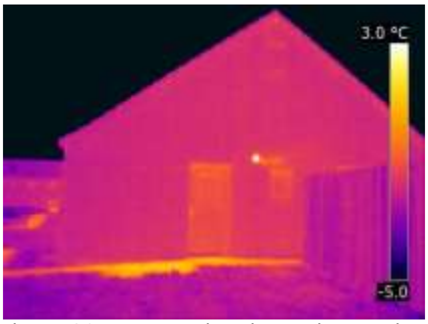


Figure C05 – West elevation IR image plot 13

Figure D06 – Internal IR image wall corner and ceiling junction plot 14

ATTMA and BSRIA specification as guidance. For purposes of the SAP calculation, the design team used 2.5$m^3/(h.m^2)$ @ 50Pa as a baseline figure, while the actual measured figures were 2.32$m^3/(h.m^2)$ @ 50Pa for plot 13 and 2.0m3/(h.m2) @ 50Pa for plot 14. They are both below the predicted figure which will benefit the SAP re-calculation.

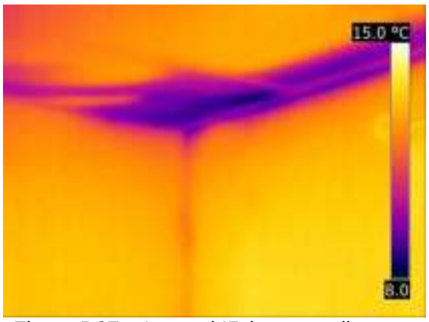


Figure D07 – Internal IR image wall corner and ceiling junction plot 14

Infrared thermographic surveys were performed under the BPE methodology and guidance explained later in page 134 of the technical appendix. Front elevations showed differences in surface temperatures and heat loss at the junctions (Figures D04 & D05). Heat loss was noticeable in areas on the roof and gable wall. Missing insulation near roof eaves and from internal service straps might explain the IR images and the weak heat loss points.


Figure D08 – Pipe work into water tank - plot 13

Field study results were used to create an as-constructed SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

- **Services Performance Audit**

Plot 13 was monitored with greater detail on the system performance. Solar Photovoltaic panels were installed in plot 13 while plot 14 has a solar thermal unit which was already evaluated in plot 6. Both plots had the same MVHR system which was tested for its performance and energy consumption.


Figure D09 – Photovoltaic panels on South elevation of plot 13

The Solar PV system includes 3 Monocrystalline Viridian Solar Clearline panels with an array of 0.9kWp installed together with a SME Sunnyboy 1200 inverter. In order to obtain the panels efficiency, the output recorded for August was compared with the expected output using solar models and on site solar radiation readings. During the month of August the panels generated 92kWh of electricity. The expected solar irradiance on that panel area (7.22m^2) is of 850kWh. This gives a system efficiency of 11% this could be regarded as low but in fact solar conversions are inefficient with many system loses.


Figure D10 – MVHR system installed in plot 13

The dwellings were installed with a Brookvent AirCycle MVHR system which claims to be 89% efficient which, after measuring its efficiency obtained 87%, which is a good efficiency of ventilation exchange. The filters were inspected and some dust and debris was observed, but this did not present any blockage or perceived reduction in performance.

Water heating was obtained by the use of a conventional combination boiler and a 3kW immersion heater in a 150Lt PowerFlow 2000 water tank. The insulation around the pipework was present but fixed by duct tape that can tend to delaminate easily, especial at high temperatures.

Finally, for purposes of system performance, testing of the hot water temperatures delivered to the kitchen and bath rooms was performed. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing of one minute intervals gave an average temperature of 58˚C which is considerably higher than the threshold and could cause some scalding. KHA will carry out programmed testing of these temperatures.

Figure D11– Hot water storage tank installed in plot 13

- **SAP re-calculation**

The SAP values for each dwelling were recalculated using as-built in-situ data (U-values, as-built air permeability). Differences between the predicted and the as-built SAP values could thus be compared, as well as the DER values of each dwelling. Plot 13 obtained a new DER value of 18.28kg/m^2/yr with a score of 84B which is just above the dwelling TER, compared with the predicted DER values of 13.27kg/m^2/yr and a score of 88B. Total yearly primary energy consumption was predicted to be 62.7kWh/m^2/yr for plot 13 compared to the as built figures which show an increase up to 88.1kWh/m^2/yr. This rise in energy use is due to the increased U-values of elements and also the decrease in the Solar PV system energy production.

- **Energy Consumption Audit**

Plot 13 is occupied by a single adult who occupies the dwelling most of the day. Space heating and hot water is used periodically and appliances are used throughout the day. Readings were taken from the 1st to the 31th of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data. A big difference was noted between SAP compared with the actual energy consumption; which is due the role uncontrolled energy has in households and the actual solar PV generation recorded.

Technical Key Findings

- Energy for space heating for the as-built calculations show close to double the as-designed predicted values.
- In-situ values have been high particularly for roofs and floors.
- Internal infra-red thermography demonstrates heat loss at the ceiling/wall junctions where low surface temperatures were observed.
- Air permeability levels were lower after construction compared with the expected values

User Satisfaction - Insulated Clay Block Porotherm by Campion Homes Ltd

New technology: Viridian PV, Brookvent AirCycle MVHR and Viridian Solar Hot Water

Overall this house was rated at 9/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m^2 at £1,019 = poorer than average construction cost
Construction period at 71 days = better than average construction period

Generally the residents considered that there was enough space in this house system, rating the size of their home very highly (9 and 10 out of 10). As with a number of the studied systems they found their living room relatively too small.

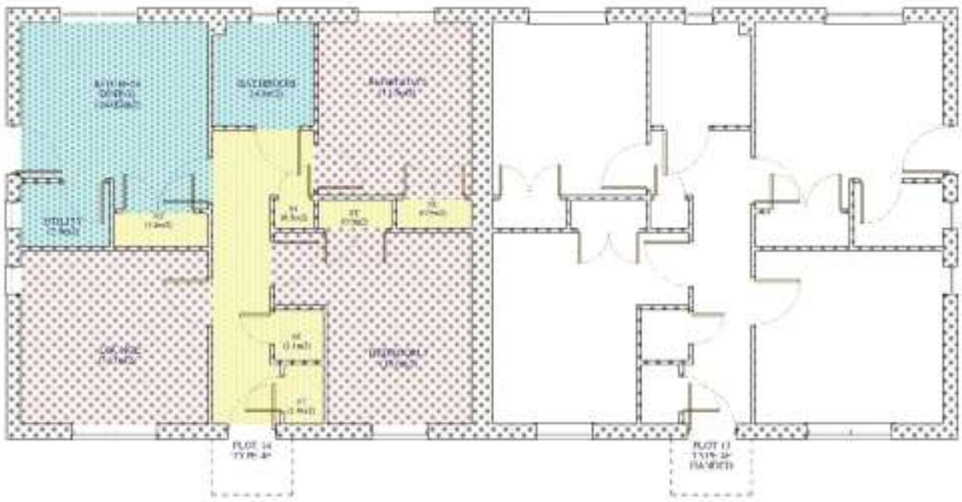


Figure D12 – Ground Floor plan block 04

Other design features such as quality of windows, position and number of sockets and radiators and bathroom fittings all scored 10/10. The quality of kitchen units scored relatively lower levels of satisfaction (7 out of 10, equating to 'fairly satisfied'). This relatively lower rating was attributed to a perception that kitchen units were not sufficiently durable in a kitchen used by a wheelchair user. It however should be noted that this flat was not designed to wheelchair standard.

With reference to **new technologies,** the residents were unaware how to operate their MVHR system and ventilated their homes by opening windows. Both residents expressed relatively low levels of satisfaction with the MVHR. The In-home Energy Display system and the central heating system as well as low energy light bulbs were all rated at 10/10.

Residents awarded a maximum score i.e. 10/10 to **overall comfort.** They both felt that the internal environment impacted positively on their sense of well-being, making them feel that it improved their health.

"I suffer from chronic obstructive pulmonary disease (COPD) and I breathe easier here - it is getting better! My husband suffers from sleep apnea - and he has been sleeping better too. It is early days but it is interesting that our first impression is that I sleep better. We feel more relaxed".

This system also scored 10/10 for **all aspects of personal control** over heating, lighting, ventilation and noise.

Based on a short time in occupation, the cost of heating was thought to be much lower than in the previous accommodation. While one resident confirmed that they were able to operate their CH system, the older resident was unable to set **the programmer** and this resident was not satisfied with the quality of instructions they received at the time of moving in.

With reference to satisfaction with **area outside** as with the previous system – residents praised the play area and landscaping generally, however they do not like not having a front garden and having to walk around the landscaped area between the car park and their front door. They also dislike the back garden not being level.

Features which were particularly LIKED	Features which were particularly DISLIKED
• Barrier free design and access • Lots of space – particularly in the kitchen • Spacious kitchen with dining area • The house is spacious	• There is not enough slope in the bathroom so water does not drain away • Back garden not being level

Table D02 – Likes and Dislikes

Key Findings from User Feedback

- Good space standards and barrier free layout design
- Spacious kitchen
- Effective heating system
- Low cost of energy from PV panels and MVHR appreciated following training

SYSTEM OVERVIEW

BLOCK 05 – PLOTS 15 &16

STRUCTURAL INSULATED PANELS

www.cuberetreat.co.uk

Figure E01 – Front elevation block 03

PROPERTY	2 x 2 Bedroom Cottages – Amenity
TECHNOLOGY & SYSTEMS SUMMARY	Structurally insulated panels - Plot 15 - Photovoltaic panels, MVHR, In-home energy display - Plot 16 - Photovoltaic panels, MVHR, In-home energy display
MAIN CONTRACTOR	John Heaney Joiners Ltd
SYSTEM PROVIDER	CUBE RE:treat
ARCHITECT	CUBE Architects

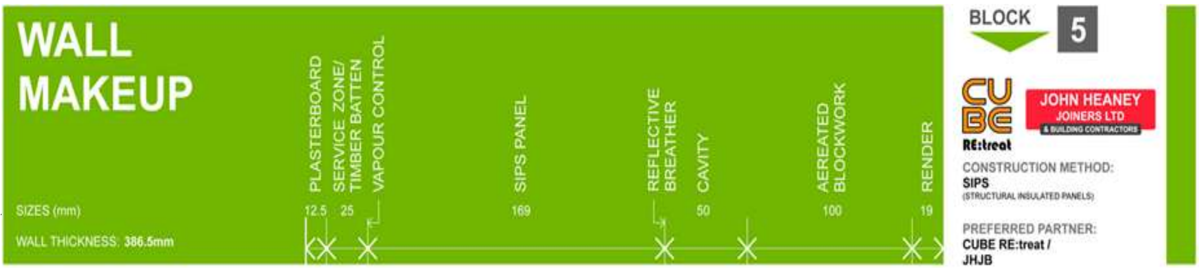


Figure E02 – Wall makeup for block 05

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 05 – PLOTS 14 &15

STRUCTURAL INSULATED PANELS

	PLOT 15		PLOT 16	
	Design	As-built	Design	As-built
AIR PERMEABILITY m³/(h.m²)@50Pa	3.0	2.5	3.0	2.5
SAP RATING	87B	87B	87B	87B
EI (CO_2) RATING	91B	90B	91B	90B
DWELLING EMISSION RATE – DER (Kg/yr)	13.65	14.44	13.69	14.48
TOTAL PRIMARY ENERGY (kWh/m²/yr)	57.28	60.96	57.42	61.11
ENERGY USE				
Space heating (kWh/year)	1937	2418	1948	2430
Water heating (kWh/year)	2030	2028	2030	2028
Lighting (kWh/year)	376	376	376	376
Pumps and fans (kWh/year)	413	413	413	413
Total (kWh/year)	4755	5235	4766	5247
ENERGY COST				
Space heating (£/year)	£60	£75	£60	£75
Water heating (£/year)	£63	£63	£63	£63
Lighting (£/year)	£43	£43	£43	£43
Pumps and fans (£/year)	£47	£47	£47	£47
Total energy cost (£/year) excluding saving from energy generated	£213	£228	£213	£228

Table E01 - Comparison of SAP between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 05 – PLOTS 15 & 16

STRUCTURAL INSULATED PANELS

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. The design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team explained that some changes were made that would impact the buildings thermal behaviour. One significant change was made on the roof insulation from a cold to a warm roof with a SIP panel as the main roof structure. This gives the opportunity for the occupier to expand into an insulated attic space. Another change during the construction stage was the installed boiler; from a conventional one to a combination boiler which provides a better efficiency and management of resources. Additional to that, other changes included, for example, the addition of a walk-in shower instead of a bath/shower arrangement and the installation of a set of foldable stairs to the attic space.

The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission rates (TER) were reviewed to identify any anomalies and possible misinterpretation of the design. In this occasion some figures were not as indicated in the drawings, but in general terms the calculation was performed to the specified design.

- **Fabric Performance Audit**

The thermal performance of the building fabric was assessed during the BPE and would later be used to explain differences in predicted energy demand. These would later explain differences in predicted energy demand.
Air permeability tests were performed by an external evaluator at post-construction and pre-occupation stage. After a review of the results, all results comply with the ATTMA and BSRIA guidance. During the SAP calculation, the design team used $3.0m^3/(h.m^2)$ @50Pa as a baseline while the actual measured figure was $2.5m^3/(h.m^2)$ @50Pa, an improvement from the predicted. (see Technical appendix page 137)

Infrared thermographic surveys tests were performed under the BPE methodology and guidance explained in page 134 of the technical appendix. Internal and external images were taken from plot 16. Front elevation Figure E05 shows an even distribution of surface temperatures on the main SIP wall system. The roof also shows a relatively even surface temperature, with the exception of the roof top left hand corner; which shows an elevated surface temperature caused by a

Figure E03 – East elevation plot 15 and 16 showing PV panels

Figure E04 – Plot 15 and 16 under construction

Figure E05 – IR image front [West elevation] plot 16 steel beam. This is not an issue as the attic space is not habitable and it is not a heated space, if this scenario changes the steel would have to be insulated. Internally it can be seen that the SIP panel used in the ceiling presents some detailing issues. The edge between the wall and the ceiling in Figure E06 shows lower surface temperatures. There are also patches where insulation is missing or a thermal bridge is occurring through the SIP ceiling. Although a warm roof construction; some heat losses are identified.

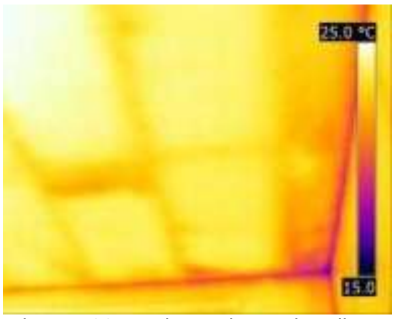


Figure E06 – IR image internal, wall corner and ceiling junction plot 16 living room

Field study results were used to create an as-constructed SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

- **Services Performance Audit**

An audit on performance was conducted on the technology installed in plot 16 where a small solar PV system was operating, together with an MVHR used as the main ventilation system. The tests were conducted after the first month of occupation.

Figure E07 – PV panel installed on plot 16

The solar PV device was installed on the back roof facing east. The panels are Sharp 250W with a Mastevolt inverter. The performance of the solar panel was correlated with statistical solar data, in-situ solar measuring equipment and solar prediction software. The panel efficiency specified by the manufacturer ranges between 13% and 15%. In-situ tests calculated the efficiency of the whole system (including invertors) as giving an average of 9.96%, which is a realistic efficiency for such systems.

Figure E08 – Extract MVHR air duct penetrating thee SIP roof panel

The dwelling was fitted with a Vectaire MVHR system which in the early occupation testing was operational and delivering comfortable temperatures. The thermal efficiency recorded was 80% in standard mode and 90% in boost mode, compared to the manufacturer's specified efficiency of 92% across the two settings. During the inspection of the device, some issues arose over the condition of the duct insulation and the location of the air handler, being in the attic, where the residents find it difficult to reach and change filters. The residents in this dwelling are elderly and find it difficult to reach the attic. It was also noticed that near the supply vents, considerable noise was perceived from air being delivered. The residents noticed this more when going to sleep when no other noise was present.

Figure E09 – Damaged insulation observed on MVHR ducting

Finally, for purposes of system performance, testing of the hot water temperatures delivered to the kitchen and bath rooms was performed. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. In this case a recorded temperature of 48˚C was obtained which is at the threshold. KHA will carry out programmed testing of these temperatures.

All light fittings were identified as having low energy light bulbs as described in the SAP and EPC calculations.

- **SAP re-calculation**

The SAP values for each dwelling were recalculated using as-built in-situ data (U-values, as-built air permeability). Differences between the predicted and the as-built SAP values could thus be compared, as well as the DER values of each dwelling. The new as-built SAP scores were obtained. Plot 16 obtained a new DER value of 14.48kg/m^2/yr with a score of 87B compared with the predicted DER value or 13.69kg/m^2/yr and a score of 87B. The SAP yearly primary energy consumption was 57.42kWh/m^2/year. In comparison, the re-calculated figure shows a yearly primary energy calculation of 61.11kWh/m^2/yr. Both figures take into account the savings in solar PV energy generated. The increase in energy also highlights the impact of realistic fabric U-values and air tightness.

- **Energy Consumption Audit**

The monitored property is occupied by two adults; both of which are retired and tend to reside in the property day and night. Electrical and gas use is consumed periodically and space heating and appliances are used throughout the day. Electrical and gas readings were taken from the energy display monitors and also physically from the dwellings installed meters. Readings were taken from the 1st to the 31th of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data. It must be noted that the SAP figures don't take into account un-regulated energy (appliances) but they do take actual Solar PV generated.

Technical Key Findings

- As-built space heating is close to the predicted as-designed SAP values.
- Some heat loss experienced internally appreciated in the infra-red thermography. Ceiling joists and junctions between wall/ceiling show lower temperatures where heat loss is apparent.
- The ventilation ducting in the attic space was in poor condition given the age of the dwelling (less than 1 year, at the time of the survey)

Figure E10 – Connection of ventilation ducting to MVHR unit

Figure E11 – In-homes Energy Display System showing total daily energy consumed and generated at plot 16

User Satisfaction - Cube Re:treat SIP's by John Heaney Joiners Ltd

New technology: Sharp PV & Vectair MVHR

Overall, this house scored 8/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 £1,138 = poorer than average construction cost
Construction period 61 days = better than average construction period

Generally the residents consider that there is **enough space** in this house type, rating the size of their home highly (Average 8.5 out of 10). Again the living room was found to be relatively too small.

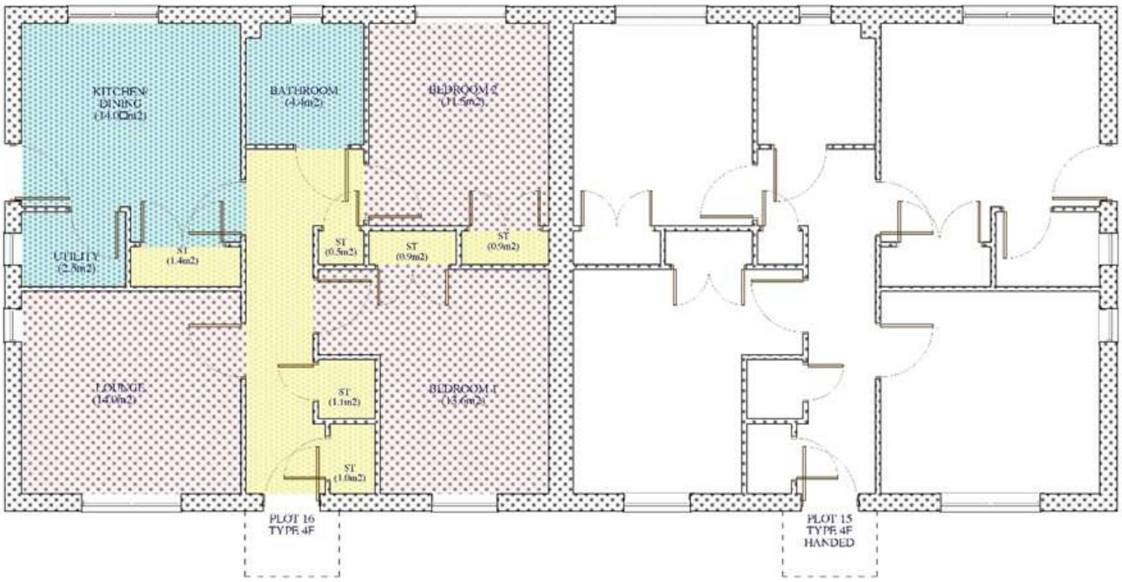


Figure E12 – Ground floor plan block

The size of the kitchen was praised, although one resident felt that there is not enough room on the worktop for food preparation. In their view just handing the sink would have resolved the problem: "*that way the drainer would have been on the right hand side of the bowl and there would have been much more space for food preparation closer to the cooker".*

With reference to **storage** user feedback again identified preference for storage cupboards to be shelved. One resident reported spending £200 on purchasing ready-made standing shelves to make full use of kitchen larder as they were unable to hang shelves therein because "*it is impossible to fix anything to plasterboard as it crumbled as there is nothing behind the plasterboard to fix things into".*

Figure E13 **-** In user's opinion just handing the sink would have provided more user friendly solution

Similarly, level of satisfaction with the **bathroom** was affected by the following problems:

- In the resident's view it is impossible to fix anything into the walls, including a toilet roll holder or a towel rail. The resident stressed that they tried to use the raw plugs that are supposed to open themselves behind the plaster board, but commented that a mesh behind the plasterboard stops the raw plugs from opening because they get caught in the mesh and the plasterboard just crumbles away.

- Another issue is that the water temperature in the bathroom was found to be too low resulting in the resident topping up water with kettles of hot water. The logic of 'anti scolding device' in the bathroom was questioned considering that pillar taps both in the wash hand basin and in the sink contain very hot water.

- Water pressure in the shower is too low: *"you have to dance around it to get wet".*

- The resident questioned the logic of having an electric shower installed over bath when mains powered shower in their view would have been so much better as water pressure locally is excellent. The fact that the electric shower would be powered by PV panel did not seem relevant in this case: having good water pressure was more important to this user than having 'free' energy.

Other design features such as position of sockets and radiators and doors scored lower than in other house types. The following features created problems for the resident:

- The radiator in the living room is obstructed by a sofa and
- The radiator is too far from the corner due to a socket positioned in the same corner – in the resident's view again it is wrongly positioned as it results in the sofa covering the radiator.
- Both front and rear door do not provide sufficient security: they could be opened too easily by the children.
- The door to the utility room is wide and takes up valuable space: in the resident's view this door would be better if it were a sliding door; this would free up much space in the utility room

Figure E14 - If the power socket was positioned on the wall behind the door, the radiator could have been positioned closer to the corner, leaving enough space for the sofa not to obstruct the radiator

The colour of the front door was also criticised – "I think that the grey paint on the front doors is appalling and drab - we *have enough grey in Scotland - grey days, grey skies...I would like to paint my door red but I do not think I would be allowed"...*

With reference to new technologies in one resident's view:

- PV panels did not appear to produce electricity in resident's opinion
- Energy costs billed for amounted to £65 per month while gas was being used only for hot water in baths. CH was not used at all by the time of the interview.
- The Vectair MVHR system was perceived to be defective and so noisy that it was turned off altogether by the resident.

Figure E15 -The MVHR ventilation duct was taped with masking tape and came off

With reference to **Satisfaction with the Area Outside** while overall levels of satisfaction with the external environment were relatively high, dislikes were based on the following opinions:

- In the back garden there is no bin storage as such - bins stand freely and the problem is that when it is windy the bins fly around the place. There should be proper storage for the bins so that they stay put.
- Regarding parking – it is fine but to get onto a footpath, user has to step over the pebbles.

Features which were particularly LIKED	Features which were particularly DISLIKED
• The layout • The kitchen • Garden space • Own front and back door • Location	• Size of living room • Not being able to make use of the loft • Difficulties in fixing shelving and pictures to internal walls. • The front garden

Table E02 - Likes and Dislikes

Key Findings from User Feedback

- Successful layout design is compromised by a small living room and poorly thought out detailed design of positions of radiators/sockets
- Spacious kitchen is compromised by lack of sufficient space on the worktop to prepare food
- Problems with fixing shelves in storage cupboards and fixing bathroom fittings/pictures into plasterboard walls affect overall levels of satisfaction. Another issue is that the water temperature and pressure in the bathroom was found to be too low

SYSTEM OVERVIEW

BLOCK 06 – PLOTS 17 & 18

SCOTFRAME VAL-U-THERM & OPEN PANEL SYSTEM

CONTROL HOUSE & PASSIVHAUS STANDARD

Figure F01 – Front elevation block 06

www.scotframe.co.uk

PROPERTY	2 x 3 Bedroom House – General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Scotframe Val-U-Therm Wall System - Plot 17 designed with an open panel system to Scottish building standards 2010 Energy standards 'Control house', in-home energy display - Plot 18 designed with the Val-U-Therm system to Passivhaus design standards, MVHR, In-home energy display
MAIN CONTRACTOR	Campion Homes
SYSTEM PROVIDER	Scotframe
ARCHITECT	Oliver & Robb Architects

Figure F02– Wall Makeup block 06

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 06 – PLOTS 17 & 18

SCOTFRAME VAL-U-THERM & OPEN PANEL SYSTEM
CONTROL HOUSE & PASSIVHAUS STANDARD

CAMPION HOMES LTD
scotframe timber frame | engineering
SPHC

	PLOT 17		PLOT 18	
	Design	**As-built**	**Design**	**As-built**
AIR PERMEABILITY $m^3/(h.m^2)$@50Pa	5.0	3.6	0.6	0.53
SAP RATING	83B	83B	85B	85B
EI (CO_2) RATING	86B	84B	88B	88B
DWELLING EMISSION RATE – DER (Kg/yr)	17.0	17.7	13.6	13.8
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	83.1	87.0	68.2	69.0
ENERGY USE				
Space heating (kWh/year)	3451	3827	767	850
Water heating (kWh/year)	2667	2661	2937	2931
Lighting (kWh/year)	445	445	428	428
Pumps and fans (kWh/year)	175	175	471	471
Total (kWh/year)	6738	7108	4603	4690
ENERGY COST				
Space heating (£/year)	£107	£119	£24	£27
Water heating (£/year)	£83	£82	£91	£91
Lighting (£/year)	£48	£48	£49	£49
Pumps and fans (£/year)	£19	£19	£54	£54
Total energy cost (£/year) excluding saving from energy generated	£256	£267	£218	£221

Table F01– Comparison of SAP between as-designed and as-built

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff of 3.1p/kWh used for space and water heating in plots 17 and 18. For lighting and fans etc standard electricity tariff is used (11.46p/kWh) in plots 18 and a 10 hour fraction tariff is used in plot 17. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 06 – PLOTS 17 & 18

SCOTFRAME VAL-U-THERM SYSTEM CONTROL HOUSE & PASSIVHAUS STANDARD

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

This block has two house types, one labelled as the standard Kingdom Housing Association House type or “Control house” (plot 17) and the other is a highly insulated timber kit built to the Passivhaus standard (plot 18). Both were built by Campion Homes Ltd. A review of both designs and the predicted performance figures was conducted. These design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. A questionnaire relating to construction design changes was issued and the design team explained that some changes were made that would impact the buildings thermal behaviour. They explained that due to the control house being paired with the Passivhaus (with its much deeper wall thickness) the room sizes had to increase to ensure the external envelope remained constant. The control house was designed to meet 2007 Building Technical Standards and meeting the client brief and energy requirements was achieved easily. The design team have identified that achieving high U-values for Passivhaus was complicated and that increasing airtightness would result in achieving better energy performance, equal to many other dwellings in the development. In plot 18, the Scotframe system was adopted; proving to be highly flexible in meeting design fabric efficiency. Few changes were encountered during the design stage, while little detailing and adaptation was needed to meet thermal and airtight efficiency; it was also regarded as cost effective.
The SAP worksheets with their associated Dwelling Emission Rates (DER) & Target Emission rates (TER) were reviewed to identify any anomalies and possible misinterpretation of the design. Some errors were identified and it was difficult to represent the calculation as set originally, especially in the living area fraction which would not accept the same values input by the design team. It was also identified that the supplied plot 17 DER SAP score was higher than the TER score resulting in not meeting the SAP predictions. Additional to the above was that the BPE Study Team identified that the set thermal bridging for the Passivhaus was 0.08W/mK when the standard requires construction free thermal bridging and figures below 0.01W/mK.

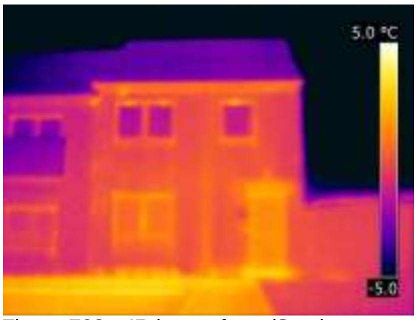


Figure F03 – IR image front (South elevation) of plot 17 and 18 (Passivhaus)

Figure F04 – IR image external, front elevation, living room window, wall and ground level junction. Connection between plot 17 and 18

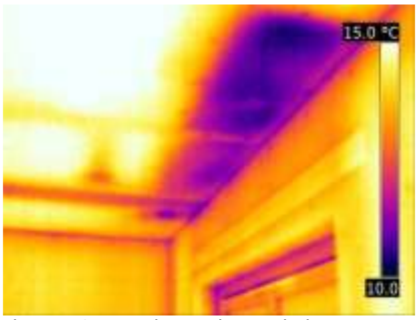


Figure F05 – IR image internal plot 17, thermogram identifying heat loss attributed to missing ceiling insulation

- **Fabric Performance Audit**

The thermal performance of the building fabric of selected plots was assessed during the BPE and would later be used to explain differences in predicted energy demand.

These would later explain an increase in energy demand. In-situ U-value evaluation and an internal/external IR thermography survey was conducted in both plots.

Air permeability tests were performed by an external evaluator at post-construction and pre-occupation stage. A full review of this appears in page 137 of the technical appendix. A full review was undertaken using ATTMA and BSRIA specification as guidance.
For purposes of the SAP calculation, the design team used $0.6m^3/(h.m^2)$ @:50Pa as a baseline figure for plot 18 and 5 $m^3/(h.m^2)$ @:50Pa for plot 17. The actual measured figures were 0.53 $m^3/(h.m^2)$ @:50Pa for plot 18 and 3.6 $m^3/(h.m^2)$ @:50Pa for plot 17.

The infrared thermographic surveys were performed under the BPE methodology and guidance explained later in page 134 of the technical appendix. Front elevations showed differences between the two dwellings but overall consistent temperatures. See Figure F03 & F04. Heat loss was remarkably noticeable internally in both dwellings. The control house showed potentially missing insulation in ceilings and skirting boards, Figure F05. Plot 18 showed inconsistencies in detailing around services, Figure 06, and at some junctions. The BPE Study Team was surprised of how many potential heat loss areas were identified in a dwelling such as a Passivhaus. For example Figure F07 in the ceiling close to the eves of the roof where large insulation patches are missing or a linear thermal bridge is acting as a heat pathway.

Field study results were used to create an as-built SAP assessment of the dwellings tested in order to obtain a comparative performance figure.

- **Services Performance Audit**

Plot 17 & 18 were monitored with greater detail on the system performance. No low carbon technology was installed in both plots. A Vokera Mynute boiler system was used for space and water heating. Plot 18 has a Paul Novus 300 MVHR system which claims to be 93% efficient. After measuring its efficiency by performing field tests, the system obtained 85% efficiency from an average performance during standard and boost modes of use. This decline in efficiency was not factored in to the re-calculation of the dwelling as SAP does not support this without other specific system data. Filters were inspected for their cleanliness and state, some dust had accumulated but generally it is sufficiently well maintained.

The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing of one minute intervals gave an average temperature above this threshold. KHA will carry out programmed testing of these temperatures.

In both plots, the majority of light fittings were equipped with energy efficient light bulbs fulfilling SAP requirements of >75% of low consumption light bulbs.

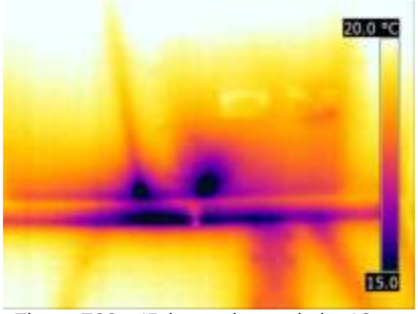


Figure F06 – IR image internal plot 18 wall and floor junction in living room.

Figure F07– First floor ceiling – missing insulation bedroom plot 18


Figure F08– MVHR unit installed in plot 18 kitchen


Figure F09– MVHR unit installed in plot 18, filter inspection after early occupation

- **SAP re-calculation**

The SAP values for each dwelling were recalculated using as-built and measured in-situ data (U-values, as-built air permeability). Differences between the predicted and the as-built SAP values could thus be compared, as well as the DER values of each dwelling. Plot 17 obtained a new DER value of 17.7kg/m^2/yr with a score of 83B and doesn't meet the aspirational values initial set as DER is above the TER compared with the predicted DER of 16.95kg/m^2/yr and a score of 83B. Plot 18 obtained 13.8kg/m^2/yr which is higher than the predicted levels of 13.6kg/m^2/yr with a score of 85B. This was due to the decreased actual air permeability score and the higher U-values for some components. The total yearly primary energy consumption was predicted to be 83.1kWh/m^2/yr for Plot 17 while plot 18 was of 68.2kWh/m^2/yr, compared to the as-built figures which show an increase up to 87kWh/m^2/yr for plot 17 and 69kWh/m^2/yr for plot 18.

- **Energy Consumption Audit**

Plot 17 is occupied by a part-time working single adult with two children; the dwelling is occupied in the evenings and some mornings. Plot 18 is occupied by three adults who use the house at various times of the day. Space heating and hot water is used regularly and many high power appliances were identified in the dwellings. Meter readings were taken from the 1st to the 31th of August 2012. The expected SAP consumption for this month of the two dwellings was quite varied as the two homes are distinctly different in their design. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data. Plot 18 has a higher SAP predicted energy use mainly due to the MVHR system which consumes 153kWh of primary energy. These predicted SAP values don't take into consideration the use of uncontrolled energy, such as electrical appliances, hence the higher measured values.

Technical Key Findings:

- Internal infrared thermography in both plots has shown many first floor ceiling/wall junctions with evident heat loss.
- External thermograms show surface temperature differences between the Passiv Haus and the control house which was evidently expected.
- Both plots show little disparity between the as-built and the as-designed energy use despite the as-built airtightness improvement.

Figure F10– Ducting connection to MVHR unit installed in plot 18

Figure F11– Ducting connection to MVHR unit installed in plot 18

Figure F12– Paul Novus MVHR facing

User Satisfaction - Control House by Scotframe Val-U-Therm & Campion Homes Ltd

No New technologies installed

Overall score 10/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 at £743 = better than average construction cost
Construction period at 65 days = better than average construction period

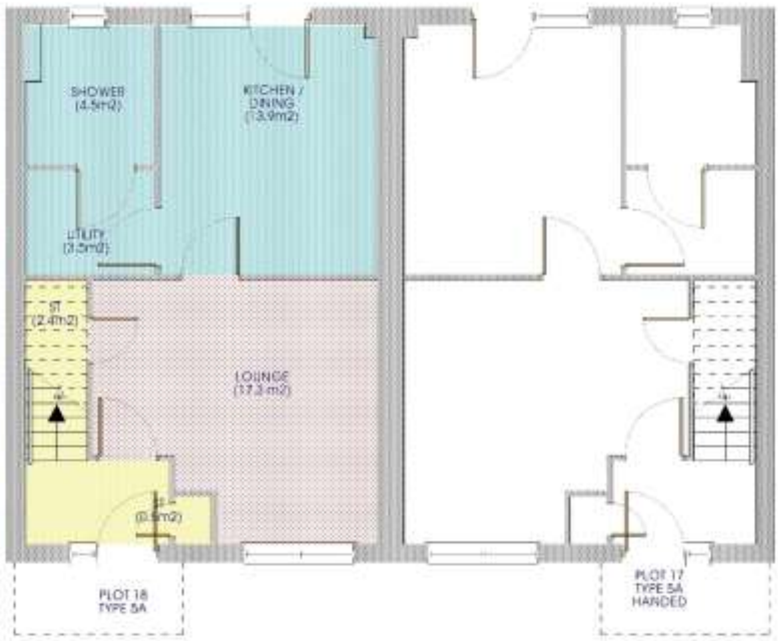


Figure F13 – Ground floor plan – Control house plot 17 (right) - block 06

Location was a problem for this resident as they do not have a car: they would have preferred to live closer to a small shop. With reference to layout design**,** as with the remaining house systems the Control House was rated very highly (10/10) with the proviso that living room and one bedroom which was 6.8m^2 were rated as relatively too small.

Other design features such as **quality of windows, position and number of sockets and radiators and bathroom fittings** were also scored 10/10, reflecting very high levels of satisfaction.

Design features which were rated particularly highly were:

- The kitchen - the space for the table was rated as 'brilliant',
- The work surface in the utility room was 'great'.
- The downstairs bathroom is great – "*I can shower there while children are asleep without worrying that I will wake them up".*

With reference to **new technologies,** while none were installed except the energy In-home Energy display in this house type**,** the resident was energy conscious and able to operate the central heating programmer.

The resident rated the **'Resident Handbook'** highly and clearly used it as a reference source. However, they reported a problem with their In-home energy display: "*based on information from the* *energy meter*, *on average I would use £1 per day for gas and for electric but this does not match with what utilities tell me".* This was a result of the resident not updating the meter with the correct energy tariff information.

With regard to **overall comfort** – this system also scored 10/10 for all aspects of personal control over heating, lighting, ventilation and noise, again reflecting very high levels of satisfaction.

Features which were particularly LIKED	Features which were particularly DISLIKED
• The size of the house • That it is designed to be more healthy	• There was nothing that the resident disliked about this house**.**

Table F02 - Likes and Dislikes

Key Findings from User Feedback

- Layout design and detailed design all meeting user requirements
- Standard heating system does not pose difficulties to the resident
- The utility room is great

User Satisfaction - Passivhaus by Scotframe Val-U-Therm & Campion Homes Ltd and the Scottish Passive House Centre

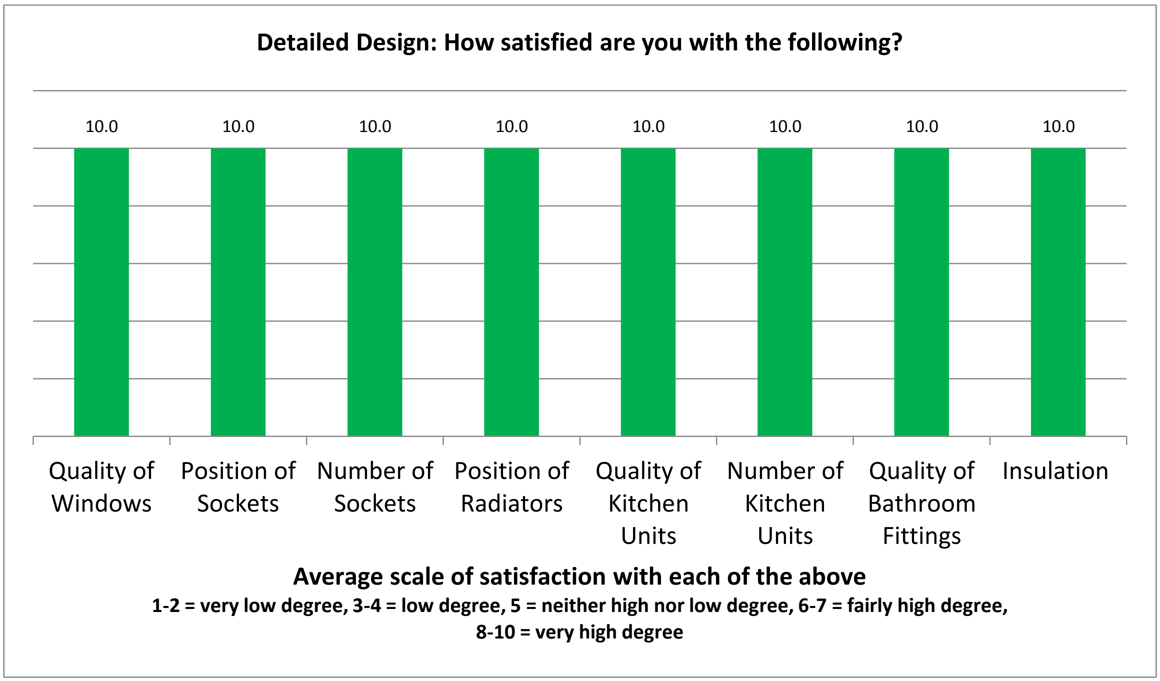
New Technology: **Paul Novus MVHR**

Overall score 10/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m² at £1,092 = poorer than average construction cost
Construction period at 65 days = better than average construction period

Figure F14 – Ground floor plan – Passivhaus plot 18 (left) - block 06

The Passivhaus afforded maximum ratings for satisfaction with all aspects of the design, including the **layout and the amount of space**.

All aspects of **detailed design** were also rated very highly: features such as **quality of windows, position and number of sockets and radiators and bathroom fittings** also scored 10/10 every time.



Graph F01 – Satisfaction levels with various aspects of detailed design

With reference to **new technologies** the residents were fully satisfied with the in-home energy display and the programmer, but they were not satisfied with the MVHR: *"We think that it is a great system but we do not think that it is working properly as some of the vents seem to pass more air than others. As a result, there are times when it is unbearably hot*. *The bedrooms are too hot - we have had to take off duvets altogether and we are still boiling. Because of this, we open the windows at night in our bedrooms to be able to go to sleep".* Kingdom has since carried out further visits and demonstrations to show the resident how to operate the MVHR system correctly.

Notwithstanding the above comments, this system also scored 10/10 for all aspects of personal control over heating, lighting, ventilation and noise, reflecting very high levels of satisfaction. Importantly, the residents believed that the quality of air in their home was better and positively affecting their health: *"you get constant fresh air so you are bound to feel healthier!"; "My son used to suffer from a blocked nose but now - it is totally opposite!"*

Based on a short time in occupation, **the cost of heating** was thought to be much lower than in their previous accommodation as the residents did not need to use their heating at all since they moved in. The residents commented that they were more aware of their energy consumption and observed the In-home Energy Display system to tell them how much energy they were using. The fact that they lived in a property designed to Passivhaus standard made them feel special and this helped them think about saving energy.

Residents of this house system were satisfied with information in the **Resident Handbook**; however, when asked about the quality of training specifically relating to operating Central Heating (CH) programmer this was rated *relatively lower* – at 7/10, but still reflecting fairly high level of satisfaction.

The residents were keen to get more training, in particular on how to use MVHR. As noted above this has since been carried out and the residents have expressed full satisfaction with the operation of the CH and MVHR.

Residents praised the **play area and landscaping**, however their level of satisfaction with the front garden and the back garden was relatively lower: the residents did not feel that the front garden belonged to them; the back garden had lots of potential but was water logged and could not be used at the time of the interview. Residents were advised that this problem was temporary and linked with the exceptionally wet summer and the building site next door.

Features which are particularly LIKED	Features which are particularly DISLIKED
• Layout design • Barrier free access if a friend comes in who uses a wheelchair. • The feel of it • Everything is perfect!	• Due to the anti-scalding thermostat, cannot get the water to be hot enough to enjoy a bath

Table F03 Likes and Dislikes

Key Findings from User Feedback

- Good layout and detailed design throughout
- Excellent thermal performance
- Initial problems with understanding MVHR system

SYSTEM OVERVIEW

BLOCK 07 – PLOTS 19, 20 & 21

K2 CLOSED PANEL TIMBER FRAME & e.CORE BATHROOM PODS

Future Affordable
by Springfield Properties PLC

Figure G01 – Front elevation block 07

www.futureaffordable.co.uk

PROPERTY	3 x 2 Bedroom Houses – General Needs
TECHNOLOGY & SYSTEMS SUMMARY	- K2 closed panel timber frame & e.Core bathroom pods - Plot 19 designed to Scottish Building Standards 2016 regulations, building integrated photovoltaic panels, ASHP, MVHR, In-home energy display - Plot 20 designed to Scottish Building Standards 2013 regulations, building integrated photovoltaic panels MVHR, In-home energy display - Plot 21 designed to Scottish Building Standards 2010 regulations, MVHR, In-home energy display
MAIN CONTRACTOR	Springfield Properties
SYSTEM PROVIDER	Springfield Properties Plc, K2, eCore
ARCHITECT	David Blaikie Architect & Kraft Architecture

Figure G02– Wall Makeup block 07

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 07 – PLOTS 19, 20 & 21

K2 CLOSED PANEL TIMBER FRAME & e.CORE BATHROOM PODS

Future Affordable
by Springfield Properties PLC

	PLOT 19		PLOT 20		PLOT 21	
	2016 Regulations		2013 Regulations		2010 Regulations	
	Design	As-built	Design	As-built	Design	As-built
AIR PERMEABILITY $m^3/(h.m^2)$ @ 50Pa	3.0	3.9	3.0	4.8	5.0	4.7
SAP RATING	100A	98A	92B	90B	85B	82B
EI (CO_2) RATING	100A	99A	96A	93A	86B	85B
DWELLING EMISSION RATE – DER (Kg/yr)	1.28	2.74	6.25	9.68	16.45	18.64
TOTAL PRIMARY ENERGY (kWh/m²/yr)	2.28	9.53	24.94	40.02	80.89	91.71
ENERGY USE						
Space heating (kWh/year)	254	461	547	1832	1692	2598
Water heating (kWh/year)	1044	1044	2650	2594	2593	2568
Lighting (kWh/year)	413	413	413	413	413	413
Pumps and fans (kWh/year)	220	220	395	395	395	395
Total (kWh/year)	1932	2138	4005	5235	5092	5975
ENERGY COST						
Space heating (£/year)	£28*	£52	£17	£57	£52	£81
Water heating (£/year)	£109*	£109	£82	£80	£80	£80
Lighting (£/year)	£50	£50	£47	£47	£47	£47
Pumps and fans (£/year)	£23	£23	£45	£45	£45	£45
Total energy cost (£/year) excluding saving from energy generated	£210#	£233	£192	£230	£225	£253

Table G01 – Comparison of SAP between as-designed and as-built (see notes below)

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed; a SAP generated electricity standing charge would be applied to plot 19 of £27. * (See SAP-Recalculation)

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 07 – PLOT 19

K2 CLOSED PANEL TIMBER FRAME & e.CORE BATHROOM PODS

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of the design aspects and the predicted performance figures was conducted. Design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. The design and construction team answered a review questionnaire as part of the study. For Plot 19 the design team mentioned that achieving 2016 building regulations was met easily. The objective was to achieve Scottish Building Regulations sustainability section 7 Gold standard which, at the prediction stage, was accomplished. During construction there were quality issues encountered on-site; where workmanship was not as expected. Another comment was that due to a supplier error, the timber floors were delivered loose rather than pre-fabricated as requested, which also led to problems with sealing at the intermediate floor level and subsequently greater risk of air infiltration. The dwelling used close-panel wall systems in combination with a volumetric Scottish timber services pod which was praised by the design team. The construction team commented that junctions between the eCore & the K2 timber kit were complex to deliver. Another observation was that during the build one of the panels was delivered on the incorrect side meaning the window opening was not in the correct place, this was not a design fault but more of a manufacturing mistake. Regardless of this, the builders were happy with the manufactured kit and no other problems were encountered. To quote the words the contractor used "Fantastic for a volume, quick build".
The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to observe inconsistencies and possible misinterpretation of the design. In this case there were few anomalies, making little or no impact on the dwelling score.

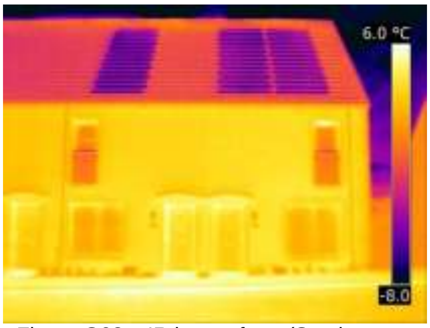


Figure G03 – IR image front (South evation) of plot 19 and 20

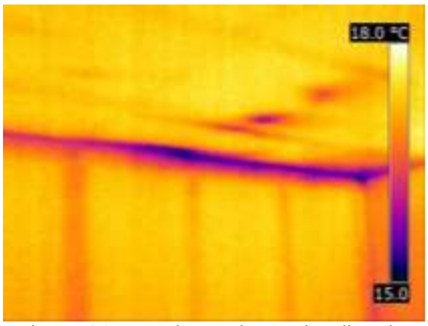


Figure G04 – IR image internal wall and ceiling junction in plot 19 bedroom identifying areas of heat loss in the thermal envelope

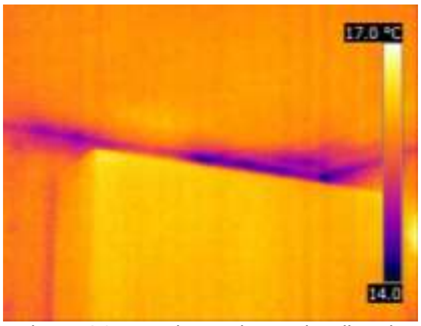


Figure G05 – IR image internal wall and ceiling junction of plot 19 in kitchen above wall cabinets showing heat loss through uncontrolled air infiltration or thermal bridging.

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of performance. These would later explain an increase in energy demand.

Air permeability tests were performed by an external evaluator after construction and before occupation. See page 137 of the technical appendix. After a review, all results comply with the ATTMA and BSRIA guidance. For purposes of the SAP calculation, the design team used $3.0m^3/(h.m^2)$ @ 50Pa to conduct their SAP calculations. The actual value measured after the dwelling was completed was of $3.9m^3/(h.m^2)$ @ 50Pa.

Infrared thermographic tests were performed under the methodology and guidance explained in page 134 of the technical appendix. The front elevation, figure G03, external survey demonstrated consistent temperatures along its envelope, with no areas where increased heat loss appeared. Internally there were some areas where heat losses were identified; the majority around ceiling corners and ceiling joists. Heat appeared to be escaping around the roof hatch (Figure G06) which may have been badly positioned or incorrectly installed. Other images show heat loss at ceiling level (Figures G04 & G05) where thermal bridging or missing insulation was the cause.

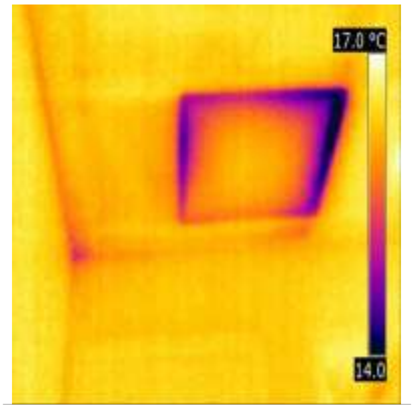


Figure G06 – IR image internal, thermogram shows ventilation heat loss around the perimeter of attic access panel of plot 19 above the landing

- **Services Performance Audit**

The dwelling has been designed with the "Gold" standard of performance as a low energy consumption home. In order to reach Gold standard the dwelling must consume less than 30kWh/m^2 and more than 50% of the energy demand has to be met by heat recovery or low carbon technologies.

This dwelling was equipped with an MVHR system, an air source heat pump, and a Solar PV system fitted as roof tiles. The MVHR was a Nuaire MXMRXBOX95-WH1 as tested in plot 21 of this block. The testing gave 81% efficiency compared with the 91% claimed by the manufacturer.


Figure G07 – ASHP installed at plot 19

A solar system of 32 x 90Wp Solesia Modern PV tiles was installed on the roof. This system gave an installed capacity of 2.88kWp, covering an area of 17m^2. The expected first year electrical generation for this system was 2,472kWh. The recorded metered electricity generated for August 2012 was 280kWh. The total amount of global irradiation on this system over the month of August (17m^2) was 1,989kWh; giving a system efficiency of 14% which is realistic taking into account system and PV module losses.


Figure G08 – Hot water tank system installed at plot 19 for use with ASHP

The dwelling does not have any mains gas installed and relies on an air source heat pump. Installed is a Daikin Altherma ERHQ006BV3 ASHP which has an expected annual generation of 20,000kWh with a net capacity of 6.0kW. A water tank of 200l was installed. The system was commissioned in-line with the certificates provided. The meters recorded during the month of August 280kWh being used by the system to provide water and space heating. An indication of performance will be calculated with annual consumption figures. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Testing at one minute intervals gave an average temperature of 47˚C which is at the threshold. KHA will carry out programmed testing of these temperatures.

The majority of light fittings were equipped with energy efficient light bulbs fulfilling SAP minimum of 75% of low consumption light bulbs.

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 19 with as-built in-situ data (U-values, as-built air permeability) the new as-built SAP scores were obtained. The obtained DER value of 2.74kg/m^2/yr with a score of 98A passes SAP score although the high floor U-value raises compliance issues. The total yearly primary energy consumption was predicted to be -5kWh/m^2/yr compared to the as built figures which show an increase up to 9.53kWh/m^2/yr.

*Tariff structures are chosen to emulate that selected by design team, for comparison to Re-calculated as-built SAP the price per kWh may have changed in accordance with SAP 2009 version 9.90 (March 2010) Table 12. Gas tariff of 3.1p/kWh used in plots 20 and 21. For water heating at plot 19 a 7 hour electricity tariff is used in line with SAP appendix F fraction equation; 12.82p/kWh (70%) high rate and 4.78p/kWh (30%) low rate. For lighting and fans etc standard electricity tariff is used (11.46p/kWh) in plots 20 and 21 and a 7 hour fraction tariff is used in plot 19.


Figure G09 – Expansion tank and ASHP water tank installed at plot 19

- **Energy Consumption Audit**

Plot 19 is occupied by a retired couple; with the dwelling being occupied throughout the day. Space heating and hot water was used regularly and many high power electrical appliances were noted in the dwelling. Readings were taken from the 1st to the 31th of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data. These figures are for the month of August and SAP calculations do not consider un-regulated energy from appliances. A more realistic energy consumption projection will be available on completion of the longer-term BPE study which will be published later in 2014.

Technical Key findings

- High performing dwelling at design stage with no gas usage for heating purposes. Efficient ASHP at early occupation stages.
- Some heat loss experienced in the first floor ceiling/wall junction observed by the thermograms showing lower surface temperature levels.
- As-designed airtightness figures were not achieved after construction which account to the increase in space heating. Equally higher than floor and roof U-Values has impacted on the annual energy use.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 07 – PLOT 20

K2 CLOSED PANEL TIMBER FRAME & e.CORE BATHROOM PODS

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of both construction designs and the predicted performance figures was conducted. Design calculations as-provided were checked for consistency and compared with calculations undertaken by the BPE Study Team. The design team answered the questionnaire with similar commentary to other block 07 plots. The target efficiency and standard in this plot was to achieve 2013 Section 7 "Silver" standard as defined by Scottish Building Regulations. During construction there were quality issues encountered on-site; where workmanship of sub-contractors was not as expected. It was also explained that due to a supplier error, the timber floors were delivered loose rather than pre-fabricated as requested, which also led to problems with sealing at the intermediate floor level and subsequently greater risk of air infiltration. The dwelling used close-panel wall systems in combination with a volumetric Scottish timber services pod which was praised by the design team. The construction team commented that junctions between the eCore & the K2 timber kit were complex to deliver. Another observation was that during the build one of the panels was delivered on the incorrect side meaning the window opening was not in the correct place, this was not a design fault but more of a manufacturing mistake. Regardless of this, the builders were happy with the manufactured kit and no other problems were encountered. To quote the words the contractor used "Fantastic for a volume, quick build".

The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to observe any anomalies and possible misinterpretation of the design. In this case there were few anomalies which make little or no impact on the rating of the dwelling. Only an NHER SAP worksheet was supplied which made comparative SAP assessment and re-calculation difficult. It is important to highlight that the original SAP calculations included secondary heating accounting to 52.7kWh/yr. This has been removed in the re-calculation of SAP as no secondary heating was witnessed at the property during the visits and surveys.

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of performance. These would later explain an increase in energy demand.

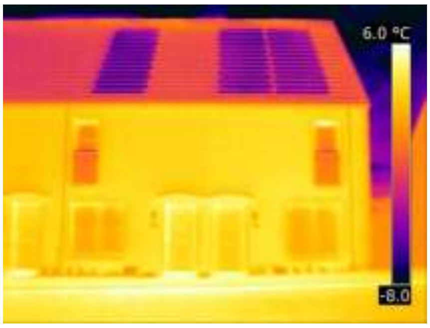


Figure H01 – IR image front (South elevation) of plot 19 and 20

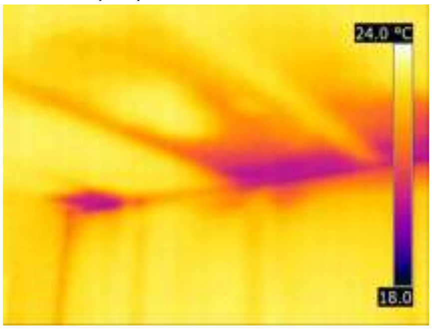


Figure H02 – IR image of ceiling junction in bedroom 2 plot 20, insulation missing on ceiling.

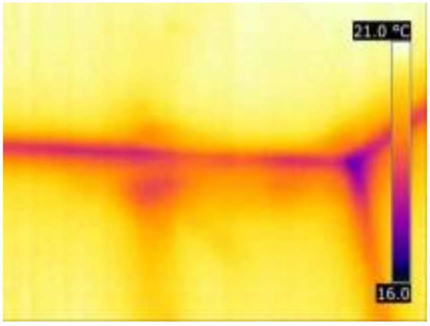


Figure H03 – IR image internal wall and ceiling junction of plot 20 showing heat loss through junction detailing

The air permeability tests were performed by an external evaluator after construction and before occupation.

After a review, all results comply with the ATTMA and BSRIA guidance. For purposes of the SAP calculation, the design team used $3.0m^3/(h.m^2)$ @ 50Pa to conduct their SAP calculations. The actual value measured after the dwelling was completed was of $4.8m^3/(h.m^2)$ @ 50Pa. See page 137 of the technical appendix for more information.

Infrared thermography tests were performed under the methodology and guidance explained in page 134 of the technical appendix. The external front elevation demonstrated consistent temperatures along its envelope, see Figure H01, with no identifiable areas where increased heat loss was appearing. Internally there were some areas where heat loss was identified; the majority of which appeared on the first floor around ceiling corners and around ceiling joists, see Figure H02 & H03. These appear mostly in the front and back rooms where it is suspected that adventitious ventilation into the roof may be the cause – this could be avoided with more careful detailing.

- **Services Performance Audit**

The dwelling has been designed with Section 7 “Silver” standard of performance as a low energy consumption home. In order to reach Silver standard the dwelling must consume less than $40kWh/m^2$ and more than 5% of the water heating energy demand has to be met by heat recovery or low carbon technologies.

- Plot 20 was equipped with an MVHR system, a standard combination boiler and a Solar PV system fitted as roof tiles.

The MVHR is a Nuaire MXMRXBOX95-WH1 system which was tested for efficiency. The field study monitoring in both boost and standard settings gave an efficiency of 81% compared with the manufacturer’s efficiency of 91%. The system was surveyed to make sure it is still performing as the commissioning sheets reported on prior to occupation.

The solar panels installed in the dwelling were the Solesia Modern 16 x 90Wp PV tiles. The system was installed to give a 1.44kWp module with an area of $8.5m^2$. The expected first year electrical generation for this system was 1,240kWh which will be compared to the annual figures obtained once the full first year BPE study is completed. The metered electricity generated for the month of August was 258kWh. The total amount of global irradiation received for the month of August on this system of $8.5m^2$ is of 994kWh. This gives a system efficiency of 15% which is realistic taking into account system and PV module losses.

Figure H04– MVHR unit installed in plot 20, filter inspection

Figure H05– MVHR unit installed in plot 20

Figure H06 – Single array of darker roof tiles [Left] are BIPV panels installed on plot 20

The space heating and hot water is supplied by a gas fired Baxi Duo-Tec combination boiler with a manufacturer specified seasonal efficiency of 91%.

The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Testing at one minute intervals gave an average temperature of 52˚C which is above the threshold. KHA will carry out programmed testing of these temperatures.

The majority of light fittings were equipped with energy efficient light bulbs which fulfils SAP minimum score of 75% of low consumption light bulbs.

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 20 with as-built in-situ data (U-values, as built air permeability) the new as built SAP scores were obtained. The obtained DER value of 9.68kg/m^2/yr with a score of 90B passes the SAP score although both high floor and roof U-value has raised compliance issues. This compared with the predicted values of 6.25kg/m^2/yr with a score of 96A. The total yearly primary energy consumption was predicted to be 24.94kWh/m^2/yr compared to the as-built figures which show an increase up to 40kWh/m^2/yr.

- **Energy Consumption Audit**

Plot 20 was occupied by a young couple with a new born child; the dwelling is occupied throughout the day by one adult and the baby, the second adult occupies the dwelling during the mornings and evenings. Space heating and hot water is used regularly and many high power electrical appliances were noted to be utilised. Electrical and renewable energy readings were taken from the energy display monitors from the 1st to the 31st of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. A more realistic energy consumption projection will be available on completion of the longer-term BPE study which will be published later in 2014.

Figure H07 – Scottish building standards (SBS)sustainability label for plot 20 showing silver active award for adhering to all Section 7 SBS silver aspects

Technical Key findings

- Plot 20 uses a gas combi-boiler as the main source of space and water heating.
- Similar heat loss patches near ceiling/wall junctions as shown in the thermograms
- Differences between the as-designed and as-built space heating energy calculations partly due to the big increase in airtightness and the floor and roof U-values.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 07 – PLOTS 21

K2 CLOSED PANEL TIMBER FRAME & e.CORE BATHROOM PODS

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of both housing designs and the predicted performance figures was conducted. The provided design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. For Plot 21 the design team received similar commentary in relation to the other two similarly constructed dwellings. The target efficiency in this plot was to achieve 2010 section 7 “Bronze” standard set by Scottish Building Regulations which, at the time of designing and obtaining building control approval, were above the current standards. During construction there were quality issues encountered on-site; where sub-contractors workmanship was not as expected. It was also mentioned that due to a supplier error, the timber floors were delivered loose rather than pre-fabricated as requested, which also led to problems with sealing at the intermediate floor level and subsequently greater risk of air infiltration. The dwelling used close-panel wall systems in combination with a volumetric Scottish timber services pod which was praised by the design team. The construction team commented that junctions between the e.Core & the K2 timber kit were complex to deliver. Another observation was that during the build one of the panels was delivered on the incorrect side meaning the window opening was not in the correct place, this was not a design fault but more of a manufacturing mistake. Regardless of this, the builders were happy with the manufactured kit and no other problems were encountered. To quote the words the contractor used "Fantastic for a volume, quick build".

The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to identify any anomalies and possible misinterpretation of the design. In this case a few anomalies were identified which make little or no impact on the score of the dwelling. Unfortunately only the NHER worksheet was supplied which made any SAP assessment and re-calculation difficult. Once again the addition of secondary heating was used in the original SAP calculations adding 165.5 kWh/yr. This was taken out of the re-calculated SAP as the monitoring team did not identify the secondary heating source during their surveys.

Figure J01 – IR image front (South elevation) of plot 21

Figure J02 – IR image back elevation plot 21

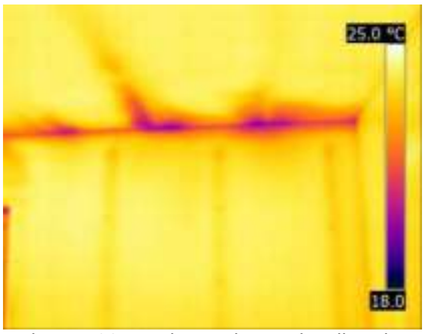


Figure J03 – IR image internal wall and ceiling junction plot 21 Bedroom 2

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of performance which might later explain any increase in energy demand. In-situ U-value evaluation and an internal/external IR thermography survey was conducted.

The air permeability tests were performed by an external evaluator after construction and before occupation. See page 137 of the technical appendix. After a review, all results comply with the ATTMA and BSRIA guidance. For purposes of the SAP calculation, the design team used 5.0 $m^3/(h.m^2)$ @ 50Pa to conduct their SAP calculations. The actual value measured after the dwelling was completed was of 4.71 $m^3/(h.m^2)$ @ 50Pa.

The infrared thermography tests were performed under the methodology and guidance explained in page134 of the technical appendix. External front elevation analysis, see figure J01, showed consistent temperatures along its envelope, with no identifiable areas where increased heat loss appeared. The back elevation also shows consistent surface temperatures as seen in Figure J02. Internally there were some areas where identifiable areas of raised heat loss were experienced. The majority were on the first floor around ceiling corners and around ceiling joists, see Figures J03 & J04. There was also some heat loss apparent around the roof hatch and around the frame, see Figure J05. Joists and wall strapping can be identified in images indicating that thermal bridging may be occurring. The issue around heat loss at roof eaves is repeated throughout the dwelling therefore requiring more detail investigation and solutions at these points.

- **Services Performance Audit**

The system and services performance was monitored in Plot 21. The dwelling has been designed with "Bronze" standard of performance as an energy efficient dwelling under current Scottish Building Regulations. The standard sets a base line for both the Silver and Gold levels. In general terms the dwelling should assimilate to 2010 Building Regulations, particularly under Section 6, following higher level accredited detailing. This dwelling is equipped with the same MVHR system as the other two dwellings, a standard combination boiler, with the exception of low carbon technology.

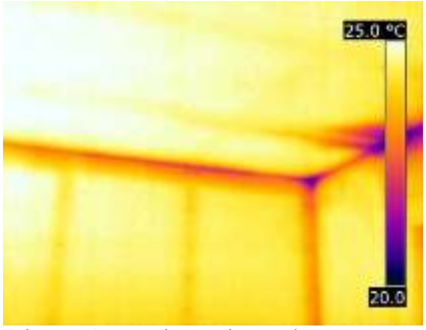


Figure J04 – IR image internal wall/ceiling junction plot 21

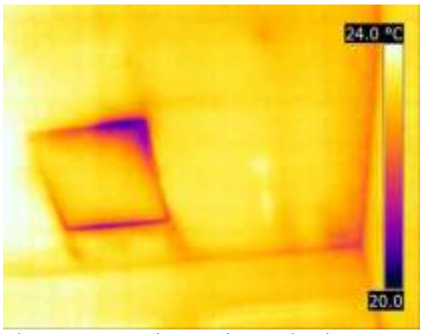


Figure J05 – IR image, internal attic access hatch in landing ceiling plot 21, identifying heat loss at points in hatch perimeter

Figure J06 – Front (South elevation) of plot 21

The MVHR is a Nuaire MXMRXBOX95-WH1 system that has been tested in this property under the standard and boost settings. The field study monitoring in both settings gave an efficiency of 81%. The system was surveyed to make sure it is still performing as the commissioning sheets reported on prior to occupation. This proved to be correct and in working order. The outside penetration of the extract duct was sealed inadequately and some pipe work was badly insulated, as it was fixed with tape that is now de-laminating; uncovering the ducting and creating heat loss and possible condensation (being in an un-heated attic space). The remainder of the pipe & duct work appeared to be properly insulated.

The space heating and hot water is supplied by a gas fired Baxi Duo-Tec combination boiler with a manufacturer's quoted efficiency of 91%.

The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing of one minute intervals gave an average temperature of 46˚C which is under the threshold. KHA will carry out programmed testing of these temperatures.

The majority of light fittings were equipped with energy efficient light bulbs which fulfils SAP minimum score of 75% of low consumption light bulbs.
SAP re-calculation

Having re-evaluated the SAP worksheets and re-calculated plot 21 with as-built in-situ data (U-values, as built air permeability) the new as built SAP scores were obtained. The revised calculation gave a DER value of 18.64kg/m^2/yr with a score of 82B which doesn't meet the SAP standard. In comparison, the predicted values were 16.45kg/m^2/yr and a score of 85B. The total yearly primary energy consumption was predicted to be 80.89kWh/m^2/yr compared to the as built figures which show an increase up to 91.7kWh/m^2/yr. The increased air permeability score and an increase in the as built U-values have impacted on the performance.

- **Energy Consumption Audit**

Plot 21 is occupied by a single mother and young child; the dwelling is occupied throughout most of the day as the adult only works part time. Electrical, gas & MVHR energy readings were taken from the energy display monitors from the 1st to the 31st of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. A more realistic energy consumption projection will be available on completion of the longer-term BPE study which will be published later in 2014.


Figure J07 – Installed MVHR unit in attic, plot 21 showing foil insulate ducting


Figure J08– Installed MVHR unit in attic


Figure J09 – Ceiling insulation, cold roof space in plot 21

Technical Key Findings

- Higher expected consumption of energy for space heating than originally designed. Due to higher air tightness score and the roof/ floor thermal U-values.
- Lack of detailing around ceiling/wall junctions as well as around the roof hatch to the attic. This is shown in the thermograms where heat loss is experienced.
- The ventilation system recorded a lower efficiency than the one stated by the manufacturer – installation and user elements have caused this decrease.

User Satisfaction - Future Affordable K2 Timber closed panel by Springfield Properties Plc.

New technologies: Altherma ASHP, Solesia PV and Nuair MVHR

Overall score for all the homes 8.6/10 = very satisfied
‘As Built’ projected average energy costs per year higher than predicted
Average cost per m^2 at £1,041 = poorer than average construction cost
Construction period at 91 days = poorer than average construction period

Residents of the Future Affordable properties expressed contrasting views about whether there was enough **space** in their homes: one rated it at 10 (2013 BS), one at 8 (2010 BS) and one at 2 (2016 BS), giving an average score of 6.7 which is a relatively low score in relation to the rest of the development and amounts to ‘fairly satisfied’ rating on the scale used by the Scottish Housing Regulator.

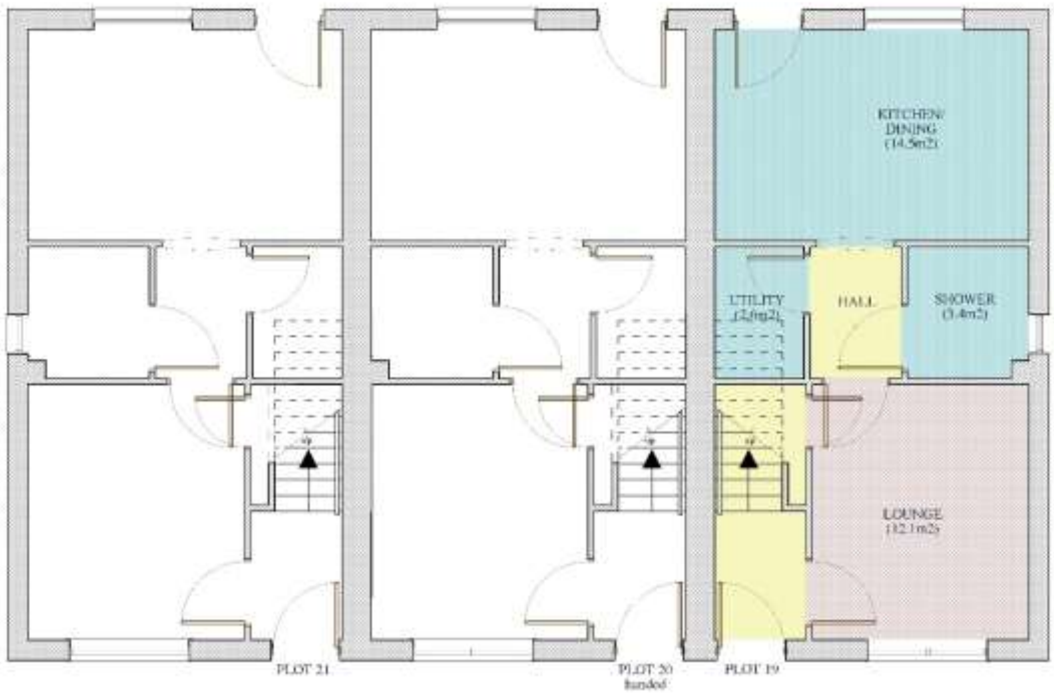


Figure J10 – Ground floor plan – block 07

The house which scored the lowest, namely 2 out of 10, which represents very low level of satisfaction with the amount of space in the home had a distinctly different layout design to the other two dwellings. According to the residents the key problem with this **layout** is that the living room is not only too small but also, the positions of the radiator, sockets and the In-home energy display system, make it tricky to arrange furniture. The living room is so small and furniture arrangement so awkward that the residents receive their guests in their kitchen.

This resulted in poor scores for **living room** meeting residents’ needs at 5.5/10 – one of the lowest average scores across Dunlin Drive: *“The living room is too small. It is meant to be for 4 people but it is just Ok for me and my daughter. If we have visitors they have nowhere to sit down. I can arrange my sofa only one way because the radiator is in the wrong place. It should be under the window - this would free another wall for a couch. The way it is - is impossible to arrange furniture”.*

Figures J11 & J12 - The living room is not only too small but also, the positions of the radiator, sockets, the programmer and the Energy Display System, make it tricky to arrange furniture.

Figure J13 - Bike shed in the back garden in compliance with 2016 Building Standards

Similarly, the **layout** of this home was rated relatively low due to disproportionate space allocated to ground floor storage and bathroom, which was perceived as 'at the expense of' the size of the living room. However, satisfaction with **storage** was rated highly as was having a downstairs shower room.

With reference to **health**, all respondents felt healthier in their new homes and a few mentioned MVHR as a possible reason in addition to just feeling happy to have a warm and secure new home.

All residents of Future Affordable system rated the quality of **instructions** on how to operate central heating programmer and low carbon technologies relatively poorly (5.5/10 – i.e. they were neither satisfied nor dissatisfied) and to improve their ability to be in control of their internal environment they mostly wished to have more training.

Other design features such as **quality of windows and bathroom fittings** scored highly.

With reference to **new technologies** satisfaction levels were mixed, in particular, about PVs generating electricity being defective after the handover although feedback about the air source heat pump was positive due to lower energy costs. With regard to **overall comfort** – the residents scored this system relatively highly.

Area outside afforded some negative feedback relating to water ponding at the back and poorly rated front garden. Provision of bike storage in the garden afforded some comments as did a spy hole in a door which already contained a glass panel – both provided to comply with the 2016 Building Standards.

Features which were particularly LIKED	Features which were particularly DISLIKED:
• Happy with my electricity bills because of insulation and the solar panels. • The kitchen is great because it is spacious and has direct link with the garden • It is really accessible and built to high standards	• The living room is far too small • There is no fence in the front garden and people come too close to living room window – would have liked a waist high fence in the front gardens

Table J01 - Likes and Dislikes

Key Findings from User Feedback

- Otherwise good design compromised by relatively far too small and poorly laid out living room where arranging furniture is a key issue.
- Thermal efficiency of homes in this system generally much appreciated
- It makes such a difference to have plenty of storage

SYSTEM OVERVIEW

BLOCK 08 – PLOTS 22 & 23

ENERGYFLO BREATHING WALL

Figure K01 – Front elevation block 08

www.energyflo.co.uk

PROPERTY	1 x 2 Bedroom House – General Needs 1 x 3 Bedroom House -General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Lomond breathing wall, Energyflo system - Plot 22 – Photovoltaic panels, voltage optimiser, Dynamic wall/CMEV, In-home energy display - Plot 23 – Photovoltaic panels, voltage optimiser, Dynamic wall/CMEV, In-home energy display
MAIN CONTRACTOR	Lomond Homes
SYSTEM PROVIDER	Lomond Homes, Energyflo
ARCHITECT	Lomond Homes

Figure K02 – Wall makeup block 08

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 08 – PLOTS 22 & 23

ENERGYFLO BREATHING WALL

	PLOT 22		PLOT 23	
	Design	As-built	Design	As-built
AIR PERMEABILITY $m^3/(h.m^2)$ @ 50Pa	3.0	2.82	3.0	2.87
SAP RATING	92A	91B	93A	92A
EI (CO_2) RATING	95A	94A	95A	94A
DWELLING EMISSION RATE – DER (Kg/yr)	6.94	8.04	6.27	7.45
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	30.01	35.38	26.2	32.3
ENERGY USE				
Space heating (kWh/year)	2470	2920	2798	3383
Water heating (kWh/year)	2879	2869	2888	2876
Lighting (kWh/year)	359	359	407	407
Pumps and fans (kWh/year)	244	244	255	255
Total (kWh/year)	5952	6391	6348	6921
ENERGY COST				
Space heating (£/year)	£77	£91	£87	£105
Water heating (£/year)	£89	£89	£90	£89
Lighting (£/year)	£41	£41	£47	£47
Pumps and fans (£/year)	£28	£28	£29	£29
Total energy cost (£/year) excluding saving from energy generated	£235	£249	£252	£270

Table K01 – Comparison table between as-designed and as-built (see notes below)

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 08: PLOTS 22 & 23

ENERGYFLO BREATHING WALL

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of both designs and the predicted performance figures provided was conducted. These design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. The design team answered the questionnaire and commented that the breathing wall system was easily incorporated to the design with minor changes to suit and comply with Building Regulations, most referred to changes in internal layouts e.g. stair widths and activity space requirements and the space standards of Housing for Varying Needs (HfVN). The design team are happy with the wall system and have been using it in other developments. Some complications resulted at a critical stage of the project with the original sub-contractor for the installation of the solar PV system, who didn't provide installation support creating difficulties in the project development; this forced the project manager to source a new sub-contractor. The design team were happy with the integration of the voltage optimiser which was easy to install and quoting the design team was "almost a one-size-fits-all, plug-and-play solution"

The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to observe anomalies and possible misinterpretation of the design. In this case there were a few anomalies identified which make little or no impact on the score of the dwelling. Orientation of the dwelling and the openings were identified as incorrect. Some other inconsistencies were identified while reviewing and re-calculating SAP. Plot 22 did not integrate the party wall type and wasn't integrated in the original calculations; the drawings show that it is a cavity wall and should have a 0.2W/m^{2}K U-value, this also applies to plot 23. Orientation of windows was stated wrongly therefore changes had to be made. Plot 23 also registered some inconsistencies. The doors and windows were wrongly orientated; north and south when in fact they are east and west. The whole building orientation was also wrong, it is west as opposed to north as added by the design team. Plot 23 used 0.10W/m^{2}K U-value for the EnergyFlo Breathing wall when it is been stated as being 0.09W/m^{2}K.

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of

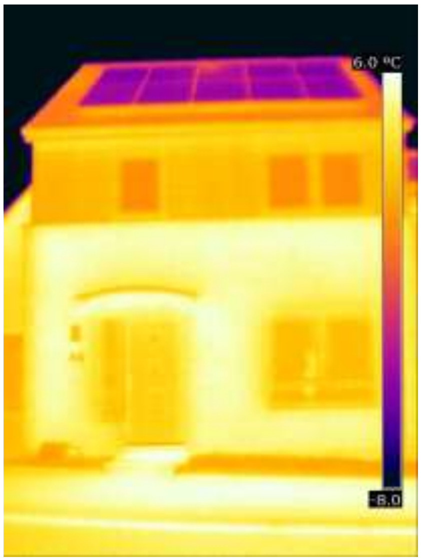


Figure K03 – IR image front (West elevation) of plot 23

Figure K04 – IR image front (West elevation) of plot 22 and 23

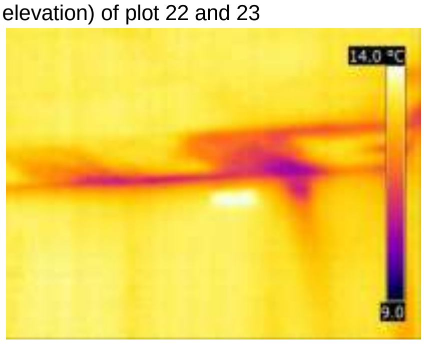


Figure K05 – IR image internal, showing thermal anomaly at wall and ceiling junction witnessed at plot 23 performance which might later explain any increase in energy demand. In-situ U-value evaluation on the breathing wall were performed together with floors and roofs. The IR thermography survey was conducted on Internal surfaces belonging to plot 23 and external images belonging to both plots.

The air permeability tests were performed by an external evaluator after construction and before occupation. See page 137 of the technical appendix. After a review, all results comply with the ATTMA and BSRIA guidance. For purposes of the SAP calculation, the design team used 3.0m^3/(h.m^2) @ 50Pa as a predicted air permeability score. The actual measured value for plot 22 was of 2.8m^3/(h.m^2) @ 50Pa and for plot 23 was 2.9m^3/(h.m^2) @ 50Pa.

The infrared thermography tests were performed under the methodology and guidance explained in page 134 of the technical appendix. External front elevation analysis shows a distinct difference between the timber cladding and the rendered wall which appears with higher surface temperatures, this is likely due partly to the differing emissivity of the materials. The junction between plot 22 and 23 (party wall) also appeared to be showing heat loss as higher temperature gradients have been detected, see Figure K04. Indoor analysis shows some potentially missing insulation in the ceiling near the eves of the roof, see Figure K05. Air is also entering the rooms through the breathable wall vents at around 6˚C which is lower than internal surface temperatures, see Figure K06.

- **Services Performance Audit**

Plot 23 of the two plots was monitored with greater detail with regard to the system performance. The dwelling has been designed with the breathing wall system in strategic locations to admit fresh pre-heated air which has been collected from the walls air infiltration system.

The dwelling is equipped with a Vent Axia Lo-Carbon MVDC-MSH ventilation MEV system. The device proved to be in working order and as initially commissioned. It is located in the attic in an un-heated space. Most duct work is insulated and placed in between the ceiling insulation, see Figure K08. It was observed that a lack of insulation installed on duct 90° bends into the unit has been badly detailed. It was evident that one of the ducts penetrating the roof was poorly finished with holes around it. It was also evident that where the solar tube penetrates the roof it permits light into the attic allowing rain water ingress, see Figure K07. Access to the unit is through an attic hatch which makes maintenance more complicated. Insulation around some ducts was missing at junctions and turns.

The space heating and hot water is supplied by a gas fired Potterton Promax 12 HE Plus boiler with a

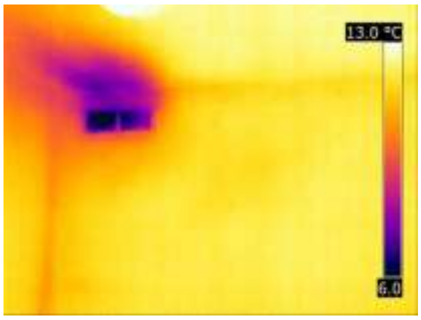


Figure K06 – IR image internal, showing temperature of air passing inward through the breathing wall vent. Thermogram at wall corner and ceiling junction.

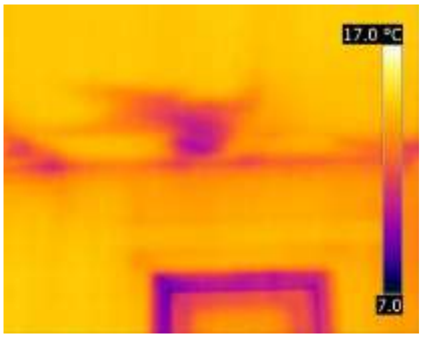


Figure K07 – Missing insulation or thermal bridge in ceiling. Plot 23 bathroom first floor


Figure K08 – Hot water tank installed at plot 23


Figure K09 – Solar tube connection to roof structure in attic

manufacturer's quoted efficiency of 90%. Hot water is stored in a 150l storage tank.

The solar PV system has 10 x 245Wp Sharp NU-E245 (J5) Monocrystalline panels covering 16.4m^2 of roof with a SMA SunnyBoy 1200 inverter capable of generating approximately 1,840kWh/yr without system loses. See Figure K08 of solar panels on roof. The monitored solar global irradiation during the month of August was 117kWh/m^2 generating approximately 1,920kWh. The monitored energy production during that month was of 237kWh giving a system efficiency against global irradiation of 12%. PV Module efficiency is approximately 15% and therefore with losses integrated in the whole system (cabling & inverter) 12% efficiency indicates that the system is performing close to the expected design. The dwelling was fitted with a voltage optimiser which was reviewed proving to be in working order and regulating voltage appropriately.
The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C.Testing of the delivery at one minute intervals gave an average temperature of 58.6˚C at the tap of the kitchen sink, which is above the threshold and could cause scalding to occupiers. KHA will carry out programmed testing of these temperatures. The majority of light fittings were equipped with energy efficient light bulbs which fulfils SAP minimum score of 75% of low consumption light bulbs.

Figure K10 – Extractor system installed in attic space of plot 23.

Figure K11 – Photovoltaic (PV) panels installed on roof of plot 23 facing West

Figure K12 – SMA Sunnyboy inverter for PV panels plot 23

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 23 with as-built in situ data (U-values, as built air permeability) the new as built SAP scores were obtained. The as-built calculation gave a DER value of 7.45 kg/m^2/yr with a score of 92A; compared with the as-designed predicted values the dwelling obtained a DER value of 6.27kg/m^2/yr with a score of 93A. The total yearly primary energy consumption was predicted to be 26.2kWh/m^2/yr compared to the as-built figures which show an increase up to 32.3kWh/m^2/yr.

- **Energy Consumption Audit**

Plot 23 is occupied by two adults with two small children; the dwelling is occupied throughout the day and the adults work at different times. Space heating and hot water is used regularly and a number of high power appliances are used. Electrical, gas & Solar PV energy readings were taken from the energy display monitors from the 1st to the 31st of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures.

Technical Key findings

- Energy for space heating is close to the as-designed predicted figures. This is due to similar as-built U-values & the lower air permeability.
- Workmanship of the air extraction unit (ducting and penetrations through fabric) was poor.
- IR images show heat loss in critical areas

User Satisfaction - Energyflo Breathing Wall by Lomond Homes

New technologies: Voltage Optimisation Unit & Sharp PV Panel and Vent Axia MEV

Overall score: 10/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 £768 = better than average construction cost
Construction Period at 90 days = poorer than average construction period

Residents of this house system were fully satisfied with the **design, layout, and the amount of space** as well as **storage**. It should be noted in particular that the size of the living room at over 17m^2 on plot 23 was praised highly.

Figure K13 – Ground floor plan – block 08

One resident of this system was very dissatisfied with the **security** of locks, awarding security of their home at only 2. It should however be noted that the installed locks are fully compliant with Secured by Design standard.

Residents were satisfied with all aspects of **detailed design** of this system.

With reference to **new technologies** users of this system remarked being told about PV panels and about the In-home energy display but they reported that they were not actually shown how to operate the central heating programmer. It was also stated that instruction at handover was a bit too quick and that instructions for the programmer were a bit difficult to follow even though the residents were encouraged to watch their instructions on the DVD.

The respondents were happy with instructions contained in the **'Resident Handbook'**, remarking that it contains all the basics about the house and has good diagrams. However, one respondent said:

“there is so much information in the handbook, but not enough - I cannot find where to buy a low energy bulb”.

One resident remarked that they regularly watched the In-home energy display system and when they see ‘the red’ that they ‘turn things off’.

With reference to **comfort**, high satisfaction levels were noted relating to temperature, air quality and noise.

Features which were particularly LIKED	Features which were particularly DISLIKED
• Spacious kitchens with dining areas • Sun pipes • Having downstairs shower • Spacious living room (plot 23) • Back gardens	• Living room is too small for the whole family (plot 22) • Not being able to use CH properly • Some of the positions of radiators • The fact that the shower in the downstairs toilet is not powerful enough and temperature fluctuates when WM is on • Front gardens do not really belong to us

Table K01 – Liked & disliked features

Key Findings from User Feedback

- Good layout design with spacious kitchen but again, compromised by living room which is too small (plot 22)
- Spacious living room (plot 23)
- It is like winning a lottery

SYSTEM OVERVIEW

BLOCK 09 – PLOTS 24 & 25

TIMBER CLOSE PANEL iQ SYSTEM

Figure L01 – Front elevation block 09

www.c-c-g.co.uk.

PROPERTY	2 x 3 Bedroom Houses - General Needs
TECHNOLOGY & SYSTEMS SUMMARY	CCG timber closed panel iQ system Plot 24 – Hybrid photovoltaic and hot water panel, MVHR, In-home energy display Plot 25 – MVHR, In-home energy display
MAIN CONTRACTOR	Campbell Construction Group (CCG)
SYSTEM PROVIDER	Campbell Construction Group (CCG)
ARCHITECT	Stephen Good (CCG)

Figure L02 – Wall makeup block 09

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 09 – PLOTS 24 & 25

TIMBER CLOSE PANEL iQ SYSTEM

CCG Building Futures Lab

	PLOT 24		PLOT 25	
	Design	**As-built**	**Design**	**As-built**
AIR PERMEABILITY m³/(h.m²)@50Pa	3.0	2.95	3.0	2.95
SAP RATING	94A	92A	85B	83B
EI (CO_2) RATING	97A	95A	88B	86B
DWELLING EMISSION RATE – DER (Kg/yr)	4.69	7.70	14.95	17.68
TOTAL PRIMARY ENERGY (kWh/m²/yr)	15.94	29.32	70.34	83.65
ENERGY USE				
Space heating (kWh/year)	1914	3176	1881	3140
Water heating (kWh/year)	1374	1368	2543	2534
Lighting (kWh/year)	437	437	437	437
Pumps and fans (kWh/year)	325	325	325	325
Total (kWh/year)	4050	5307	5187	6436
ENERGY COST				
Space heating (£/year)	£59	£98	£58	£97
Water heating (£/year)	£43	£42	£79	£79
Lighting (£/year)	£50	£50	£50	£50
Pumps and fans (£/year)	£37	£37	£37	£37
Total energy cost (£/year) excluding saving from energy generated	£189	£228	£225	£263

Table L01 – Comparison table between as-designed and as-built (see notes below)

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE & EARLY OCCUPATION STUDY

BLOCK 09: PLOTS 24 & 25

TIMBER CLOSE PANEL iQ SYSTEM

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of both designs and the predicted performance figures was conducted. The supplied design calculations were checked for consistency and compared with comparable calculations undertaken by the BPE Study Team.

CCG have developed their volumetric offsite construction system in their fabrication plant after extensive R&D. The dwelling produced for this HIS development implements their iQ close panel system delivered to comply with Kingdom requirements. The design team have stated that there were no changes in the design and build of these two dwellings and adapting the system to the house type was straight-forward; given the flexibility of the system. The building was equipped with a hybrid solar thermal/ PV system which required some technical adaptation given its novelty.

The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to observe anomalies and possible misinterpretation of the design. In this case there were relatively few anomalies identified, which make little or no impact on the re-calculated design stage SAP. Orientation of the dwelling and the openings were identified as incorrect.

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of performance and could later explain any increase in energy demand. In-situ U-value evaluation was conducted on the iQ wall system and on a typical floor and roof. The IR thermography survey was conducted on Internal surfaces belonging to plot 25 and external images belonging to both plots.

The air permeability tests were performed by an external evaluator after construction and before occupation. See page 137 of the technical appendix. After a review, all results comply with the ATTMA and BSRIA guidance. For purposes of the SAP calculation, the design team used 3.0m^3/(h.m^2) @ 50Pa as a predicted air permeability score. The actual measured value for both was of 2.95m^3/(h.m^2) @ 50Pa which is very close to the predicted value and shows consistency in the design and build.

The infrared thermography tests were performed under the methodology and guidance explained in page 134 of

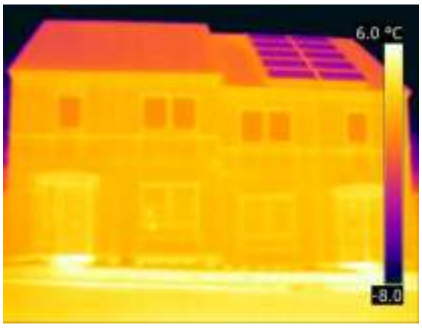


Figure L03 – IR image front (West elevation) of plot 24 and 25

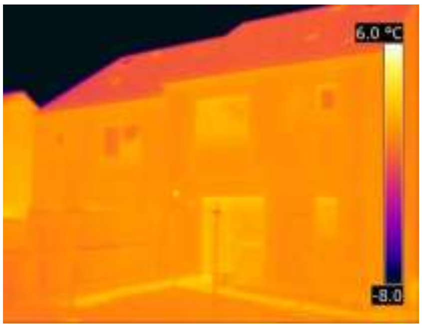


Figure L04 – IR image rear (East elevation) of plot 24 and 25

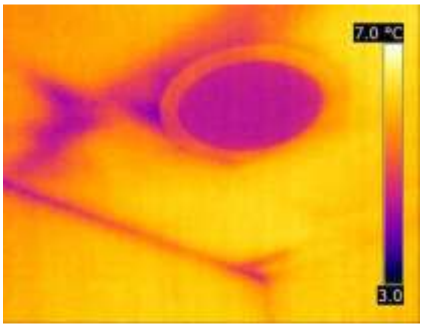


Figure L05 – IR image internal wall, ceiling and sun tube at plot 25, showing thermal irregularities around perimeter of solar light tube the technical appendix. Thermograms of the front and back elevations show even temperature distribution across the surfaces suggesting homogeneity. Distinct vertical and horizontal timber studs can be identified from elevated streaks in surface temperature (Figure L03). Internal images show some heat loss appearing close to roof eaves around the perimeter of the building (Figure L06). This linear thermal anomaly suggests thermal bridging or air leakage has compromised the thermal envelope resulting in the noticeable drops in surface temperatures. Detailing issues have been identified around the solar light tube in the first floor showing heat loss and possibly air leakage near the solar tube rim and frame. Lack of insulation near those areas could also be the culprit. (Figure L05).

Figure L06– IR image internal, showing irregular surface temperature difference at window, and ceiling junction at plot 25


Figure L07– Hybrid PVT panel installed on plot 24, orientated West


Figure L08– Insulated water pipe work from the solar water collector. Ceiling penetration has not been sealed.

- **Services Performance Audit**

Plot 24 was monitored with greater detail in respect of the system performance. The dwelling has been designed with the use of a hybrid solar system that generates electricity and heats water. It is based on a single panel system which benefits from heat absorbed below the PV panels to heat up the passing water.

The dwelling was equipped with Nuaire MRXBOX95-WH1 MVHR system which has been assessed for its efficiency resulting in an 81% efficiency compared with 91% efficiency claimed by the manufacturer. This may be cause by system loses and factors affected by the installation.

The space heating and hot water is supplied by the Solar thermal hybrid system integrated to the PV system in conjunction with a 180l Gledhill water tank fitted with a 3kW immersion heater for back up. Both plots were installed with different boiler systems; plot 24 has an Alpha Intech 26C Combination boiler while plot 25 has a Worcester Junior Greenstar 28i Combination boiler.

The hybrid or PVT system is produced by Newform energy & Solimpeks. The model installed is a Volther Powervolt 10 x 190Wp Monocrystalline panels providing a total of 1.9kW Solar PV system. The thermal aspect of the hybrid panel is a 10 x 460Wp flat plate system with a total output of 4.6kW (Figure L05). During the monitoring period, the Solar PV panels produced 158kWh of energy. The total global irradiation for that roof orientation and angle was calculated to be 1,120kWh during the month of August. This gives a system efficiency of 14%. Solar thermal efficiency was not calculated as no output from the energy logging equipment could be obtained. The system appeared to be installed adequately although there was some ducting and ceiling penetrations that were not finished effectively (Figure L06).

The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing of one minute intervals gave an average temperature of

58˚C which is above the threshold and could cause scalding to occupiers. KHA will carry out programmed testing of these temperatures.

The majority of light fittings were equipped with energy efficient light bulbs which fulfils SAP minimum score of 75% of low consumption light bulbs.

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 24 & 25 with as-built in-situ data (U-values, as built air permeability) the new as built SAP scores were obtained. The new in-situ measurements gave a DER value for plot 24 of 7.7kg/m^2/yr with a score of 92A this is a decrease in fabric performance compared to the as-designed SAP score 4.69kg/m^2/yr and a score of 94A. The new calculation using in-situ measured data provided a DER for plot 25 as 17.68kg/m^2/yr with a SAP score of 83B, again this is a decrease in performance when compared to the predicted value of 14.95kg/m^2/yr and a score of 85B.

The total yearly primary energy consumption for plot 24 was predicted to be 15.94kWh/m^2/yr compared to the as-built figures which show an increase up to 29.32kWh/m^2/yr. For plot 25 the predicted primary energy consumption was 70.34kWh/m^2/yr compared with the re-calculated figure of 83.65kWh/m^2/yr.

- **Energy Consumption Audit**

Plot 24 is occupied by two adults and a teenager; the dwelling is occupied throughout the day and the adults work at different times. Space heating and hot water is used regularly and many high power appliances were noted in use. Electrical, gas & Solar PV energy readings were taken from the energy display monitors from the 1st to the 31st of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. A more realistic energy consumption projection will be available on completion of the longer-term BPE study which will be published later in 2014.

Figure L09 – Hot water tank installed in plot 24

Figure L10 – Heat meter installed above consumer unit in plot 24

Technical Key Findings

- Despite the lower than predicted air permeability scores, the dwelling is expected to consume more energy in space heating as predicted, partly due to high U-values for floors and roof.

- Some heat loss in the ceiling/ wall junction showing lack of detailing or workmanship.

- The hybrid solar system performed as expected with minor deficiencies, the study focused over a small period and at early

User Satisfaction - Timber Closed Panel iQ System by CCG Building Futures Ltd

New technologies: Newform energy & Solimpeks Hybrid photovoltaic and hot water panel and Nuaire MVHR

Overall score 9/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 at £903 = better than average construction cost
Construction period 49 days = better than average construction period

Residents of the CCG Timber Close Panel System rated their homes very highly and both residents loved the **size** of their spacious kitchens. They, however felt that their **living room** was too small: *"The living room is too small- I have a three piece suite and the chair needs to be pushed right into the corner"*

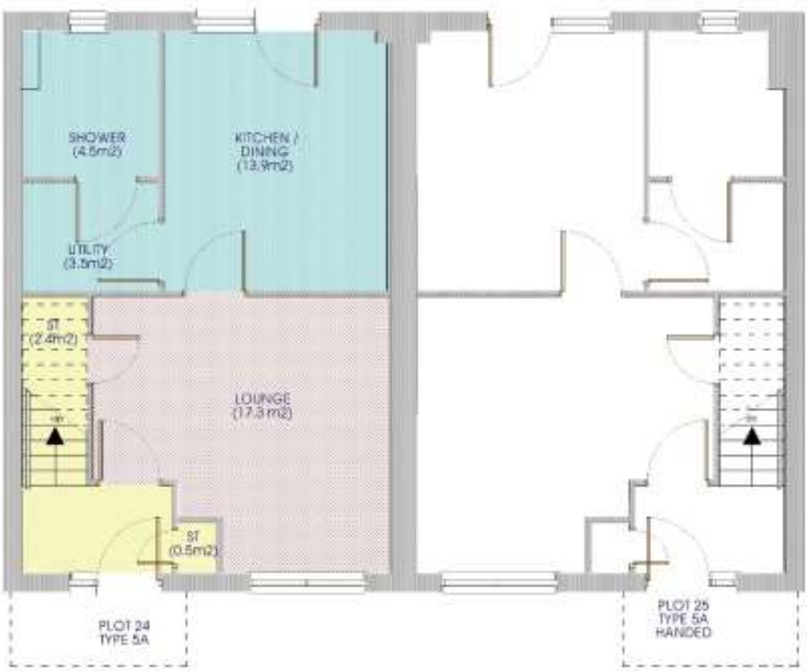


Figure L11 - Ground floor plan – block 09

There was a preference for the children's bedrooms to be of equal size: "*The third bedroom which is 6.8m^2 is a lot smaller - there is a battle of who gets the smaller room".* Residents also stated that there could be more storage.

With reference to **detailed design**, there was preference for more kitchen units. Position of radiators also presented a problem with furniture arranging and this lowered the overall score which nonetheless reflected very high levels of satisfaction.

With reference to new technologies discussion focused on '*not being shown how to operate the programmer'* and a shade of frustration that during the handover the focus was on talking about solar panels, instead of showing exactly how to operate the programmer and the In-home energy display system. One resident advised that they learnt how to operate the heating system themselves and this clearly is a credit to them. Another resident stated that they read the instruction manual and asked a friend to help them, which again reflects positively on them taking initiative. However, overall in the residents' opinion *"the instruction at handover was too quick".*

The residents of this house system advised that nobody told them how to operate the MVHR and that they could not learn enough about it from the Resident Handbook: *"It has good diagrams but not enough information about MVHR"*

Features which were particularly LIKED	**Features which were particularly DISLIKED**
• Large, spacious kitchen with space for a dining table • Having downstairs shower • Having utility room • The different colours on the houses. • The glass canopy	• The living room is too small • There could be more storage • The third bedroom is a lot smaller: kid's bedrooms should be of similar size • Poor water pressure in the shower • Temperature in the shower fluctuates when WM is on • Quality of bathroom fittings is poor • Not enough artificial light in the large kitchen which has just one pendant • Not being able to use CH properly

Table L02 - Liked & disliked features

Key Findings from User Feedback

- Well-proportioned and detailed, flexible house with good layout design and dining kitchen but compromised by the living room which is considered to be too small.
- It has a shower room – not just a WC
- Good that access is on one level

SYSTEM OVERVIEW

BLOCK 10 – PLOTS 32 & 33

INSULATED CONCRETE FORMWORK

Bobin Developments
HOUSE BUILDERS & DEVELOPERS
Beco Wallform
BUILDING FOR THE FUTURE

Figure M01 – Front elevation block 10

www.bobinhomes.co.uk

PROPERTY	1 x 2 Bedroom House - General Needs 1 x 3 Bedroom House - General Needs
TECHNOLOGY & SYSTEMS SUMMARY	Beco Wallform, Insulated Concrete Formwork Plot 32 - In-home energy display Plot 33 - MVHR, In-home energy display
MAIN CONTRACTOR	Bobin Developments
SYSTEM PROVIDER	Beco Wallform
ARCHITECT	Peter Riddoch

Figure M02 – Wall makeup of block 10

DESIGNED & MEASURED SAP OUTPUTS

BLOCK 10 – PLOTS 32 & 33

INSULATED CONCRETE FORMWORK

Bobin Developments
HOUSE BUILDERS & DEVELOPERS
BecoWallform
BUILDING FOR THE FUTURE

	PLOT 32		PLOT 33	
	Design	**As-built**	**Design**	**As-built**
AIR PERMEABILITY $m^3/(h./m^2)$ @ 50Pa	3.0	2.9	3.0	2.18
SAP RATING	83B	82B	85B	84B
EI (CO_2) RATING	87B	85B	88B	87B
DWELLING EMISSION RATE – DER (Kg/yr)	17.04	19.11	14.24	16.11
TOTAL PRIMARY ENERGY ($kWh/m^2/yr$)	80.39	90.60	67.47	76.06
ENERGY USE				
Space heating (kWh/year)	2295	3157	1288	2138
Water heating (kWh/year)	2804	2783	2924	2892
Lighting (kWh/year)	360	360	414	414
Pumps and fans (kWh/year)	175	175	356	356
Total (kWh/year)	5633	6476	4983	5801
ENERGY COST				
Space heating (£/year)	£71	£98	£40	£66
Water heating (£/year)	£87	£86	£91	£90
Lighting (£/year)	£41	£41	£47	£47
Pumps and fans (£/year)	£20	£20	£41	£41
Total energy cost (£/year) excluding saving from energy generated	£219	£245	£219	£244

Table M01 – Comparison of SAP between as-designed and as-built (see notes below)

The table above lists the building performance values as obtained using the Standard Assessment Procedure (SAP). Values for each plot are divided into columns showing SAP results generated at design stage and values generated from SAP using as-built values for component U-values and Air tightness. The design stage SAP results in this table differ marginally from the originally submitted SAP results as obtaining exact figures when re-calculating design predictions was not achieved. Essential to analysing these results is the representative difference between as-designed and as-built.

Note: Additional standing charges to energy costs have been removed. Utility tariffs chosen based on submitted SAP provided by design team. Gas tariff: 3.1p/kWh, standard electricity tariff: 11.46p/kWh. Tariffs may have changed from original submitted SAP to meet updated SAP 2009 version 9.90 (March 2010) Table 12 for comparison to as-built SAP.

POST CONSTRUCTION PERFORMANCE &
EARLY OCCUPATION STUDY

BLOCK 10: PLOTS 32 & 33

INSULATED CONCRETE FORMWORK

For: Kingdom Housing Association
Housing Innovation Showcase 2012

By: Edinburgh Napier University
Scottish Energy centre

- **Design & Construction Audit**

A review of the design and the predicted performance figures was conducted. These design calculations were checked for consistency and compared with calculations undertaken by the BPE Study Team. Both the design and construction team answered the questionnaire sent and a number of conclusions were taken from their response. In the design stage, no changes were highlighted that would impact the buildings thermal behaviour. At the construction stage; the design chosen by Kingdom experienced minor alterations to the overall dimensions to suit the size of the pre-formed blocks. With regard to structural engineering, a cantilevered section and a retaining wall required extra detailing which involved the use of reinforcement bars. According to the system providers their contractors have predominantly been involved with timber frame builds, this project involved a learning curve to get over the characteristics of timber frame/ cavity / block construction to a solid wall design.

The SAP worksheets and their attached Dwelling Emission Rates (DER) & Target Emission rates (TER) were analysed and reviewed to observe anomalies and possible misinterpretation of the design. In this occasion both plots had some inconsistencies to the as-built survey and the drawings supplied. For example in plot 32 had a wrong building orientation; the front door was not added to the calculation; there were three missing windows; no party wall was added; the water tank insulation was stated as being 50mm when 75mm should be used to comply; floor area was wrong, used 41.71m2 when in fact its 42.06m2; ceiling area was added incorrectly and finally dwelling was modelled with an MVHR system when in fact non is installed.
Plot 33 had: two south orientated were windows missing; windows were wrongly orientated; the water tank insulation was 50mm and should be 75mm to comply; floor area was incorrect, was 47.88 when in fact it should be 48.52; ceiling area also had to be changed to tie in with this.
The changes to the building form and technology installed were documented by the monitoring team after the dwelling was handed over to Kingdom. Any alteration observed by the monitoring team which impacts on the buildings thermal performance has been accounted for within the 'as-designed' SAP calculations conducted by the monitoring team.

Figure M03 – Construction stage of plot 32

Figure M04 – Concrete pumped into cavity created by polystyrene blocks which forms the complete structural envelope

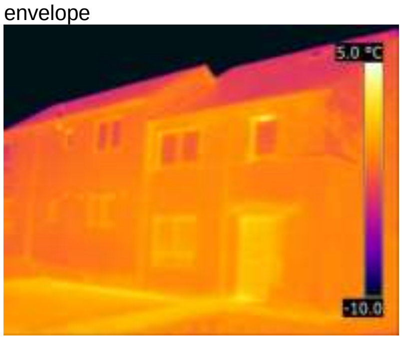


Figure M05 – IR image front (South elevation) of plot 32 and 33

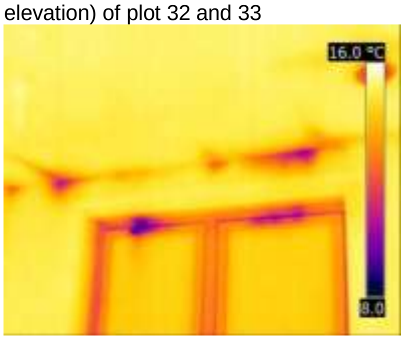


Figure M06 –Internal IR image, heat loss on ceiling/wall junction, captured in bedroom 2 plot 33

- **Fabric Performance Audit**

The buildings fabric was monitored and reviewed in order to compare with the predicted levels of performance. These would later explain an increase in energy demand.

The air permeability tests were performed after construction and before occupation. A full review of this appears in page 137 of the technical appendix. The tests on both plots were performed by an external evaluator. After a review of the results, all results comply with the ATTMA and BSRIA guidance. During the SAP calculation, the design team used 3.0m3/(h./m2)@50Pa as a baseline while the actual measured figure was 2.9m3/(h./m2)@50Pa in plot 32 & 2.18 m3/(h./m2)@50Pa in plot 33, showing an improvement from the predicted. It is worth mentioning that plot 32 has no MVHR system and a low as-built air permeability figure has been obtained which can create air quality problems and doesn't fulfil the recommendations set by SBS that states that <5 m3/(h./m2)@50Pa requires alternative ventilation solutions.


Figure M07 – Ripped foil coated insulation into MVHR unit in plot 33

The infrared thermography tests were performed under the methodology and guidance explained in page 134 of the technical appendix. External images were taken of both plots 32 & 33 while internal images concentrate on plot 33.
Front elevation images show an even distribution of surface temperatures except at the party wall junction where an increase in heat loss was identified. The roof shows lower temperatures where heat has been retained through insulation on the ceiling (cold roof). The back elevation IR study indicates an even distribution of surface temperatures.
Internally it was difficult to identify the many apparent heat loss patches and cold bridging. The double leaf polystyrene wall with a cavity filled concrete core, restricted thermal transmittance by thermal inertia (concrete) and the insulations high thermal resistance. Some heat loss was identified at the ceiling level near the roof eves where insulation is not reaching smaller areas or perhaps indicates some air leakage.


Figure M08 – Insulation and coating applied to ducting of MVHR unit plot 33

- **Services Performance Audit**

The audit on performance was conducted on the technology in plot 33 where an MVHR was installed as the main ventilation system. The tests were conducted after the first month of occupation.


Figure M09 – Ceiling insulation and air handling ducting, plot 33

The MVHR is a Titon HRV1.75 Q Plus system which in the early occupation testing was operational and delivering comfortable temperatures. The efficiency recorded was of 78% in standard mode (boost mode installed post-testing), compared to the manufacturer's quoted efficiency of 91%. During inspection of the device it was noted that the duct work installed to the air handling unit was insulated but workmanship issues were identified. Flexible ducting (pre-insulated) was ripped and tightly fixed which could create apertures in the future and underperformance.

The use of adhesive tape in joints was also spotted, which could de-laminate in the coming years. Foam insulation to fill duct holes was used, which looks unsightly and exaggerated.

Finally, for purposes of system performance, testing of the hot water temperatures delivered to the kitchen and bath rooms was performed. The hot water supply temperature to a bath or wash basin should be limited to a maximum of 48˚C. Our testing to a one minute interval reading of water in the hot water taps and an average temperature of 48˚C was obtained which is at the threshold. KHA will carry out programmed testing of these temperatures.

All light fittings were identified as having low energy light bulbs as described in the SAP and EPC calculations.

- **SAP re-calculation**

Having re-evaluated the SAP worksheets and re-calculated plot 32 & 33 with as-built in situ data (U-values, as built air permeability) the new as built SAP scores were obtained. Plot 33 obtained a new DER value of 16.11kg/m2/yr with a score of 84B passing marginally below its TER of 16.69 kg/m2/yr. Plot 32 didn't meet the aspirational values in this aspect as the influence of higher U-values increased the DER to 19.11kg/m2/yr which is above TER of 18.25kg/m2/yr. The predicted SAP yearly primary energy consumption for plot 33 was 67.47kWh/m2/year and 76.06kWh/m2/year with as-built figures. Plot 32 has a predicted primary energy figure of 80.39kWh/m2/year compared with an as-built figure of 90.6kWh/m2/year which is a 12% increase.

- **Energy Consumption Audit**

The monitored property is occupied by two adults and a 10 year old child; one of the adult's works during the day and the other remains at home, the child is at school during the day. Electrical and gas use is consumed as space heating and appliances are used throughout the day. Electrical and gas readings were taken from the energy display monitors and also physically from the dwellings installed meters. Readings were taken from the 1st to the 31st of August 2012. Re-calculations for the month of August were not possible as they were deemed to be inaccurate as many figures were not given as monthly figures. This created a lot of speculation, especially for lighting, pumps and fans. This energy comparison will be done with yearly data. A more realistic energy consumption projection will be available on completion of the longer-term BPE study which will be published later in 2014.

Figure M10 – MVHR unit installed in attic at plot 33

Technical Key findings

- Floor and roof as-built U-values have increased the space heating calculations hence the higher values.
- Ventilation system is located in the attic where its duct system was observed to be badly insulated with unusual sealing techniques.
- Infra-red thermography shows little indications of heat loss partly due to the double layer of insulation and concrete core

User Satisfaction – Insulated Concrete Formwork (ICF) by Bobin Developments & Beco Wallform

New Technology: Tilton MVHR

Overall score: 9.5/10 = very satisfied
'As Built' projected average energy costs per year higher than predicted
Average cost per m2 at £908 = poorer than average construction cost
Construction period 104 days = poorer than average construction period

One of the residents of the Beco Wallform System was very satisfied with their home and reported that that it is excellent and very **spacious** giving it a 10/10 rating even though they felt that the living room was too small as it was difficult to arrange furniture in it. However, **dining kitchen** was rated very highly – and in residents' view - perfect for family living.

Figure M11 – Ground floor plan – block 10

Figure M12 - Living room is too small for the whole family to sit together and it is not easy to place a TV set.

Another resident (plot 32) was dissatisfied and scored layout 4 out of 10, with key reason for the low score relating to a relatively small **living room**. However, overall, satisfaction with the **layout design** of this system was high, although the smallest bedroom over the stairs was reported to have awkward storage space.

Satisfaction with **utility facilities**, downstairs **shower room** and **back garden** was high.

One of the residents complained that they would have preferred if the downstairs shower was heated by gas rather than electricity as they were worried about the cost of electricity to heat the hot water for showering. They could not understand why the downstairs shower was electric when there was a gas supply in the property.

Figure M13 - Spacious kitchen – large enough for dining table and chairs – a feature much loved by the residents

With reference to **new technologies** one resident showed a level of initiative and reported that: *"I learnt all information about how to operate the heating system ourselves. We were not given detailed instructions during the handover even though there was an interpreter, but there was too much information all at the same time - we were not able to take it all in. After a while I tested the heating system myself - I found that all radiators were needing to be bled, which I did myself and then I adjusted the pressure in the boiler as by then it had dropped".*

The resident read about MVHR on the internet and was happy with this, stating that they were happy to change the filters themselves when needed even though Kingdom opts to carry out filter changes rather than relying on the residents to do this.

Another resident claimed that they have not been advised about the MVHR system even though Kingdom provided instruction, backed by an interpreter. Residents also claimed that they were not advised to keep the windows closed in order to allow for the MVHR system to work efficiently. However, they admitted to having missed the workshop and presentation when these issues were discussed. Generally, MVHR received praise because it *"makes the air cleaner and we feel much more comfortable compared with our previous home. It is never too dry or too humid".*

Figure M14 - Glass canopy - a feature much liked by many residents

One resident commented that the advice in the **Handbook** is very general for a technically skilled user but may be complicated for an average user.

With reference to satisfaction levels with **Area Outside Home,** again there was a problem with drainage outside as rainwater in the back garden was not draining effectively: the puddle is so big that residents need to walk around the house to get to the bin store.

Features which were particularly LIKED	Features which were particularly DISLIKED
• The house is new, well designed, functional and technologically advanced • Excellent heating and ventilation • Relatively low heating costs • Extra toilet is really helpful for a family of 5 • The windows are of the newest technology • The rear garden gives an opportunity to grow own vegetables and flowers • Glass canopy over the front door	• In residents' view the amount of ventilation in the kitchen is not sufficient to quickly filter cooking smells resulting in residents relying on opening windows for ventilation; residents installed a cooker hood themselves to assist with ventilation • Electrically heated shower downstairs – resident would have preferred gas • Downstairs toilet is unsightly because the waste pipe is very visible - it could have been arranged in the same way as the upstairs version • Rainwater pipe is situated in the middle of the front façade of building which is unsightly

Table M01- Liked & disliked features

Key Findings from User Feedback

- Altogether the running costs are very economical
- On balance there is nothing we do not like
- Before we paid £45 per week for heating and we were not comfortable. Now it is £20 and we are very comfortable

TECHNICAL SUMMARY

This report highlights the early occupation performance of the houses in the HIS developed by Kingdom. The HIS has provided 27 new homes within 10 blocks. The first three blocks are flatted accommodation in the form of two ground floor and two first floor flats. Blocks 4 & 5 are homes designed to amenity standards in the form of single storey semi-detached dwellings. The remaining 5 blocks are two storey semi-detached homes. All the blocks have been designed to fit into an integrated wall product provided by the selected system providers and with various technologies for space and water heating. A series of homes were designed and later built to prescribed buildings standards; this is the case of plot 18 in block 6 built to the German Passivhaus energy standard and the three Future Affordable homes in block 7 which were designed to meet Bronze, Silver and Gold standards set by the Scottish Building Standards (SBS) Section 7 Sustainability. The remaining homes were constructed with SBS requirements and the brief provided by Kingdom.

The Building Performance Evaluation (BPE) Study Team performed a detailed test of the building fabric to a representative sample of plots in the HIS development. These were conducted in combination with other test results performed by third party monitoring teams.

Fabric Performance

The fabric performance study was undertaken on each dwelling type using the same standardised methodology. Three main elements of the homes were evaluated; the walls (different in each block type); the roof (at ceiling height) and the floors (on the floor boards). They were evaluated over a 15 day monitoring period using standard heat flux apparatus to determine the as-built thermal transmittance (U-value). These tests were conducted in two phases; one directly after the houses were finished, during spring 2012 and a second phase to validate the phase one results, during the following heating season between the months of December and January 2012/13.

The U-value results obtained were then used to evaluate the building overall performance by entering them in a re-calculation of the Standard Assessment Procedure (SAP). The BPE Study Team have determined that U-value results on their own do not give a clear representation of overall building performance, therefore utilising them in an energy consumption tool like SAP was a more representative method of demonstrating and comparing predicted against as-built performance. Anonymized U-value results are presented in graphs 23 – 25 in pages 164, 165 and table 6 in page 166 of this Report from which individual system providers can abstract performance figures against the range of reported values, as is normal practice for such studies.

In general, measured U-values were identified as being above the initially predicted levels. From the frequency graphs produced in pages 164 to 165 of this technical appendix, it is clear that the design calculated values for walls, roof and floors achieved the benchmarks set by Scottish Building Standards but many of the measured results fell below this threshold.

The measured as-built results were rarely close to the predicted values creating concerns about the methodologies adopted both in testing and the standardised prediction tools. In some buildings the results that let their as-built performance down were the floors of dwellings which achieved good results for both walls and roofs. The ISO standard method applied was used to re-evaluate the construction elements tested in order to check the validity and repeatability of the reported results, this provided good correlation.

Reasons for these discrepancies are now achieving greater prominence following the publication of work by BBA (2012) on Air movement & thermal performance, amongst others, on the performance gap between predicted and measured U-values attributed to the actual amount of structural timber in walls, roof and floor and influence of interstitial and adventitious ventilation. There are other factors that are influential, for example construction faults within the component, climatic conditions and the dynamic influence of indoor and outdoor temperatures making in-situ testing representative.

Air Tightness

Air tightness testing of the completed dwellings, conducted by third party testing teams, was evaluated by the BPE Study Team for their consistency against industry standards and regulations. Some minor and repeating inconsistencies were noted in some of the tests conducted, that does not necessarily invalidate the tests, but affects the accuracy of the results.

Pressurisation testing of the completed homes showed that air tightness was in many cases close-to below the predicted and designed values. In some cases levels were above predicted which impacted on the SAP re-calculation conducted as part of the outputs of this Report.

All measurements were below the current recommended default levels of air tightness set at 10.0 m3/(h.m2)@50Pa and also below the benchmark figure of 7.0 m3/(h.m2)@50Pa set by SBS which can be obtained by designing and building to the accredited details set by of the buildings standards in Scotland. Equally, the results fell under the ‘air quality barrier’ of 5 m3/(h.m2)@50Pa where the introduction of mechanical ventilation is recommended. The predicted levels of air tightness reached values approaching 3.0 m3/(h.m2)@50Pa with some dwellings also aspiring to values between 2.5 and 2.0 m3/(h.m2)@50Pa. In reality once these dwellings were tested post-completion, the majority achieved 2.5 m3/(h.m2)@50Pa.

The results, although generally higher than the targets set by each dwelling system provider, affected the SAP calculated heat loss due to air-leakage by <10% and had a minimal impact on the as-built performance of the dwellings.

Infrared Thermography

The results of this survey are presented in page 141 of this technical appendix. A repeating trend of heat loss in external images was the wall base course around exposed walls; these showed distinct areas of heat loss in the majority of dwellings regardless of their floor insulation detailing and construction type. Another representative area where external heat loss was observed was at the junction between sloping roof of the entrance lobbies in the flatted accommodation (Blocks 1, 2 & 3). Heat loss was also identified at the top ridge of the roof in connection with the wall of the flats.

Internally, results showed a very varied picture. Most of the issues were observed at the ceiling levels close to the eaves of the roof and also in ground floor walls; where skirting heat loss results from thermal bridging or more-likely air infiltration.

In ceilings large patches of heat-loss were observed in some dwellings; perhaps driven by the lack of insulation close to eaves or simply the incorrect positioning of insulation in the structure. The BPE team recognise that in some points within the roof, typically at eaves level, ventilation is supplied into the roof void resulting in air infiltration causing heat loss in these areas. However, some images were not just at the ceiling/wall junctions; extending beyond that into the room itself between ceiling joists. Other issues in ceilings were identified as service ducts carrying pipe work or other which was poorly sealed or insulated creating a cold area within the room. Some thermal bridging was also identified as repeating timber elements for structural reasons or joist location within the building dimensions.

In ground floors, heat loss was observed near kitchen service points, behind cabinets and some junctions between walls where thermal bridging and ventilation were the likely culprits.
After conducting some of the tests and talking to the system providers, some contractors and designers have observed these issues and have taken action where possible. This includes a re-design of panel connections, avoiding thermal bridging, and also a re-think in the way in which contractors handle insulation installation.

Heating & Hot Water Services

Dwellings were fitted with different low-carbon technologies that supplied space heating and water heating in various ways. Some dwellings, particularly in those that were not fitted with low carbon technologies, had conventional gas-boilers installed which were initially specified as high performing to suit the needs of the residents. These installations were not tested for combustion efficiency. The dwellings with low carbon technology were tested per type and product in order to minimise repetition.

Monitored technology was evaluated at an early occupation period and therefore the BPE Study Team considered that results are similar to the predicted both by the system providers and the manufacturers. This was shown by the small decrease in system efficiencies. Longer term monitoring after longer occupation will determine whether technology performance is in line with the predicted. The technology was tested in two ways, firstly on the accuracy of its specification, in line with the SAP calculation, e.g. tank sizes, tank and pipe insulation, and adequate capacity of system. Secondly it looked at the system performance and efficiency in line with the manufacturer's expectations. This was done with the aid of additional metering equipment and energy monitoring gathering data on energy production and heated water.

During the monitoring period, a decrease in efficiency from the systems rarely declined below 10% in comparison with the manufacturers data. This is due to the small monitoring periods and also the time of the year in which the tests were conducted. BPE Study Team considers that a longer period of system use, after 1 or 2 years of occupation, would further indicate if any efficiency decline or performance variations are obtained. Sub-metering of the systems and other appliances segregating energy use would identify system problems more accurately.

As reported in each case study, field testing of hot water temperature levels were recorded over 1 minute intervals. There were some properties that recorded between a 10- 15% increase above the threshold of 48°C causing possible scalding. These properties should be monitored closely and all water temperature regulators checked for efficiency and delivery of acceptable temperatures of water. Although most homes are fitted with mixer water taps, high water temperatures can still be a threat. A regular water temperature check-up should be programmed, as well as making sure boiler hot water delivery programing is as standard. It should be noted that as standard Kingdom carry out a bi-annual check on water temperatures.

Early occupation energy consumption

Energy consumption during this initially short period of monitoring is explained in page 138 to 140. Because of the nature of the project and the periods in which the dwellings were occupied much of the available data on energy consumption could only be collated during late summer of 2012. Such a period is not representative of the building occupancy and for this reason, the BPE Study Team require a full annual data monitoring to make a more concise and accurate comparison of performance, where a full summer and winter period is experienced. This data has been recorded during this first year of occupation giving the BPE Study Team the opportunity to gather, analyse and report on the results later in 2014.

Figure 9 - Play area under construction

Acoustic performance – Pre Occupation

The measurements were carried out on the following dates;

First site visit – 10th March 2012
Second site visit – 26th April 2012
Third site visit – 27th April 2012

The full airborne sound insulation results of the separating wall constructions are given in pages 167 to 176. The single figure sound insulation ratings calculated in accordance with BS EN ISO 717: 1997 are shown in Table 4 (below) relative to the requirements of Section 5 of the Technical Handbook to the Building (Scotland) Regulations 2004.

The results given in Table 04 & 05 (below) indicate that the sound insulation of the tested wall constructions have complied with the requirements laid down in the aforementioned regulations.

Block	Source Room	Volume (m^3)	Receiving Room	Volume (m^3)
1 - Powerwall	Plot 4 Bedroom2	35	Plot 1 Bedroom 2	35
	Plot 3 Bedroom 2	35	Plot 2 Bedroom 2	35
2 - Campion	Plot 5 Bedroom 2	35	Plot 8 Bedroom 2	35
	Plot 7 Bedroom 2	35	Plot 6 Bedroom 2	35
3 - Stewart Milne	Plot 12 Bedroom 2	35	Plot 9 Bedroom 2	35
	Plot 11 Bedroom 2	35	Plot 10 Bedroom 2	35
4 - Campion	Plot 14 Front bedroom	40	Plot 13 Front Bedroom	40
	Plot 14 Rear Bedroom	32	Plot 13 Rear Bedroom	32
5 - Cube	Plot 16 Front Bedroom	40	Plot 15 Front Bedroom	40
	Plot 16 Rear Bedroom	32	Plot 15 Rear bedroom	32
6 - Campion	Plot 18 Living room	65	Plot 17 Living room	65
	Plot 18 Rear Bedroom	32	Plot 17 Rear Bedroom	32
7 - Springfield	Plot 20 Kitchen	45	Plot 21 Kitchen	45
	Plot 20 Kitchen	45	Plot 19 Kitchen	45
8 - Lomond	Plot 23 Kitchen	39	Plot 22 Kitchen	61
	Plot 23 Rear Bed	27	Plot 22 Bedroom	61
9 - CCG	Plot 25, Living room	45	Plot 24, Living room	45
	Plot 25, Bedroom 2	33	Plot 24, Bedroom 2	33
10 - Bobin	Plot 33 Front Bedroom	27	Plot 32 Front Bedroom	27
	Plot 33 Living room	40	Plot 32 Kitchen	30

Table 4 - Sound Insulation tests (walls)

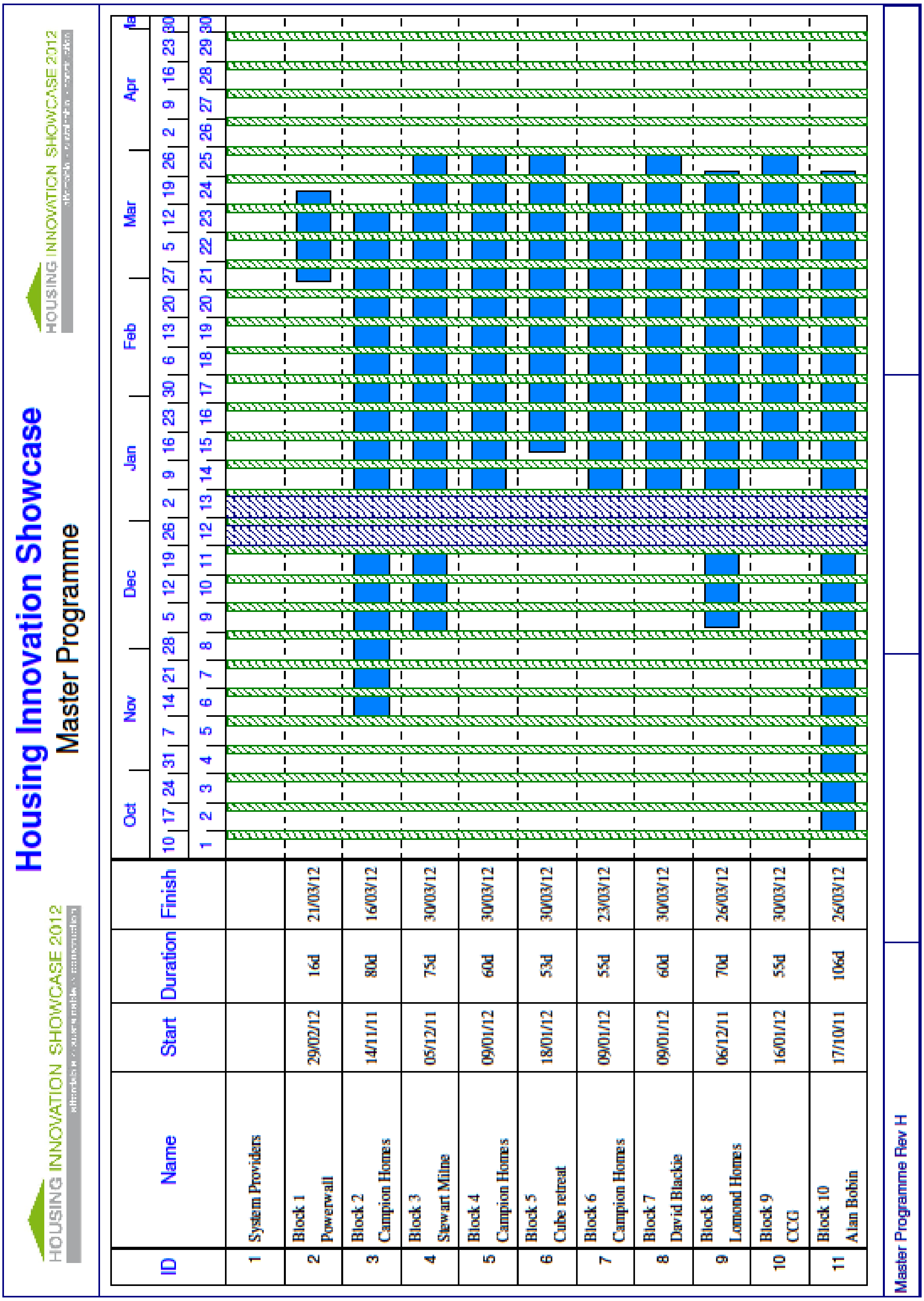
Block	**Source Room**	**Receiving Room**	**Airborne $D_{nT,w}$ (Min 52 dB)**	**Impact $L'_{nT,w}$ (Max 61 dB)**	**Pass/Fail**
1 - Powerwall	Plot 4 Bedroom 2	Plot 3 Bedroom 2	65	53	**Pass**
	Plot 4 Living room	Plot 3 Living room	62	51	**Pass**
2 - Campion	Plot 5 Bedroom 2	Plot 6 Bedroom 2	60	55	**Pass**
	Plot 8 Bedroom 2	Plot 7 Bedroom 2	57	54	**Pass**
3 - Stewart Milne	Plot 12 Bedroom 2	Plot 11 Bedroom 2	63	52	**Pass**
	Plot 11 Living room	Plot 10 Living room	59	53	**Pass**

Table 5 - Sound Insulation tests (floors)

APPENDICES

Site Plan – Phase 1 - Housing Innovation Showcase

HIS Master Programme



ID	Name	Start	Duration	Finish
1	System Providers			
2	Block 1 Powerwall	29/02/12	16d	21/03/12
3	Block 2 Campion Homes	14/11/11	80d	16/03/12
4	Block 3 Stewart Milne	05/12/11	75d	30/03/12
5	Block 4 Campion Homes	09/01/12	60d	30/03/12
6	Block 5 Cube retreat	18/01/12	53d	30/03/12
7	Block 6 Campion Homes	09/01/12	55d	23/03/12
8	Block 7 David Blackie	09/01/12	60d	30/03/12
9	Block 8 Lomond Homes	06/12/11	70d	26/03/12
10	Block 9 CCG	16/01/12	55d	30/03/12
11	Block 10 Alan Bobin	17/10/11	106d	26/03/12

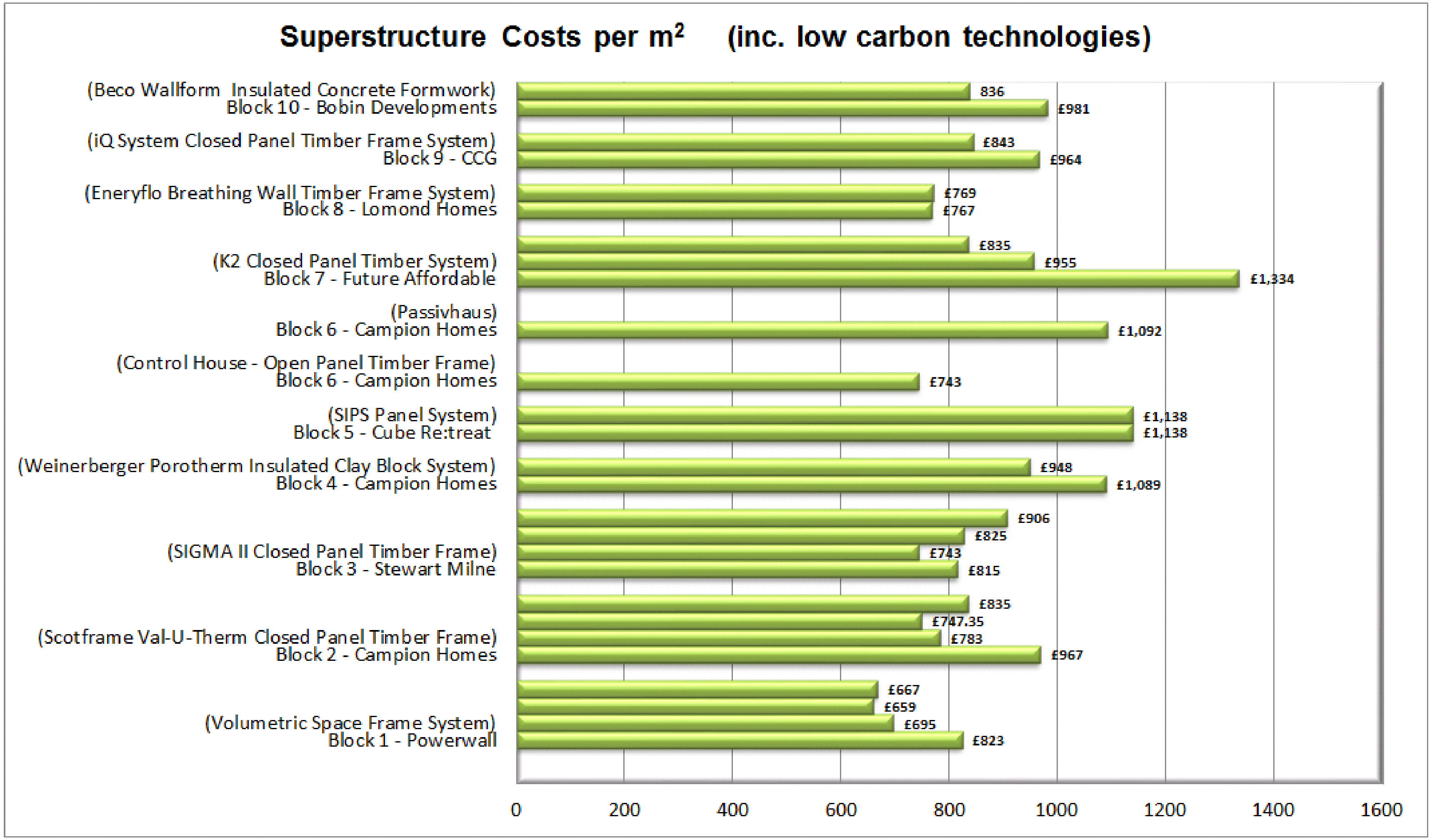
Final Account Cost per System Type

Contractor & Construction Type	Plot No	Property Type	Floor Area	Superstructure Costs (inc. low carbon technologies)	Superstructure Costs per m2 (inc. LCT)	Construction Period (no. days)
Blo Chart Area wall	Plot 1	2 Bed Ground Floor Flat	77.62	£63,875	£822.92	91
(Volumetric Space Frame System)	Plot 2	2 Bed First Floor Flat	86.35	£60,017	£695.04	91
	Plot 3	2 Bed First Floor Flat	86.35	£56,917	£659.14	91
	Plot 4	2 Bed Ground Floor Flat	77.62	£51,775	£667.03	91
Block 2 - Campion Homes	Plot 5	2 Bed Ground Floor Flat	78.14	£75,542	£966.75	106
(Scotframe Val-U-Therm Closed Panel Timber Frame)	Plot 6	2 Bed First Floor Flat	87.31	£68,333	£782.65	106
	Plot 7	2 Bed First Floor Flat	87.31	£65,251	£747.35	106
	Plot 8	2 Bed Ground Floor Flat	78.14	£65,251	£835.05	106
Block 3 - Stewart Milne	Plot 9	2 Bed Ground Floor Flat	77.90	£63,513	£815.31	126
(SIGMA II Closed Panel Timber Frame)	Plot 10	2 Bed First Floor Flat	85.50	£63,513	£742.84	126
	Plot 11	2 Bed First Floor Flat	85.50	£70,613	£825.88	126
	Plot 12	2 Bed Ground Floor Flat	77.90	£70,613	£906.46	126
Block 4 - Campion Homes	Plot 13	2 Bed Single Storey Cottage	78.80	£85,789	£1,088.69	71
(Weinerberger Porotherm Insulated Clay Block System)	Plot 14	2 Bed Single Storey Cottage	78.80	£74,740	£948.48	71
Block 5 - Cube Re:treat	Plot 15	2 Bed Single Storey Cottage	78.67	£89,547	£1,138.26	61
(SIPS Panel System)	Plot 16	2 Bed Single Storey Cottage	78.67	£89,547	£1,138.26	61
Block 6 - Campion Homes	Plot 17	3 Bed 2 Storey House	96.92	£72,045	£743.35	65
(Control House - Open Panel Timber Frame)						
Block 6 - Campion Homes	Plot 18	3 Bed 2 Storey House	93.96	£102,568	£1,091.61	65
(Passivhaus)						
Block 7 - Future Affordable	Plot 19	2 Bed 2 Storey House - 2016 Regs	83.20	£111,030	£1,334.50	91
(K2 Closed Panel Timber System)	Plot 20	2 Bed 2 Storey House - 2013 Regs	83.20	£79,492	£955.43	91
	Plot 21	2 Bed 2 Storey House - 2010 Regs	83.20	£69,476	£835.05	91
Block 8 - Lomond Homes	Plot 22	2 Bed 2 Storey House	83.42	£63,983	£767.00	90
(Enerflo Breathing Wall Timber Frame System)	Plot 23	3 Bed 2 Storey House	95.76	£73,653	£769.14	90
Block 9 - CCG	Plot 24	3 Bed 2 Storey House	95.80	£92,375	£964.25	49
(iQ System Closed Panel Timber Frame System)	Plot 25	3 Bed 2 Storey House	95.80	£80,766	£843.07	49
Block 10 - Bobin Developments	Plot 32	2 Bed 2 Storey House	83.42	£81,805	£980.64	104
(Beco Wallform Insulated Concrete Formwork)	Plot 33	3 Bed 2 Storey House	95.76	£80,025	£835.68	104

Note: The costs detailed within the table above are based on Final Account Information -

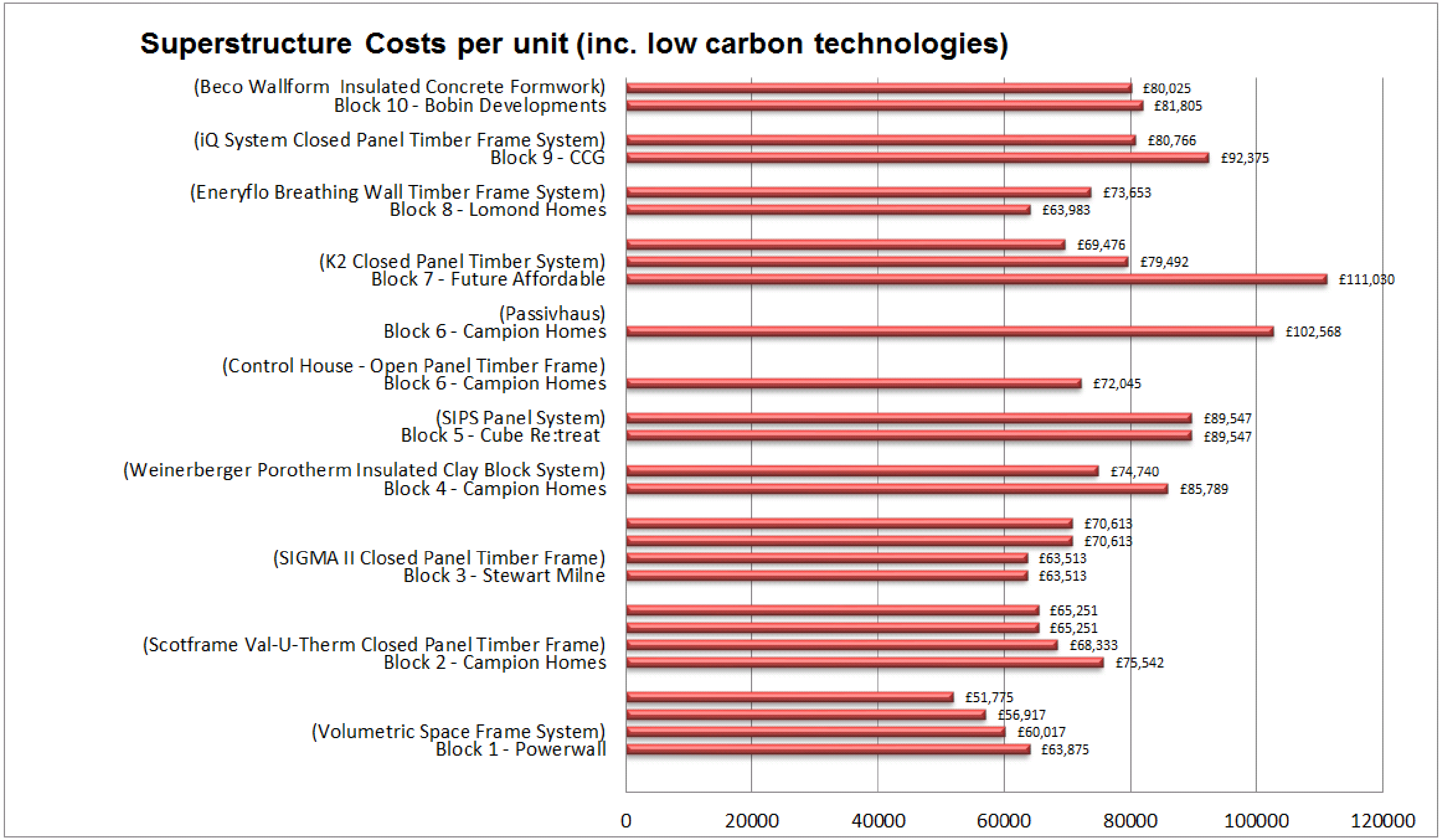
Table 5 - Final Account Costs per System Type

Superstructure costs per m2



Graph 18 – Superstructure cost per m2

Superstructure Costs per unit



Graph 19 – Superstructure Cost per unit

Methodology - Approach to monitoring & testing

Disclaimer: While every care has been taken to ensure that the information contained within this technical document is correct, the authors give no warranty and make no representation as to its accuracy and accept no liability for any errors or omissions.

Design & construction audit, drawings & SAP calculation review

In order to conduct the study it was essential to follow certain prescribed methodologies which would guide and set a standard to follow. The study follows a generic methodology proposed by CIBSE TM22 (2006) which was used in the recent Technology Strategy Board POE funding stream. Their document “Guidance to conducting Building Performance Evaluations” was used as a guide to conduct most of the work.
The study reviewed the design drawings and specifications, examining the dwellings for construction quality, and observing and taking note of any changes during design stage or construction process. These apparent differences were investigated with the aid of a questionnaire sent to both the design team members of each of the house types and the fabrication or on site construction professionals. Many conclusions on the impact of changes were abstracted from the responses of such questionnaire.
Also important was the review of the SAP calculations to ensure these accurately represented the design of the dwelling and to make sure the design aspect of each dwelling have been input correctly and are true to the dimensions, fabric performance and services. This should establish the ‘as designed’ performance of the dwelling.

Fabric performance

The monitoring of the performance of the envelope was conducted in different stages. Some elements were performed by a third party evaluator and the BPE Study Team collated the results. The rest of the testing was performed pre-occupation of the dwellings during the months of April and May 2012. The results thus obtained were used in the re-evaluation and calculation of SAP values for selected dwellings within each block in order to obtain as-built early occupation performance.

The following sub headings explain the methodology adopted on each evaluation.

Air Permeability Testing

In terms of the air permeability testing, a third party testing team conducted pressurisation testing which is now a standard requirement under the Scottish Building regulations since October 2011. Dwellings require testing with a maximum allowable air permeability score of 7m3/h./m2@ 50 Pa. The BPE Study Team conducted a review of the air leakage tests conducted to all dwelling types and identified compliance under ATTMA 2007 and BSRIA guidelines.

Testing should comply with the ATTMA standard (ATTMA 2007) but in all cases the basic test should be extended to include both pressurisation and depressurisation. Leakage detection, using smoke should ideally be performed at the same time but in this case the client did not request such test. Results of the review are displayed in the form of a compliance table which points out elements that should be presented for both pressurisation and depressurisation and the final, reported air permeability shall be the mean of these two values.

Infra-red thermography

Infra-red thermography (IRT) is used as a diagnostic tool. It provides an infra-red image which gives an indication of surface temperatures and can enable thermal anomalies in construction to be identified. Such anomalies may be the result of gaps in insulation layers, different insulation characteristics, air movement within the structure or, more usually, a combination of all three.
IRT was used to locate areas of significant temperature differences and inhomogeneous construction elements. The resulting images show surface temperatures which identify possible hot and cold paths. In images taken from the inside of a building identifying thermal bridging and heat escaping are represented by lower surface temperatures, indicated by a blue or purple colour which may be the

result of insulation detailing or air infiltration/exfiltration at specific areas in the envelope. In external infrared thermography, the reverse is shown; higher surface temperatures represented by colours ranging from red, through orange to yellow indicate higher thermal losses than surrounding detail across the envelope.
Specific requirements required to undertake such a study include:

- Internal to external temperature difference of approximately 10°C or more for at least four hours immediately preceding the survey.
- Minimal solar exposure to the facade is limited for at least four hours immediately preceding the survey for low thermal mass structures and longer for high mass structures. Study undertaken after midnight.
- Building envelope surfaces remain dry before and throughout the survey
- Wind speeds are less than 2 m/s (light to moderate breeze).

Results are presented in accordance to BS EN 13187: 1999 which include thermograms, alongside conventional photographic records of the same views and related to the external facades and internal walls of the building. Areas of specific concern have been commented on beside the relevant image.

In-situ measurement of U-values

In-situ measurement of U-values is provided by means of heat flux sensors that provide a direct measure of flux from a surface into and through a construction element. They can be used to determine the U-value of individual construction materials (which is often not deemed necessary as manufacturers have been required to undertake such testing and provide data on the material U-values in order to market their product) or, more usefully in the BPE projects, the U-value of surfaces of whole elements of the building envelope comprising several layers, e.g. block-work, insulation, render, or a sandwich SIP panel. Its value lies in providing data that enables investigative examination of a range of heat loss mechanisms. Although such measures can be valuable on their own, particularly when used in occupied dwellings, they can be particularly enlightening if undertaken in conjunction with whole house heat loss measurement and extended energy monitoring trials.

Heat flux sensors were located on surfaces representative of the wall, floor and ceiling fabric evaluated, making reference to the results of infra-red thermography to site sensors in suitable areas, i.e. avoiding isolated anomalies in fabric performance such as cold bridges.

Heat flux sensors and temperature sensors were installed in each element of the dwelling being studied on northerly orientated elements in areas with little exposure to wind and rain. Sensors were left in place for at least two weeks with measurements taken at one-minute intervals, logged via a data acquisition system. Tests were carried out in accordance with ISO 9869.

Services performance testing & evaluation

The evaluation of the technology and systems implemented into the different dwellings was performed after they were fully operational and during early occupation. The BPE Study Team was cautious that the occupiers of the dwellings would be un-familiar with the technology and that adaptation and use of the equipment would take place on a prolonged manner and with adequate guidance from the Housing Association.

The BPE Study Team acknowledge the fact that the performance of the technology installed in the homes doesn't only depend on the manufacturer's product efficiency in combination with its design but will also depend on the operation and maintenance of such systems. For this reason it was important that the evaluation of the technology implemented in the dwellings was conducted at least one month post-occupation to give the home owner time to adapt and establish that pre-handover commissioning was operational. The team highlights the fact that actual technology performance will be more evident after a whole yearly operation and use, and this first phase of testing is only an indication of early occupation and first use efficiency.
The testing took place between the months of August and September 2012. The Low Carbon Technology (renewables) installed in each property varied in most cases, however there were repeated makes and models installed in the development. For example, solar PV panel makes and models were installed in 3 different properties varying only the peak output and location. The same

case applies to MVHR units and ASHP. In order to avoid repeated information and to lower the work load, evaluation of the technology was performed on a single make and model.

The services and technology testing was performed on the following:

- Review of performance of 12 different micro-generation technologies including; Solar PV, Solar Thermal, air source heat pumps (ASHP), micro combined heat and power (mCHP), and hybrid electric and water heating panels.
- Review of performance of 7 different makes and models of mechanical ventilation with heat recovery systems (MVHR)
- Review of energy efficient lighting and hot water

The results of the performance and efficiency testing of the above technology are representative of that moment in time in which the testing was conducted and therefore set out results during that period.

There were three areas which this early operation of technology would focus on. The first would look at the energy saved or generated against expected benchmarking performance expectations; the second, which is particular to MVHR and ASHP is the energy consumed and the third is the quality of installation, its maintenance and its operation conditions.

The first two were obtained by the installation of real time display and energy monitoring devices in the dwellings which monitor the consumption of electricity and gas and also record generated or consumed energy (electric or heat) from any low carbon technology.

SAP energy consumption monitoring

Standard Assessment Procedure (SAP)

All dwellings during design stage, for building control purposes, are evaluated using the Standard Assessment Procedure (SAP) in order to obtain predicted energy consumption (kWh/m^2/year) and environmental impact assessment which focuses on the expected CO_2 emissions the home will emit per year.   These were performed by the design teams involved in each of the blocks of the HIS and were submitted to the BPE survey team for evaluation. Any issues surrounding these calculations and predicted levels of performance were then highlighted in the case studies of each house type.

The adopted standard for energy performance evaluation of dwellings the Standard Assessment Procedure (SAP) is the methodology used by the Department of Energy & Climate Change (DECC) to assess and compare the energy and environmental performance of dwellings. Its purpose is to provide accurate and reliable assessments of dwelling energy performances and was thus used with the field data collected above to re-calculate an as-built SAP performance of the dwelling. This gave an early occupation performance indication but the BPE Study Team recommends that these early indicators are read with caution as they do not include a complete yearly heating cycle. It is recommended that a full year study is performed in order to give a clearer performance comparison.

SAP Energy Consumption monitoring

The SAP calculator shows energy consumption as yearly predicted primary energy figures for space hearting, hot water heating, electricity for pumps and other needs (dependant on technology) and lighting. It also, if included in the dwelling, deducts any generated energy from a renewable source.

This information is generally derived annually from the SAP/ DER worksheets and if needed can be extracted on a monthly basis. This comes with some assumptions as pump and lighting electricity is only given as a yearly value and not as a monthly set of figures as space and water heating does. This was overcome by dividing these figures equally over 12 months which in reality would not be the case, i.e. artificial lighting tends to be used more during winter months.

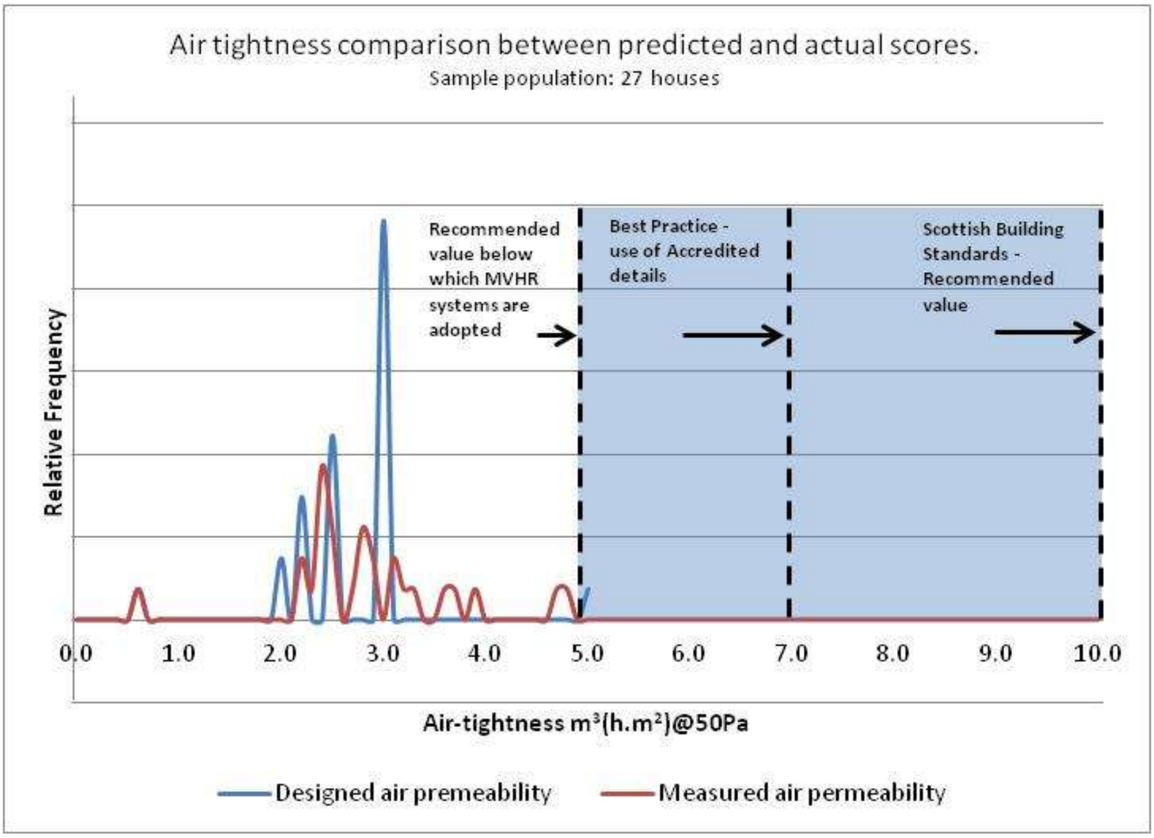
In order to obtain comparable energy data from each of the dwellings, it was essential to analyse and collate energy usage from the dwellings. This information, especially electricity and gas consumption, together with the low carbon technology installed, would give an indication of consumption that can be comparable at a later stage.

For the first part of results and to give an indication of early occupation energy usage, the month of August 2012 was initially selected. The reason this month was selected was because this was the month in which all residents had their energy monitoring equipment in operation after a snagging period and it was a month in which residents were starting to get acclimatised to their new home environment. Information was downloaded at the end of that month and initial calculations and assumptions were taken from that. The BPE Study Team recognises that this is too short a period in which to give an accurate or representative indication of performance and the initial approach deemed to be too short and unrepresentative comparison period. A longer-term Part 2 evaluation of energy performance will provide more insightful and representative evaluations of the buildings and technologies installed therein; subject to differing occupational, behavioural and comfort requirements.

Part of this study included third party monitoring and assessments which were reviewed by the BPE Study Team. Air tightness testing was performed by Stuart King Architecture & Design Ltd and Robin Mackenzie Partnership (RMP) who are members of The British Institute of Non-Destructive Testing (BINDT) and who follow the guidelines set by the Air Tightness Testing and Measurement Association (ATTMA) and The Building Services Research and Information Association (BSRIA) specification. The acoustic measurements were also performed by the Robin Mackenzie Partnership (RMP) who produced an independent study testing the majority of the components of each block in the site.

Review of compliance testing

Air tightness testing – Pre Occupation



Graph 18 - Comparison graph showing the frequency of results

The 27 homes in the HIS were pressure tested at post-completion to measure their air tightness. The air permeability tests conducted on these dwellings occurred between the months of March and April

2012. The BPE Study Team received all the results from the tests and a review of these was carried out. An analysis was conducted of the results obtained in relation to ATTMA, BSRIA guidelines & BS13829 (British Standards).

The air permeability results ranged from 0.6 $m^3/(h.m^2)$@50Pa for the Passive house dwelling in block 6 to 4.8 $m^3/(h.m^2)$@50Pa in the 2013 Future Affordable dwelling between plots 19 and 21 in block 7. The mean completion air permeability for all 27 dwellings was 2.8 $m^3/(h.m^2)$@50Pa. In most cases the measured values were within the predicted performance with some considerably lower than the designed values. Other tests, particularly in block 1 and 7 the design values are considerably lower than the as-built values. With the exception of the Passive House dwelling, the results are within a range of higher than 2.0 $m^3/(h.m^2)$@50Pa and lower than 5 $m^3/(h.m^2)$@50Pa which is becoming a recommended level for highly efficient buildings in the UK where it is recognised that some form of mechanical ventilation should be adopted.

Building Regulations in Scotland; section 6.2.4, indicate that "it is recommended that buildings are designed to achieve a value of 10 $m^3/(h.m^2)$@50Pa or better to allow a balanced approach to managing building heat loss" and it is explained that by taking into consideration the Building Standards Accredited Details lower infiltration rates can be achieved. Graph 20 above shows the frequency which the as-designed and as-built infiltration results have achieved. It is clear that the as-built results show a higher frequency level between 2 - 4 $m^3/(h.m^2)$@50Pa. Compared to the levels of air permeability at design stage, it is clear that these sit between 2 - 3 $m^3/(h.m^2)$@50Pa which highlights how the majority are below the 3 $m^3/(h.m^2)$@50Pa.

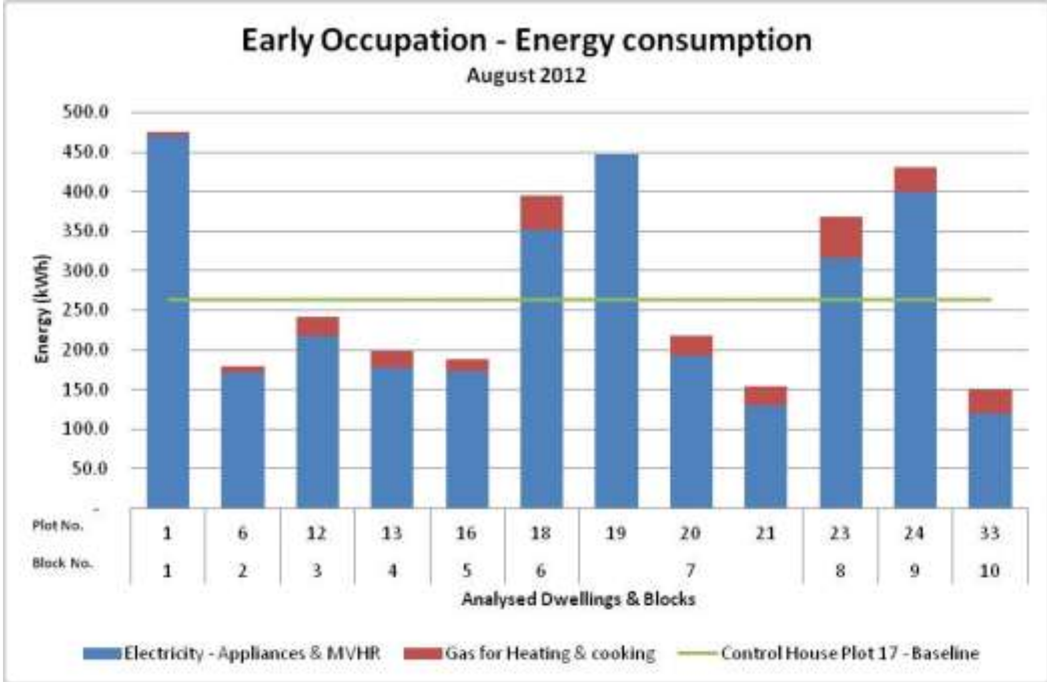
An important observation is made in this same section of the Building Regulations in Scotland; "Lower air infiltration rates, of <5 $m^3/(h.m^2)$@50Pa, may give rise to problems with internal air quality and condensation". This scenario has been experienced in the vast majority of the dwellings, hence the adoption of mechanical ventilation in most of them.

Early occupation energy consumption review

As explained in page 136 of this document, early occupation energy consumption figures were obtained through the use of real time display energy logging equipment which captured energy use and generation through one hour intervals. The loggers use three channelling ports which obtained energy readings for electricity and gas consumption and a third for a low carbon technology or an MVHR unit, where installed.

The information obtained from the logging devices was useful too as it gave a representation of the energy generation through the use of solar panels (electricity) or solar hot water panels (heat meter) and indicated whether any initial commissioning faults might be present.

Data was obtained and displayed from the month of August 2012. A wider annual energy consumption analysis will be made on the dwellings following the first year of occupation. This whole year study will give a better interpretation of energy use which will be compared with predicted levels of energy use. The BPE Study Team recognise that longer periods of energy use covering a complete heating seasons can give a better indication of energy use. With a study of the first year of energy consumption early occupation trends can be compared with the control dwelling. This information will also be comparable to annualised performance predictions at design stage (SAP).
Graph 21 below presents an overview of energy consumption over the period in which the dwellings were monitored. The monitoring has been continuous throughout the occupation period but the information below represents early occupation in which the residents have been in a try-out and adjustment period. This period represents mixed usage with residents from different backgrounds with various patterns of living and working. An example would be the usage of energy as in their previous occupied dwellings which in some cases was a pattern taken from poor energy efficient dwellings therefore creating frugal or in some cases negative attitudes to energy use. Another pattern is that of awareness and interest which falls under an experimental attitude of energy use because of the novelty of the building and its technology driven performance. Both are part of a wider scope out with this present BPE as it bridges over to a social sciences study. The BPE Study Team recognises this scope as an important part of discovering resident's energy use.



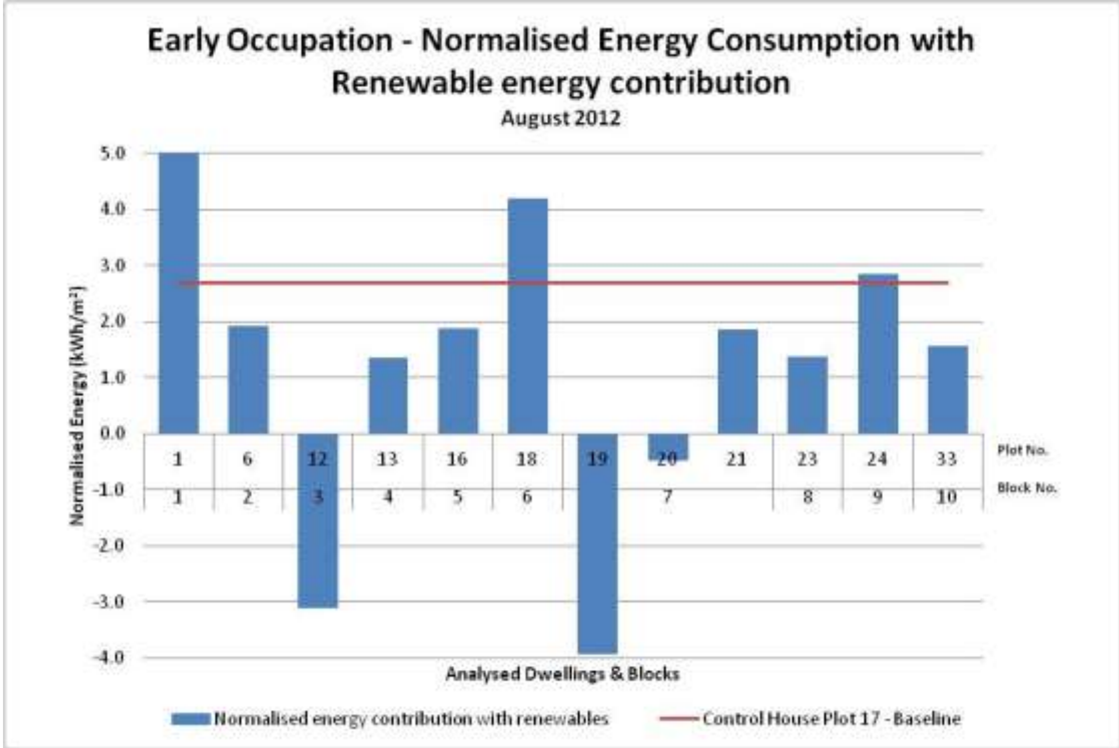
Graph 19 - Energy consumption over the month of August 2012

In this study the measured data was provided as a wide representation of energy use. Energy monitoring was provided by the logging devices with three active energy channels logging consumed energy and, in others, generated energy. The dwellings were not sub-metered to measure individual energy consumption of appliances or energy related devices. A common trend of logging total dwelling electricity and gas consumption was used but additional to this was the logging of renewable energy or recognised significant energy consumers (e.g. MVHR).

The data displayed in Graph 21 above groups the energy consumed by these devices but segregates the energy produced by low carbon technology. Graph 21 shows a representation of early occupation energy use throughout the month of August, generally considered a non-heating month where space heating is rarely used. The graph shows electricity consumed by appliances and also for powering ventilation systems (MVHR or MV). Additional to this is the use of mains gas for water heating and for cooking.

The information is compared with the baseline data obtained for the control dwelling in plot 17 which is a basic representation of a standard building archetype built by Kingdom Housing Association. The dwelling may not be appropriate for comparison with flatted properties in blocks 1, 2 & 3 but can act as a simple comparator. In some buildings gas was not used at all but a low carbon technology provided the servicing instead (mCHP or ASHP), this is the case of plot number 19 and that is reflected on the high use of electricity for powering such devices and for cooking. Plot 17 built as the control house (standard Kingdom house to current Building Regulations) is used as the baseline dwelling for comparison between the three Future Affordable (block 7) dwellings, especially plot 21 built in line with 2010 Building Regulations with an MVHR system installed; it shows low energy consumption (150kWh) linked possibly to the occupational patterns of use or the technology implementation. Plot 20 has the same MVHR system with higher energy consumption (>200kWh) with different occupational patterns and then on the higher spectrum plot 19 shows much higher consumption (450kWh) but with the knowledge of the use of MVHR and ASHP and once again a different occupancy pattern.

The consumption graph 21 above can help identify some other heavy electrical consumers. For example plot 18, which is the passive house dwelling installed with an MVHR unit, the dwelling has been identified as having many appliances. The same high energy use is observed by plot 23 with mechanical ventilation (MV) and plot 24 with an MVHR system. Plot 1 also is a heavy consumer and this may be linked to the use of the ASHP installed. Identifying a more accurate reason for high electricity use can be strengthened by conducting an occupancy study linked with a sub-metering of the devices and appliances. A sub metering study of each appliance will give a refined actual energy consumption pattern which can be segregated between controlled electricity and gas for space or water heating and appliances.



Graph 20 – Normalised energy consumption with the impact of low carbon technologies - August 2012

Many of the dwellings have been installed with integrated low carbon technologies, providing electricity or heat to the property. The generation of electricity by low carbon technologies is rarely used directly in the dwelling as different occupational patterns and energy use occurs at different times of the day. Most of the dwellings use their electricity outside normal working hours and any electricity generated is being sold back to the electrical grid. For the purposes of this study and for comparison reasons, graph 22 above normalises energy from low carbon technologies by total energy consumed as this is how predicted levels of energy efficiency have been measured (SAP).

In order to make an adequate comparison between dwelling energy usage, the energy consumed has been added (electricity & gas) to give the total dwelling consumption and the energy generated as heat or electricity has been subtracted to obtain energy balance of the dwellings. Additional to this, energy has been normalised by the dwellings footprint which can be used to give a more relevant comparison between dwellings. Once again, plot 17 has been used as a baseline comparator - but it is a dwelling that has no low carbon technology installed.

A comparison between dwellings taking into account low carbon systems is not adequate because this study monitored during a short period of occupation at an early stage of the buildings life span, thus difficult to obtain real conclusions.

The consumption of energy during this early occupation has only been recorded during the summer month of August which does not give a real indication of energy performance. SAP software predicts energy use for space and water heating on a month-by-month basis but it is the additional energy usage that is difficult to extract that also contributes to the buildings consumption, e.g. lighting, pumps and low carbon technologies. A yearly account of energy use would simplify this comparison and produce better comparison. Results on the first year’s energy outputs will be reported later in 2014.

Fabric technical survey

In addition to the case studies presented above the following are extended fabric surveys which expand on the performance of the dwelling.

Infra-red Thermography

Reference to the methodology adapted to conduct such surveys is presented in page 134 & 135 of this document. It is important to highlight that the analysis hereby presented is a representation of images obtained at the particular time of survey and prevailing climatic conditions. Infrared thermography shows qualitative images at a moment in time which enable the visualisation of heat loss/gain.

The environmental conditions were recorded before and after the survey for each property. The survey concentrated on external views of selected dwellings which gave a representative example of the dwelling type. Internal images were also taken of these flats/ dwellings. In instances where flats were located, a ground and first floor flat was surveyed. Exceptions arose in blocks 6 & 7 where all dwellings were surveyed because of the different dwelling type.

The images were taken during the night on the14th and 15th of April 2012, some additional images were taken on the 16th of June 2012 mainly of internal surfaces. The external conditions at the start of the survey were as follows:

- Outdoor temperature: 8.9 °C
- Wind Speed: 2.0 m/s-1
- Relative Humidity: 82%
- Sky conditions: 60% Overcast
- Building Surface: Dry, no presence of humid surfaces

At the end of the survey, the conditions had remained relatively stable as follows:

- Outdoor temperature: 8.9 °C
- Wind Speed: 2.5 m/s-1
- Relative Humidity: 88%
- Sky conditions: 60% Overcast
- Building Surface: Dry, no presence of humid surfaces

The average internal temperature of the dwellings was 25.0˚C and the BPE survey team made sure that a temperature difference (ΔT or delta-T) of the internal and external conditions prevailed above 10˚ by obtaining from all surveys an average of 16.7˚C.

Property: Block 1 – Powerwall **Type of Survey: External envelope**

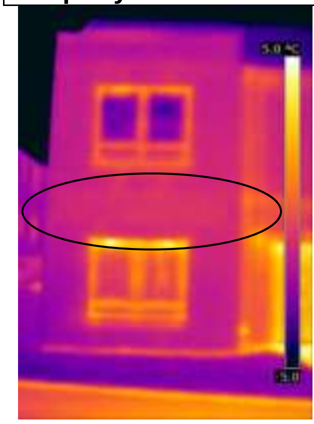


Fig. IR01 – Front elevation

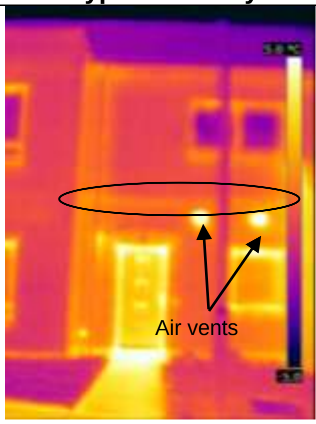


Fig. IR02 – Entrance to plot 4

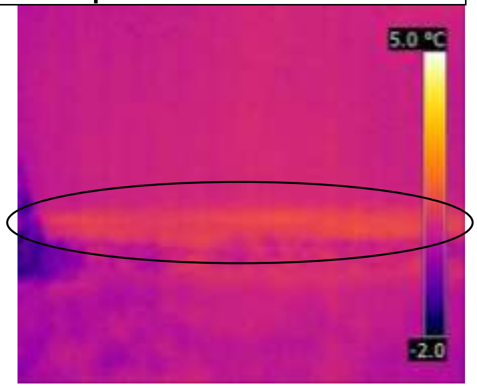


Fig. IR03 – Detail image of wall plinth

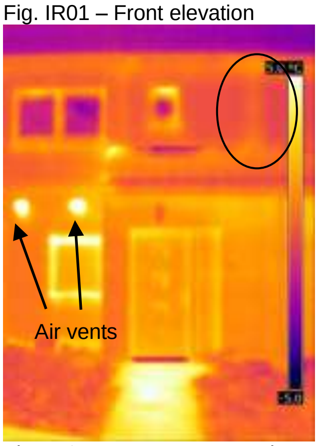


Fig. IR04 – Front entrance plot 3

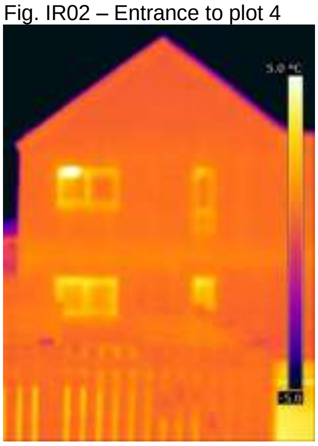


Fig. 05 – North side elevation

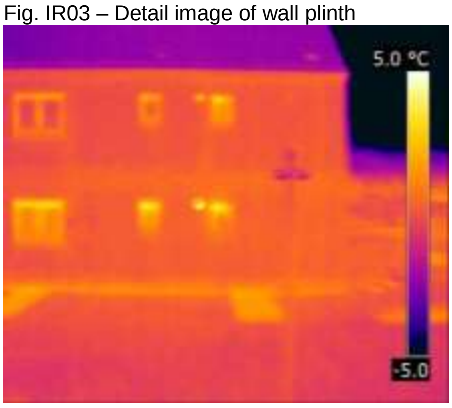
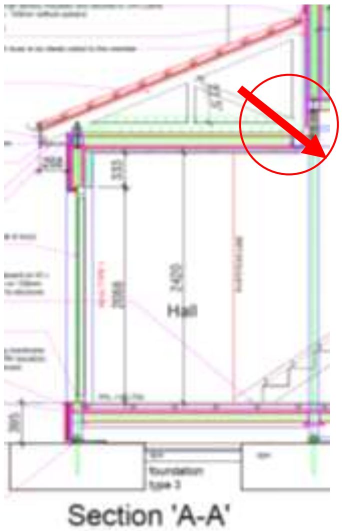


Fig. IR06 – Back elevation plots 3 & 4

Detail 01



Detail 02

Fig. IR07 – Front elevation view

Comments: The external infra-red thermography images demonstrate junction details where higher surface temperatures are experienced. Figures IR01 & IR02 show intermediate floor/ceiling junction temperature variations of up to 2˚C. This can also be perceived in Figure IR05 & IR04 at the north & front elevations where a horizontal zone & a vertical line (wall studs transmitting heat) marks heat loss. Figures IR07 show images of the side wall entrance lobby to plot 3. Distinct increase of surface temperatures is experienced all across the wall particularly at the wall junction with the main building volume. Detail 02 and other details supplied show where in the roof void there may be a thermal bridge. IR03 shows the base of the wall (plinth) where increased surface temperatures at the floor shows heat loss. In Detail 01 insulation stops close to the steel floor beam, transmitting heat & acting as a thermal bridge.

Property: Block 1 – Powerwall Type of Survey: Internal – Plots 3 & 4

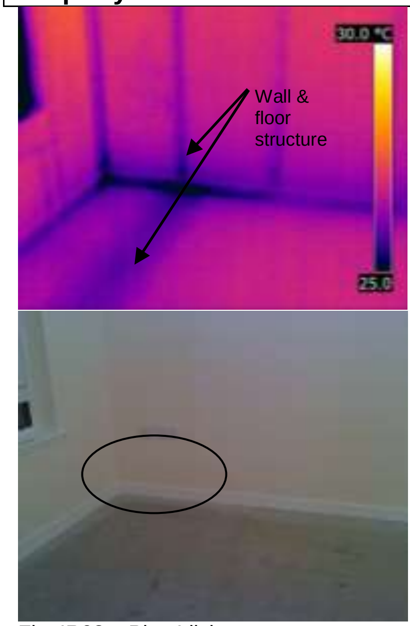


Fig. IR08 – Plot 4 living room

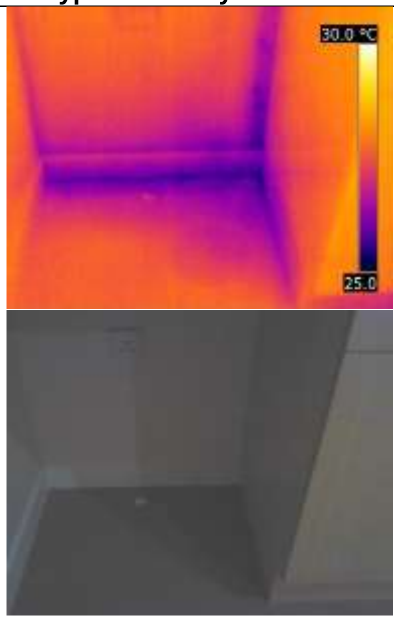


Fig. IR09– Plot 4 Kitchen

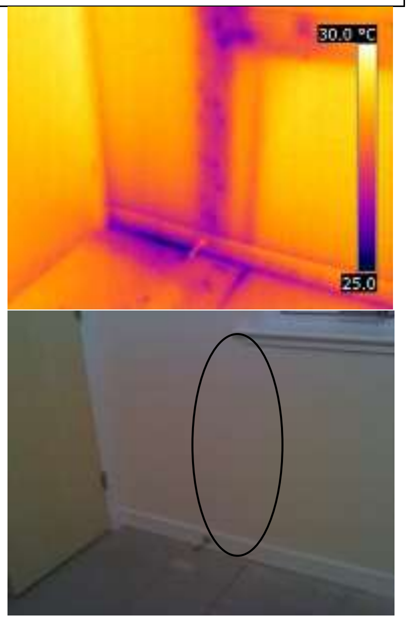


Fig. IR10 – Plot 4 Bedroom

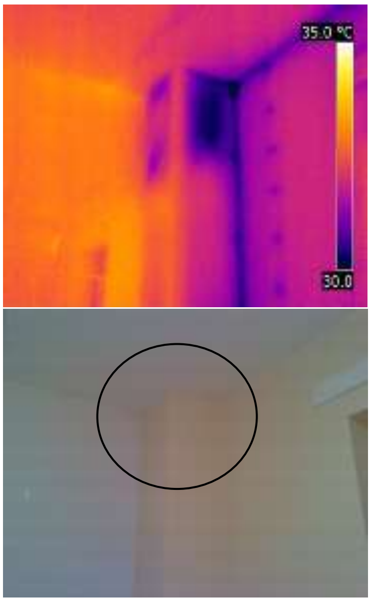


Fig. IR11 – Plot 4 Bathroom

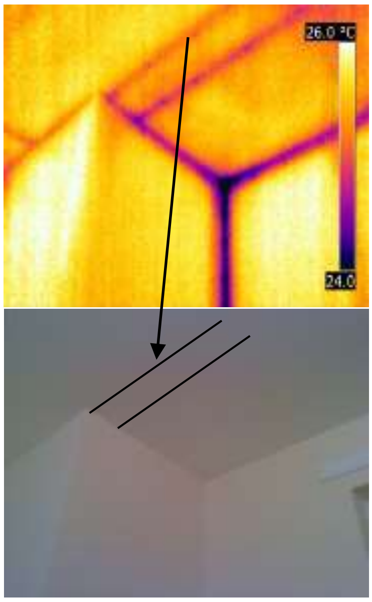


Fig. IR12 – Plot 3 Bedroom

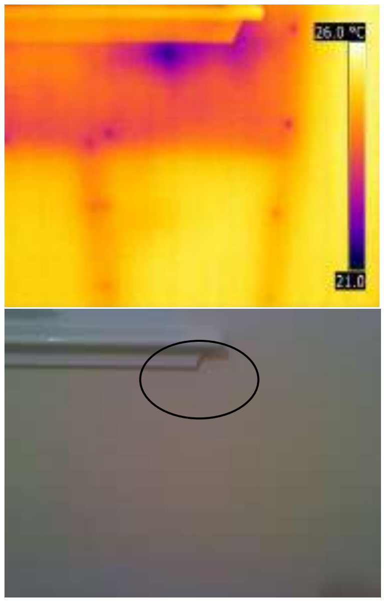


Fig. IR13 – Plot 3 Bedroom

Comments: Thermograms from both plots 3 & 4 show some areas of concern where air infiltration or thermal bridging are facilitating the passage of heat. As can be appreciated in the above images, the surface temperature differences can be in the region of between 3 & 4˚C. IR08 shows how wall and floor studs are transmitting heat. Concentrated areas of thermal bridging shown at the base of the wall studs indicate some concern. This is similarly experienced in IR09 in the kitchen behind the cabinets. IR10 shows a stud serving as a support to the above window where there are possibly repeated stud work acting as a thermal bridge. IR11 shows how service ducts are badly insulated and can be an evident pathway of heat loss. Fixings nearly the ducts are also acting as point thermal bridges. IR 13 shows a detail of heat loss appearing under the internal window sill surrounded by stud fixings. IR12 shows the ceiling of plot 3 where intersection between walls shows heat loss but also a structural beam spanning across above the ceiling is also acting as a heat path through possibly thermal bridging. Although the temperature range is not big, there is indication of heat escaping.

Property: Block 2 – Scotframe	Type of Survey: External envelope

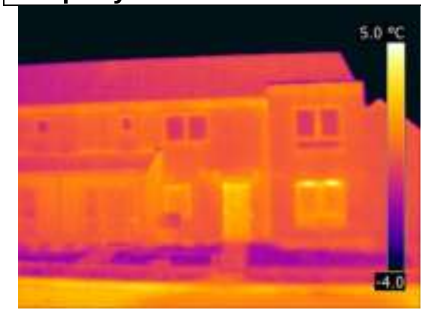


Fig. IR14 – Front elevation plots 5 & 6

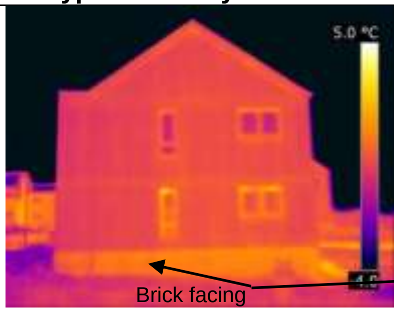


Fig. IR15 – Side elevation plots 5 & 6

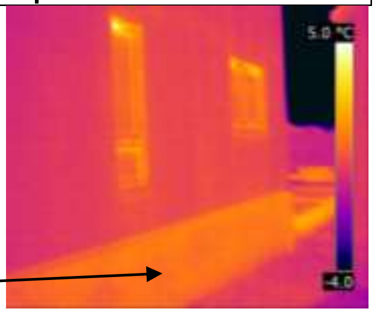


Fig. IR16 – Detail image of side facing brick

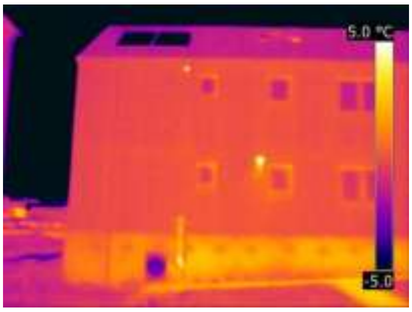


Fig. IR17 – Back elevation plots 5 & 6

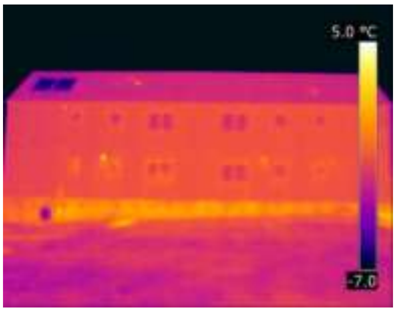


Fig. IR18– Back elevation – Whole block

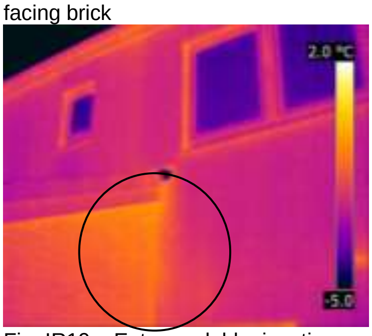
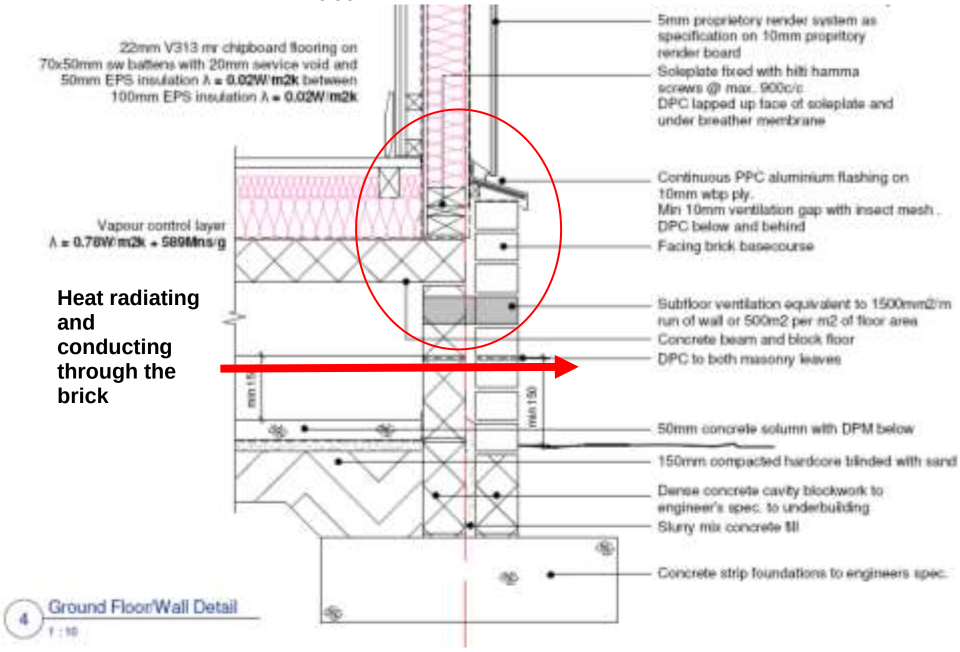


Fig. IR19 – Entrance lobby junction



Detail 03

Comments: As can be appreciated in the above images, there are concerns over the perimeter facing brick under the floor. Thermograms IR15, IR16, IR17 & IR18 show at different scales the band of heat escaping underneath the flats. Looking closely at the design drawings in detail 03 above, it is clear that provision of insulation is drawn in such a way that it overlaps the floor insulation. This would have decreased any possibility of heat escaping in that junction transmitting itself down the brick facing. There is a big distinction between the walls of the flats and this brick facing. This heat may lead to simply indicating that temperatures under the floor are higher than externally, conductance of heat from a large floor area will increase the air in this void which is shown to conduct to colder brick surfaces. IR19 shows a different concern, where the roof of the entrance lobby which is only insulated at ceiling level, shows heat loss at the junction point. It is also interesting to point out hot surface temperatures of the lobby wall are higher than the rest of the walls in the flats.

Fig. IR20 – Plot 5 living room

Fig. IR21 – Plot 6 Living room

Fig. IR22 – Plot 6 Kitchen

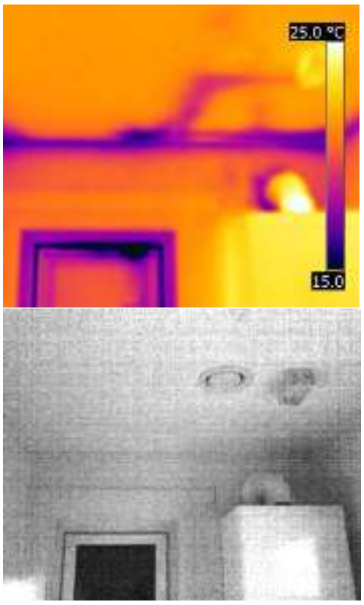


Fig. IR23 – Plot 6 Kitchen

Fig. IR24– Plot 6 Bedroom

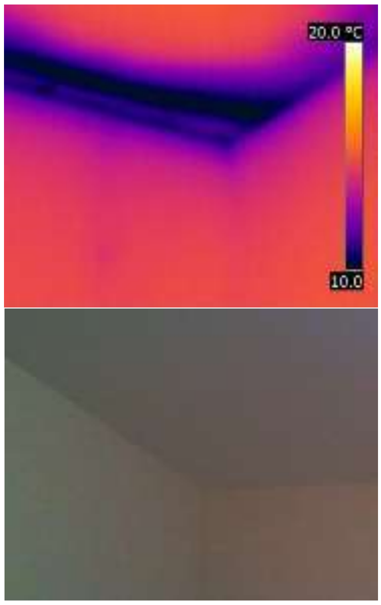


Fig. IR25– Plot 6 Bedroom

Comments: Internal thermograms shown above indicate some concerns at skirting level and at ceilings where missing or misplaced insulation or thermal bridging of structural elements have created heat loss. IR20 shows how in plot 5 skirting levels have highlighted heat loss. Thermograms of the top flat in plot 6 show some concerns around ceiling levels. IR21 clearly indicates missing insulation or insulation that hasn't been placed correctly. Image IR22 is similar to IR23 where missing or misplaced insulation near the eaves and wall/ceiling junction show areas of heat loss conducting through joists. Image IR24 shows repeated joists close to walls where insulation could not be installed. IR25 is a detailed image of this joist which affects a wider area around it from conducting elements.

Property: Block 3 – Stewart Milne – Sigma II **Type of Survey: External envelope**

Fig. IR25 – Front elevation

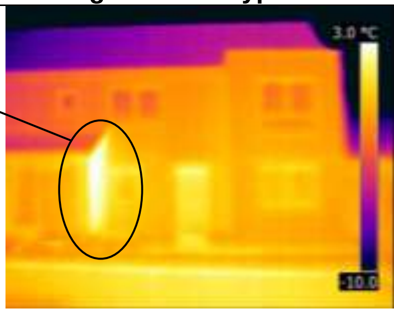


Fig. IR26 – Entrance to plot 4

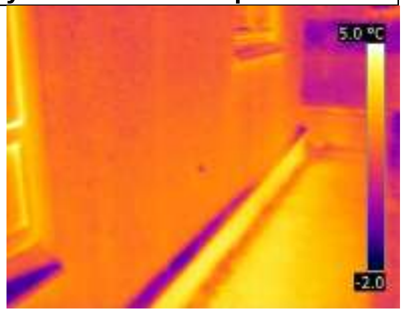


Fig. IR27 – Detail image of wall plinth

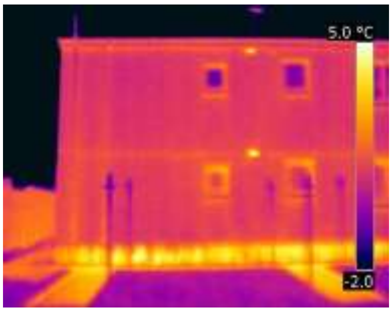


Fig. IR28– Front entrance plot 3

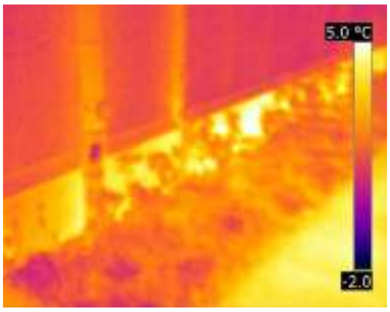


Fig. IR29 – North side elevation

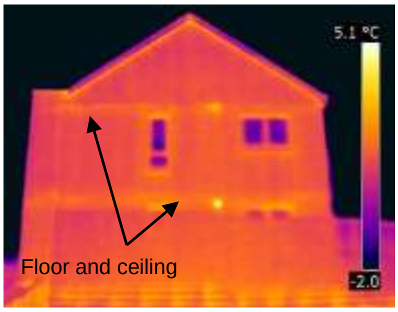
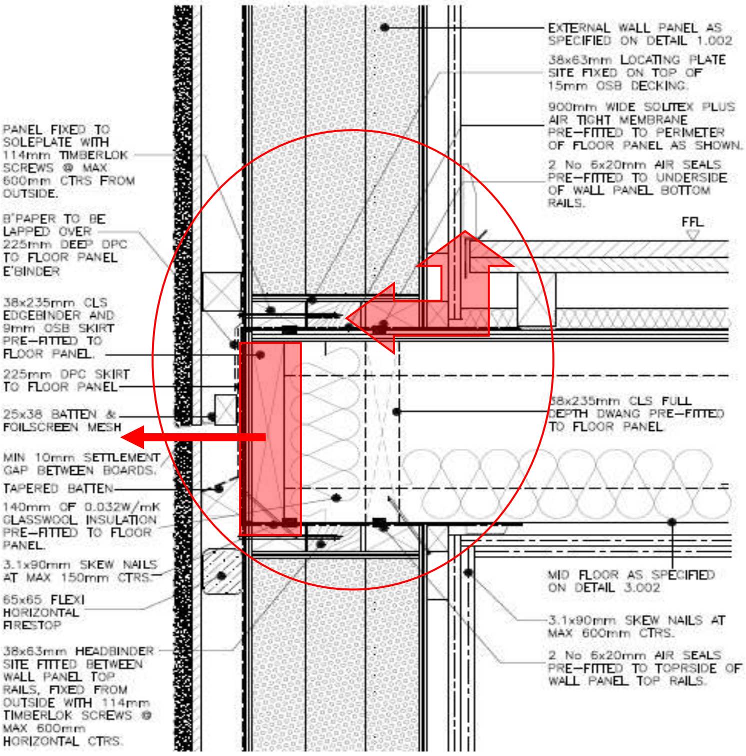
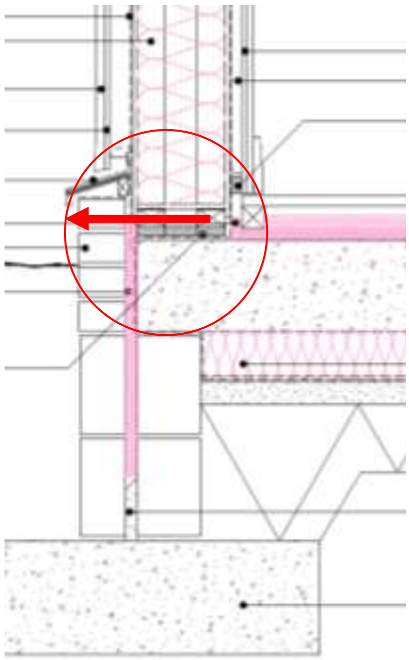


Fig. IR30 – Back elevation plots 3 & 4



Detail 04



Detail 05

Comments: These external thermograms show three potential heat loss problems. The first is shown in imagesIR25 & IR26 where the entrance lobby to flat 10 shows heat loss at the junction between the side wall of the lobby and the connecting wall. Details show that insulation reaches only the ceiling level of that sloping mono-pitch roof and it is at these points where heat is escaping. IR 26, 27 & 28 show another area of concern; where the brick base course is exposed and heat conducting itself from the concrete slab where little insulation is positioned; as seen in detail 05. The sole plate conducts heat to the concrete slab and heat escapes as a thermal bridge. A third concern is displayed in IR30 where external wall images show higher surface temperatures at the ceiling and intermediate floors of the flats. Detail 04 shows how sole plate and floor panels indicate heat conduction originating from the half- filled floor.

Property: Block 3 – Stewart Milne – Sigma II Type of Survey: Internal – Plots 9 & 10

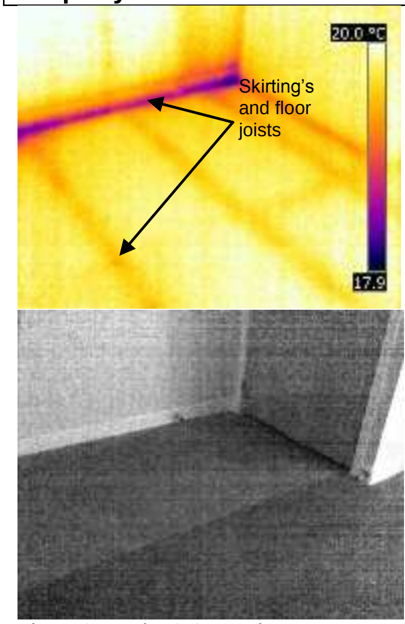


Fig. IR31 – Plot 9 GF Bedroom

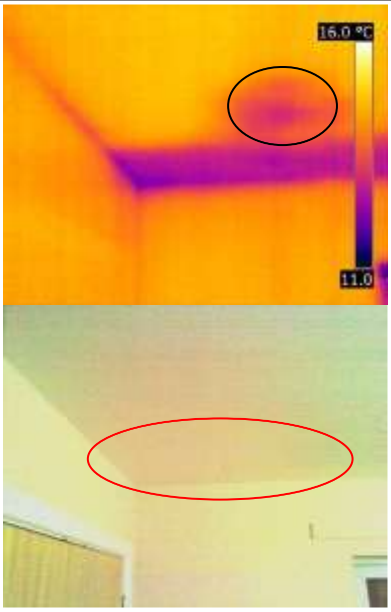


Fig. IR32 – Plot 10 Bedroom

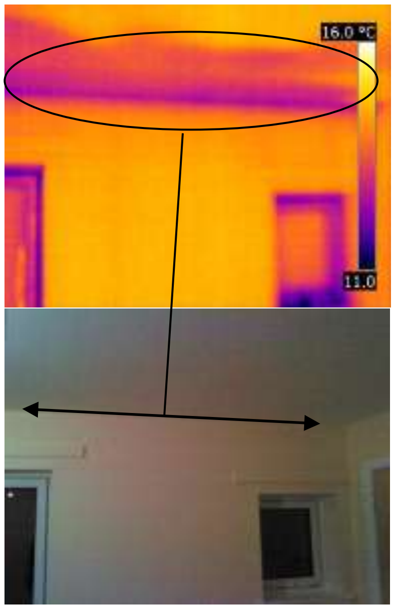


Fig. IR33– Plot 10 Bedroom 1

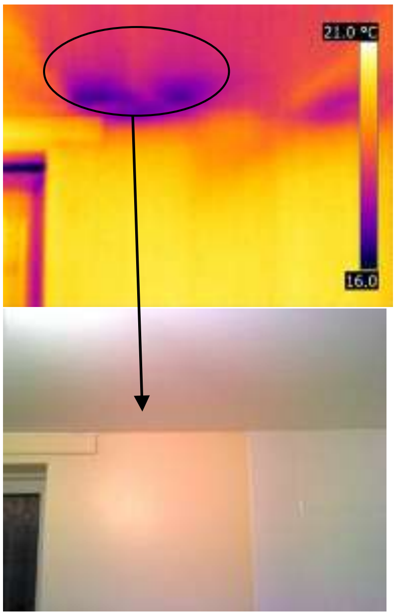


Fig. IR34 – Plot 10 Bathroom

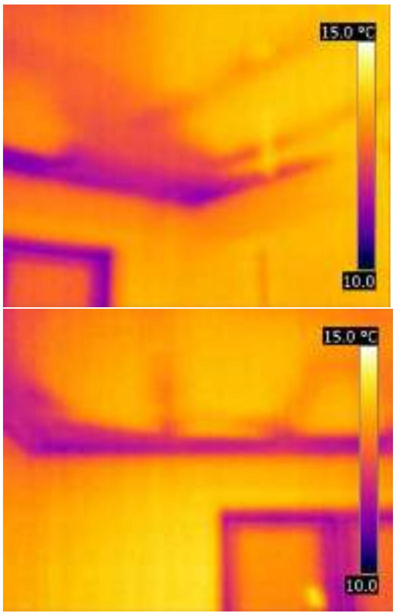


Fig. IR35 & IR36 – Plot 10 Living

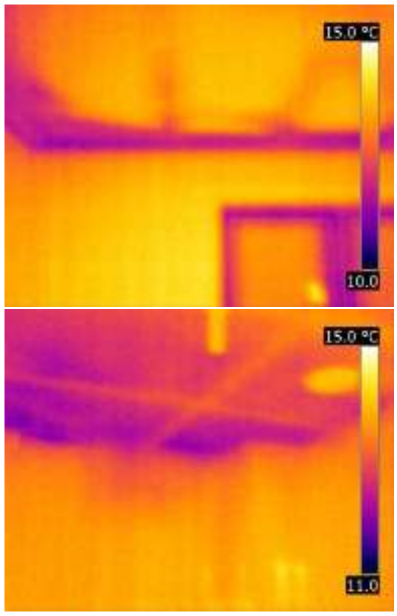


Fig. IR37 & IR38– Plot 10 Living

Comments: Thermograms in the two dwellings demonstrate some concerns around services where possible installations may me producing thermal bridging or skirting's and floor joists where Thermal bridging is also appearing. Image IR31 demonstrates heat loss at the skirting connection between wall and floor. The first floor property, plot 10, shows some concerning issues around the ceilings close to the eaves of roofs. Image IR32 begins to show possible missing insulation and a circular patch where a blocked service point may be located which is showing heat loss. The rest of the images from IR33 to IR 38 show a repeated trend in the ceilings of the bedrooms and the living room, as well as the bathroom. There appear to be patches of misplaced or missing insulation close to the wall and where the eaves meet. Large patches are shown, for example IR34 and IR38. They all show how heat loss as a concern, especially in the depth that it reaches into the rooms in between ceiling joists. The majority of these heat loss patches appear across the ceiling from one side to the other indicating that heat is escaping or that air infiltration is creating heat loss pathways. Although the temperature variation is not large, there is still a different of 2 to 3˚C which is significant in the performance of the dwelling.

Property: Block 4 – Porotherm **Type of Survey: External envelope**

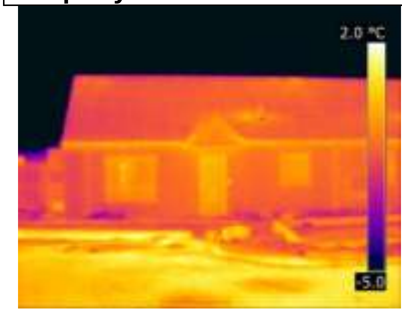


Fig. IR39 – Front elevation plot 14

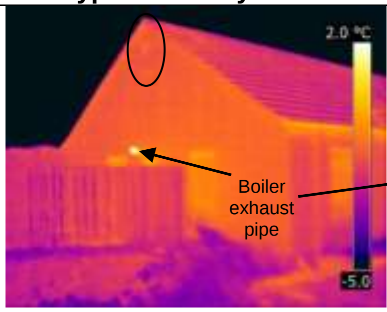


Fig. IR40 – Side elevation plot 14

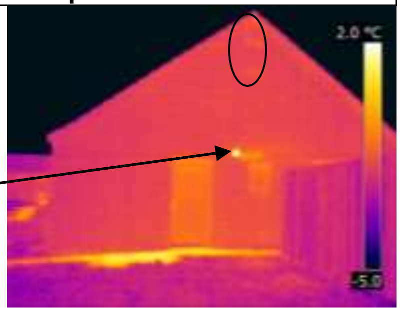


Fig. IR41 – Side elevation plot 14

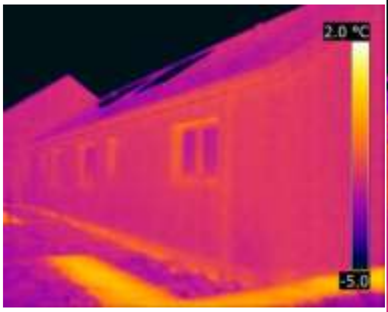


Fig. IR42– Back elevation Plot 13 & 14

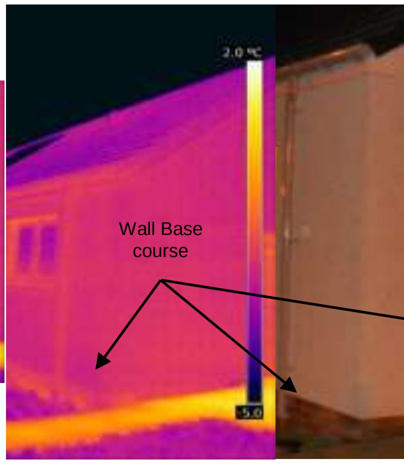
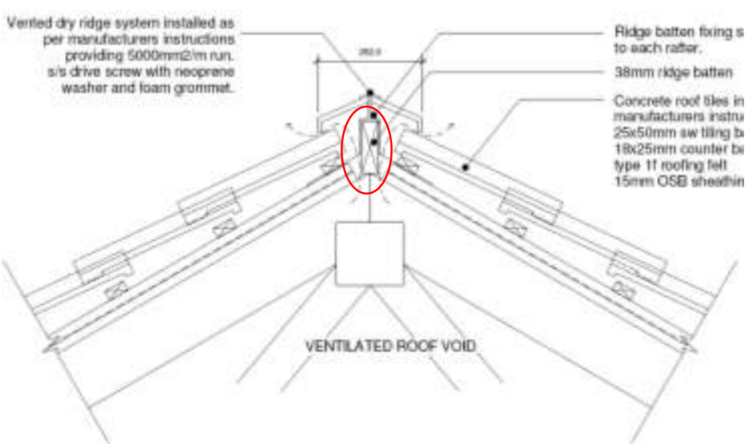
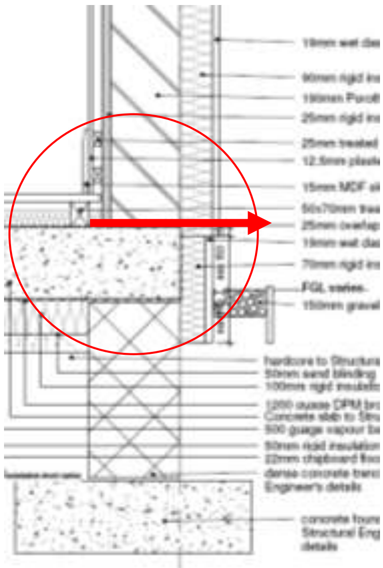


Fig. IR43 –Detail back elevation Plot 14

Fig. IR44 –Back elevation plot 14



Detail 06



Detail 07

Comments: The external thermograms show an even distribution of surface temperatures. There are some concerns in the gable end of the two dwellings where small patches of higher surface temperatures appear. IR40 & IR41 show this to some degree where a difference of 1 to 2˚C can be observed. Analysing detail 06, the ventilated cold roof shows little indication of the reasons to these patches of higher surface temperatures. A possibility is the placement of the ridge batten and adjoining timber elements that at this point are creating a small thermal bridge. The space behind it is un-occupied and un-heated therefore no big risk is identified. Another area of concern is the perimeter wall brick base course that appears to be showing higher surface temperatures. Images IR42 to IR44 show this repeated problem all-round the building. Detail 07 shows insulation is placed in front of the concrete slab with pebble dash render when in fact it has a brick base course as shown in IR43.

Property: Block 4 – Porotherm Type of Survey: Internal – Plot 14

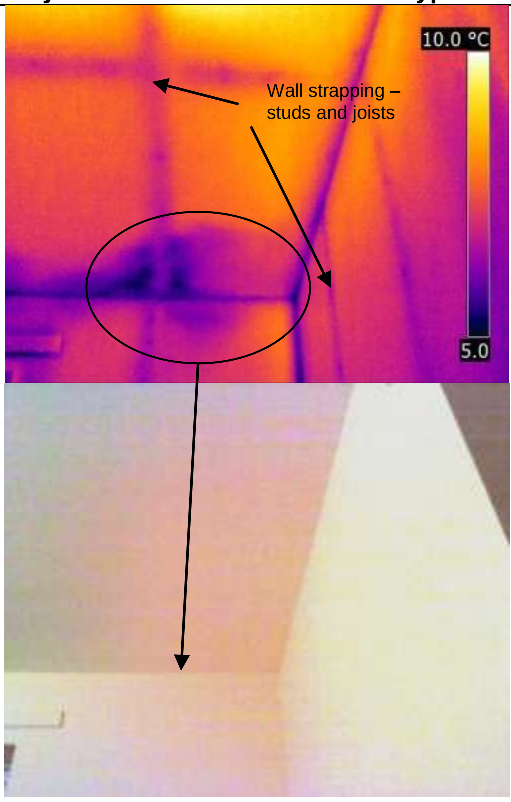


Fig. IR45 – Plot 14 Living room

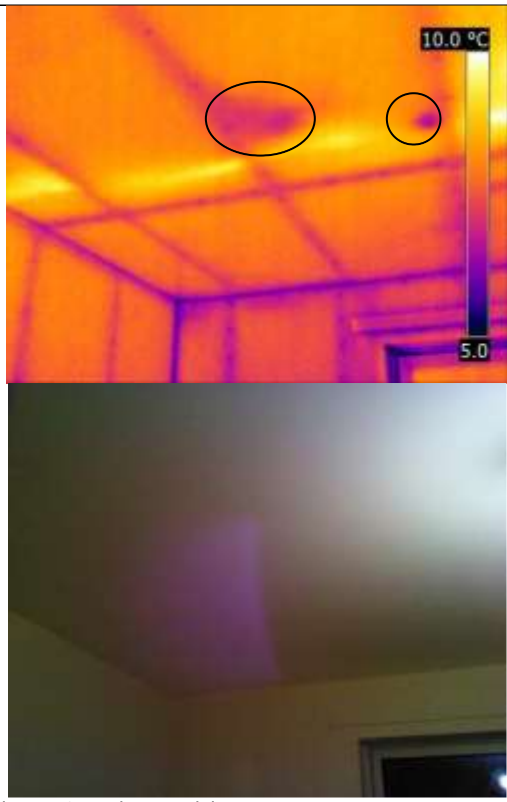


Fig. IR46 – Plot 14 Living room

Fig. IR47 – Plot 14 Bedroom

Fig. IR48 – Plot 14 Kitchen

Comments: The internal thermograms show some concerns at skirting level and ceiling/ eaves level. Image IR47 shows a large patch of lower surface temperatures where possible un-controlled ventilation appears and where insulation may be missing or is installed leaving gaps. Wall/ ceiling straps are shown all-round which may be due to the way the rigid insulation behind it has been placed. Details show the straps on top of the insulation and the image shows that possibly insulation was placed in between the insulation creating a small thermal bridge. IR46 also shows some additional circular patches where services are penetrating or have been cancelled. Image IR47 shows a different concern. At the base of the wall at skirting level, a large heat loss patch appears migrating upwards. IR48 shows some concerns above the kitchen cabinet where heat loss is experienced on the ceiling branching over and conducting through the ceiling joists. The same is experienced in thermogram IR45 in the living room.

Property: Block 5 – CUBE RE-treat Type of Survey: External envelope

Fig. IR49 – Front elevation plot 16

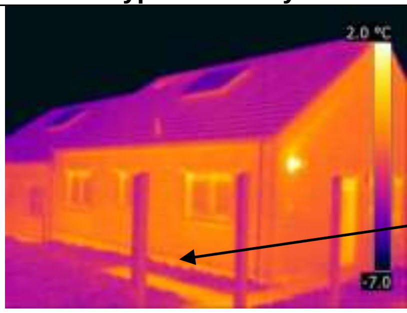


Fig. IR50 – Side and back elevation plot 16

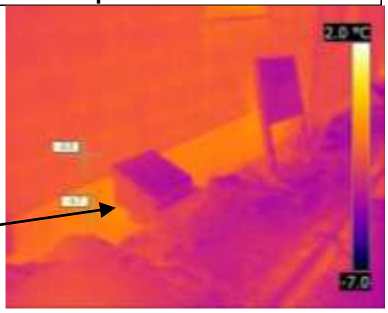


Fig. IR51 – Detail of brick base course

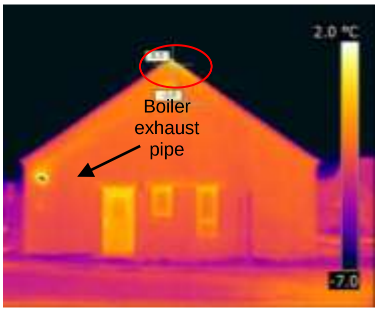


Fig. IR52– Side elevation plot 16

Fig. IR53– Side elevation plot 16

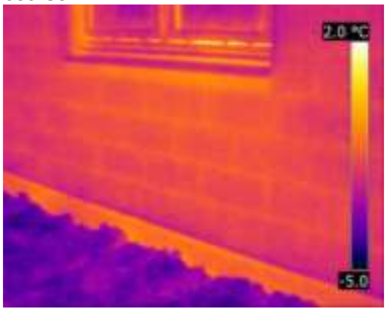
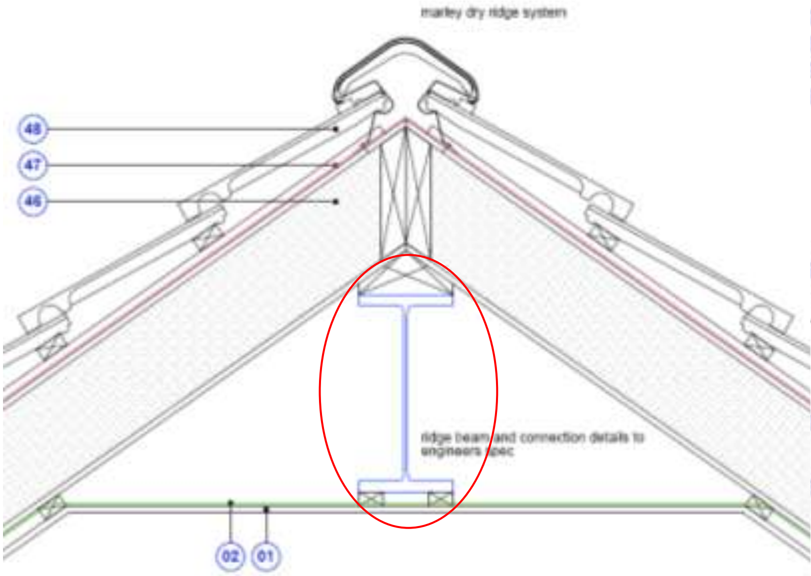
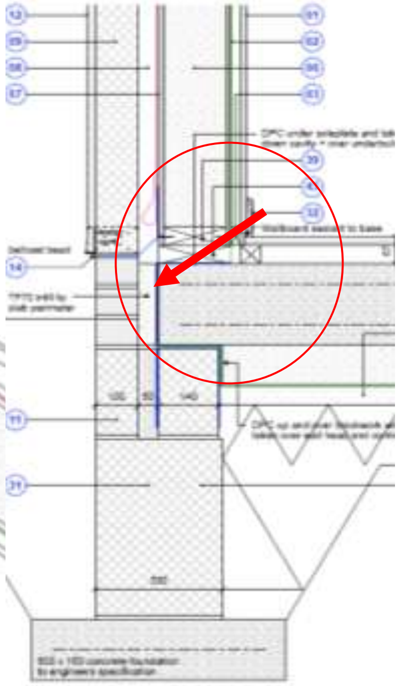


Fig. IR54– More details of brick base course



Key:
01 - 12.5mm Gyproc Wallboard 02 – Tyvec Airguard VCL
46 – 194 SIPs Eco panel 47 – Roof membrane 48 – Roof tiles

Detail 08



Detail 09

Comments: Front elevation (IR49) image shows an even distribution of surface temperatures on the main SIP wall system. The roof also has even surface temperatures although the top left hand corner shows an increase in temperature. This could be because of a ridge steel beam that rests at that point spanning from both gable ends, see detail 08. The attic space is no occupied therefore not presenting a direct thermal issue. Once this attic is occupied the beam would be insulated accordingly. Image IR52 also shows this where top roof ridge shows some heat conducting. There is also a grille or ventilation box on the wall as it approaches the ridge of the roof that shows an increase in surface temperatures. In image IR50 of the back elevation, an even distribution of low surface temperatures is shown. A boiler duct on the corner of the rear and side elevations shows heat escaping which is normal. An area which shows concern is located in IR50 and IR51 at the base course where an increase in surface temperatures around the perimeter indicates thermal bridging or under floor conductance of heat. Detail 09 shows a possible path way of heat through the timber sole plate/ packers across to the brick base course. The temperature difference is small (1˚C) but nevertheless showing heat escaping.

Fig. IR55 – Plot 16 Kitchen

Fig. IR56 – Plot 16 Living room

Fig. IR57 – Plot 16 Bedroom

Fig. IR58 – Plot 16 Bedroom

Comments: Image IR55 shows a ceiling image where some minor cross section joist is evidenced by surface heat losses. The image also shows some circular patches perhaps belonging to pipe work or electrical boxes that may have been cancelled and blocked. The corner also shows heat loss often can be thermal bridges where repeated timber elements are placed for structural integrity. Thermogram IR56 shows insulation missing or badly installed leaving gaps between joists and at eaves where it can be difficult to reach. Image IR657 represents pipe work carrying hot water from boiler to radiators. It is clear that a heat source appears to emit heat as it travels to the radiator. This may indicate that the pipe work is un insulated and even if the floor slab is insulated retaining heat within the envelope of the dwelling, it is recommended that pipe work is insulated so that temperature controls (TRV's) provide effective control. In image IR58 the circular area is an air duct from the MVHR system, the system was turned off at the time of the survey. Additional heat loss in edges also shows concern.

Property: Block 6 – Passiv haus plot 18 & Control house plot 17 - Type of Survey: External envelope

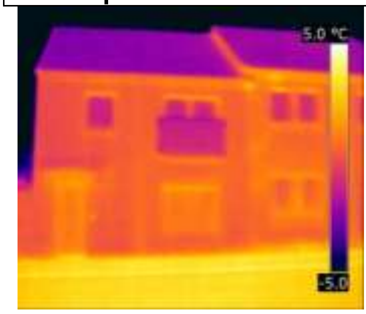


Fig. IR59 – Front elevation plot 18

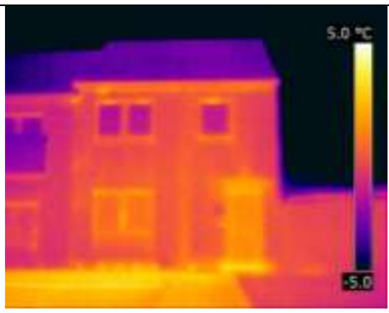


Fig. IR60– Front elevation plot 17

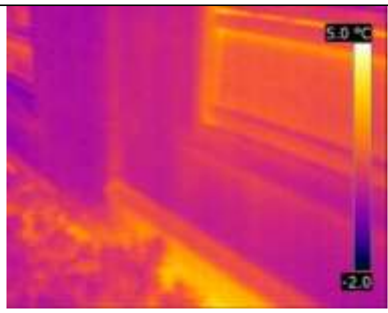


Fig. IR61 – Detail of party wall

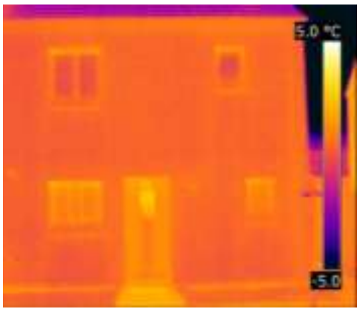


Fig. IR62– Back elevation plot 18

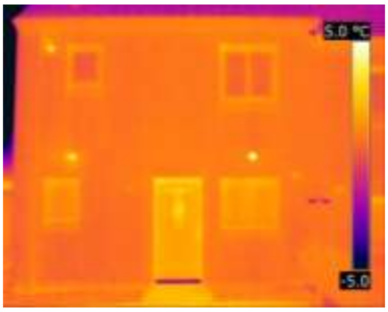


Fig. IR63– Back elevation plot 17

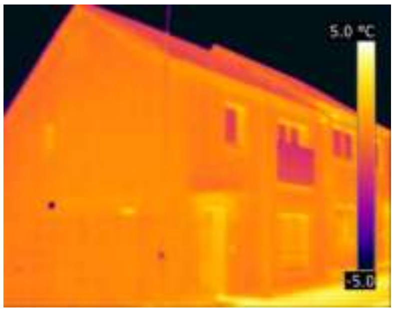
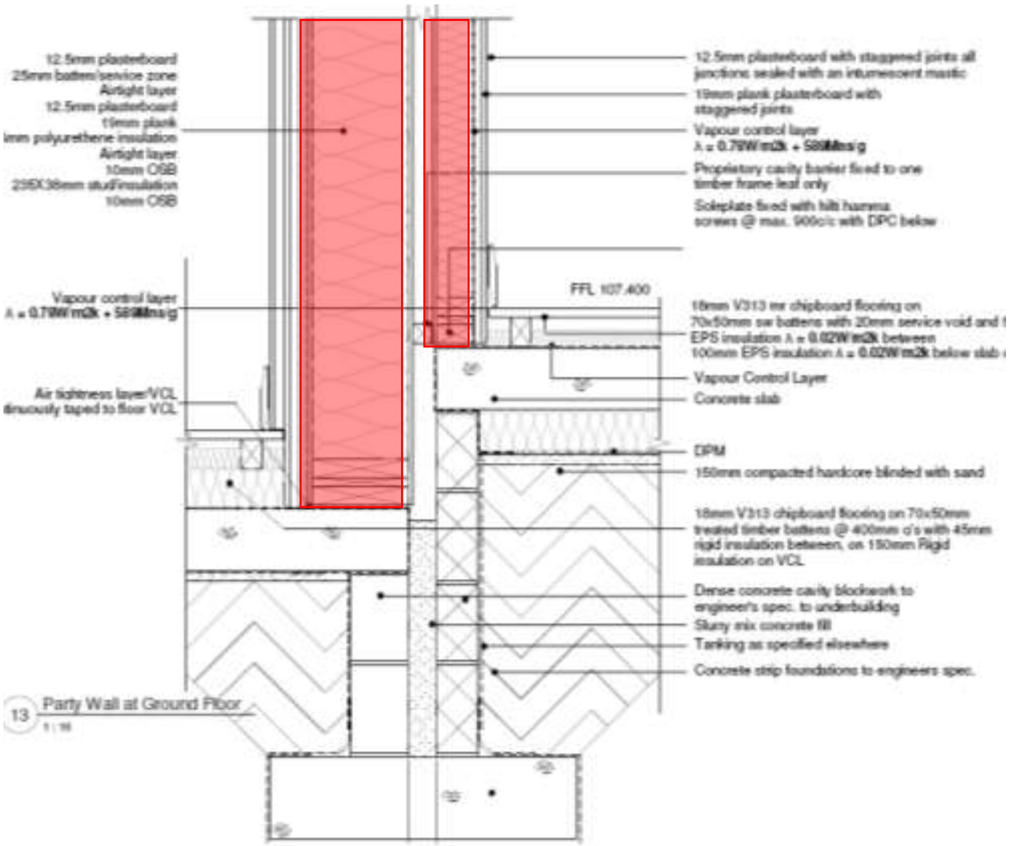


Fig. IR64–Side view of both dwellings



Detail 10

Comments: Both dwellings present even surface temperatures in all elevations. There is a distinct difference between the walls in plot 17 (control house) and plot 18 (Passivhaus). This can be observed in IR61 where the party wall and the two front walls are against each other. The left hand wall from plot 18 is significantly lower in surface temperature than the right hand wall of plot 17. Detail 10 shows the distinction between them. Plot 17 has a thinner insulated wall compared to plot 18 hence the difference in surface temperature. The contrast is interesting as a whole elevation image in IR60 where both elevations can be seen.

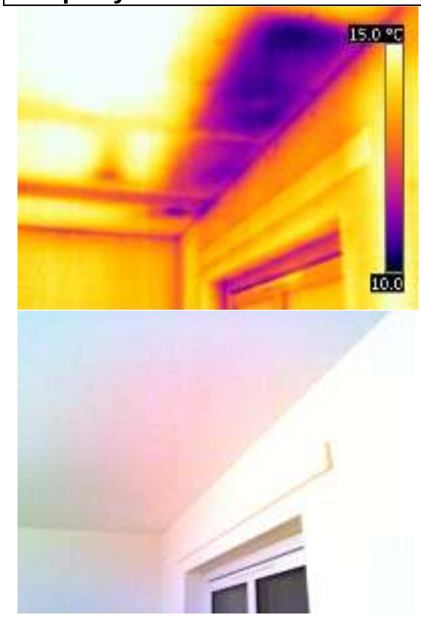


Fig. IR65– Bedroom

Fig. IR66 – Living room

Fig. IR67– Bedroom

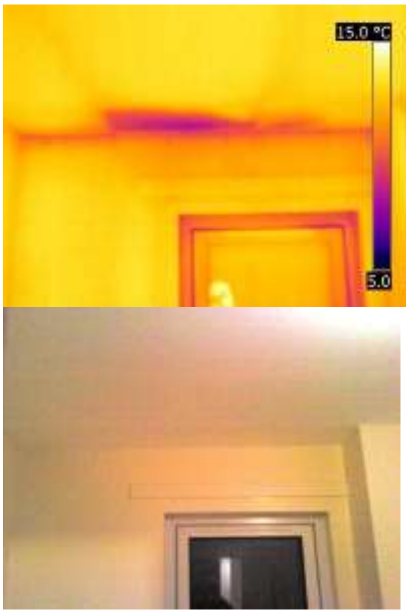


Fig. IR68– Bathroom

Fig. IR69– Bathroom

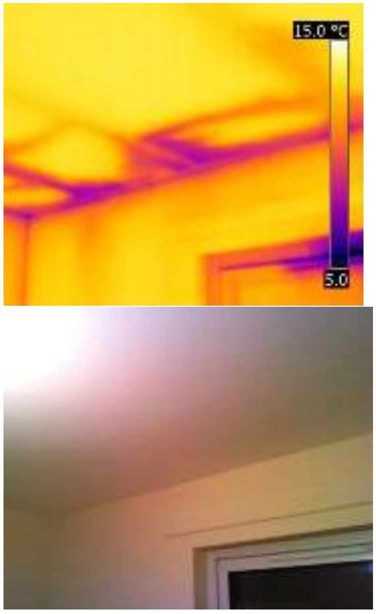


Fig. IR70– Bedroom

Comments: Internal thermograms of the control house show many concerns around the floor and also on the ceilings in the first floor. Image IR65 is of particular concern where a large un insulated section near the eaves of the roof shows heat loss. There are repeated images where ceiling insulation is badly installed or missing completely. Many of the examples above are near junctions between ceilings and wall where detailing can be complicated. IR66 is interesting as it highlights some concern close to the window and adjacent walls. A large heat loss area is located in the wall/floor junction where an element there appears to be creating a thermal bridge.

Property: Block 6 – Passivhaus **Type of Survey: Internal – Plot 18**

Fig. IR71– Bedroom

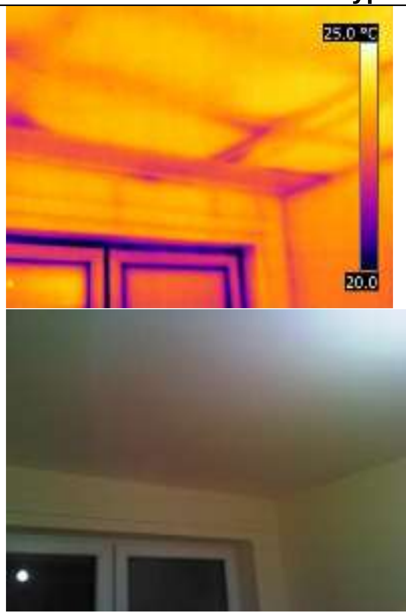


Fig. IR72 – Bedroom

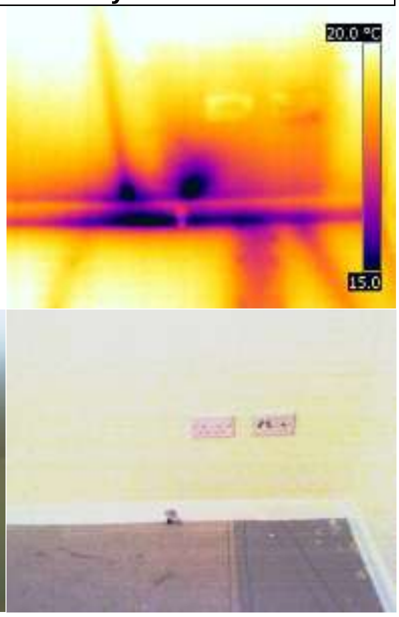


Fig. IR73 – Living room

Fig. IR74 – Bathroom down stairs

Fig. IR75– Bedroom

Fig. IR76– Bedroom

Comments: The thermograms belonging to plot 18 show a range of ceiling and floor concerns. IR71 & 72 identifies similar concerns to IR75 & 76 where ceiling heat loss is experienced. There are many colder surface temperatures represented as long patches or concentrated corner patches showing heat loss developing either from missing insulation or air infiltration. Image IR73 shows a floor image where heat loss is experienced on the wall and skirting level. There are two concerns here. The first to do with the skirting area where that junction shows a cold bridge to the floor adventitious ventilation ingress and also the two circular patches on the wall that may be related to rising thermal bridging or missing insulation in that area. Image IR74 shows heat loss close to the switched off radiator where possible pipe work and holes around them are creating a colder surface temperature and heat loss. Often holes around pipe work are left un insulated or sealed as they were after a sequential part of the fitting of insulation.

Property: Block 7 – Future Affordable Plots 19, 20 & 21 Type of Survey: External envelope

Fig. IR77 – Front elevation plot 21 & 20

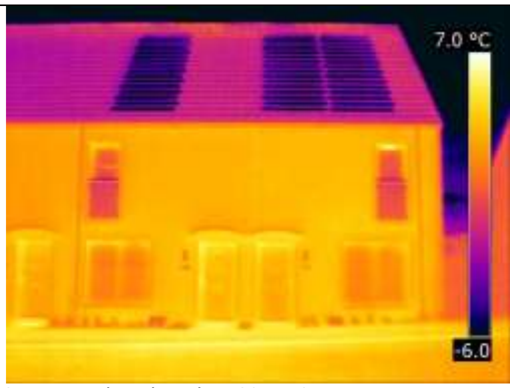


Fig. IR78 – Front elevation plots 20 & 19

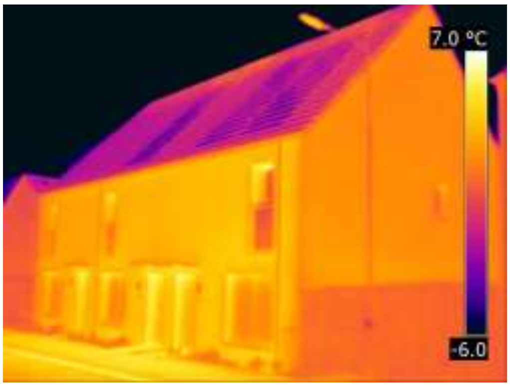


Fig. IR79– Side view of plots 21, 20 & 19

Fig. IR80–Back elevation plots 19 & 20

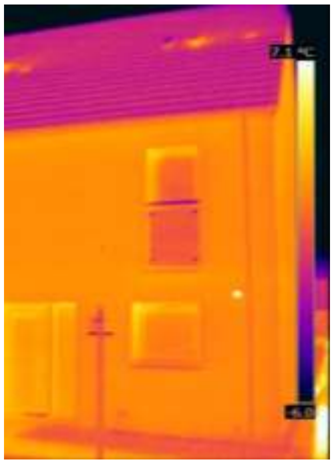


Fig. IR81 – Back elevation plot 21

Comments: The three dwellings present very similar circumstances despite their different building standards design & construction methodology. All the elevations present even surface temperatures with minimal variations. IR77 shows the front elevation of plot 21 and plot 20. Some heat loss is experienced at the top ridge of the roof in the three dwellings and this may originate from rising heat from heated spaces. Image IR79 shows the 3 dwellings with little external surface temperature differences. Images IR80 & IR81 shows the back elevations with an even distribution of surface temperatures.

Property: Block 7 – Future Affordable 2016	Type of Survey: Internal – Plot 19

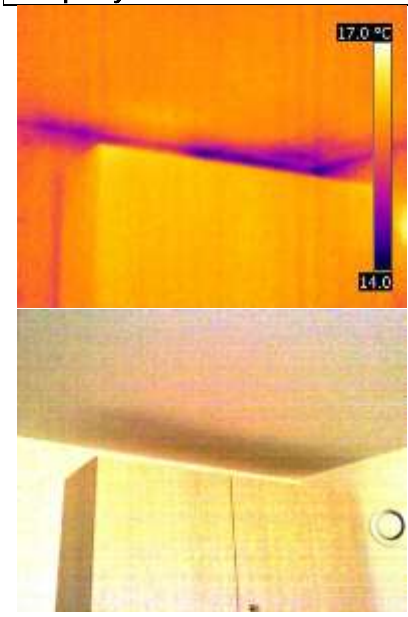


Fig. IR82 – Kitchen

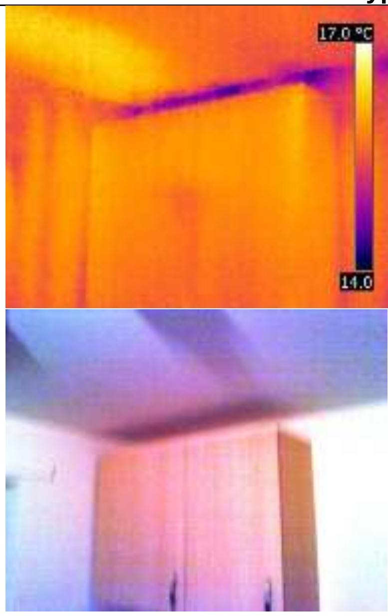


Fig. IR83– Kitchen

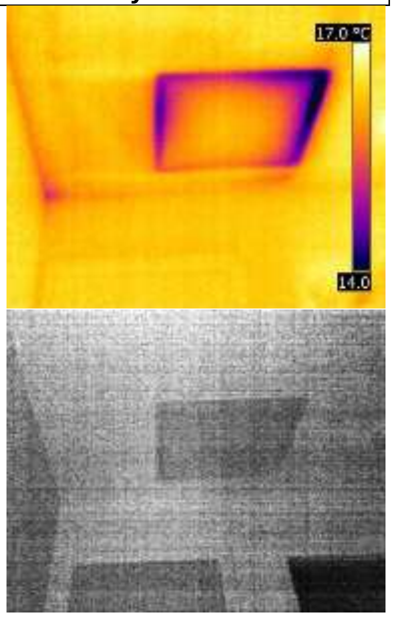


Fig. IR84 – Top of Staircase

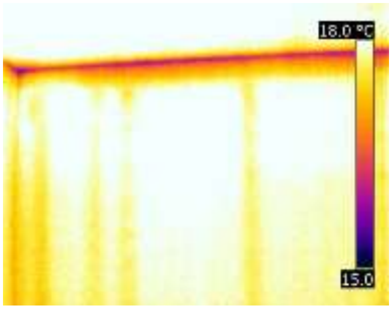


Fig. IR85 – Bedroom

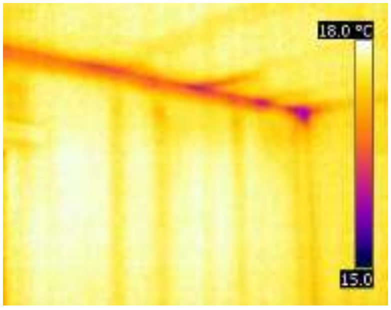


Fig. IR86 - Bedroom

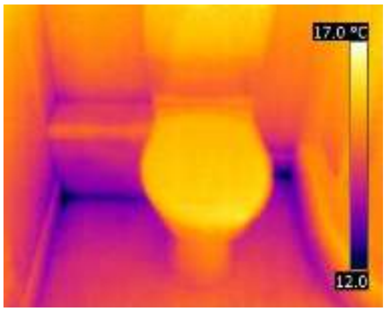


Fig. IR87 – Bathroom

Comments: Internal images show some heat loss in corners and junctions between walls and ceilings. Images IR82 & IR83 show heat loss above kitchen cabinets. These areas are close to roof eaves where insulating in small areas becomes difficult. The attic hatch in image IR84 is acting as a heat escape as lower temperatures are observed around the frame. Repeated strapping of plasterboard shows up in images IR85 & IR86. IR87 shows some heat loss at the back of the WC in the bathroom, this could be caused by services and areas where air infiltration appears.

Property: Block 7 – Future Affordable 2013 Type of Survey: Internal – Plot 20

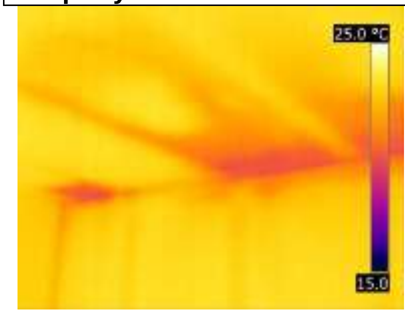


Fig. IR88 – Bedroom

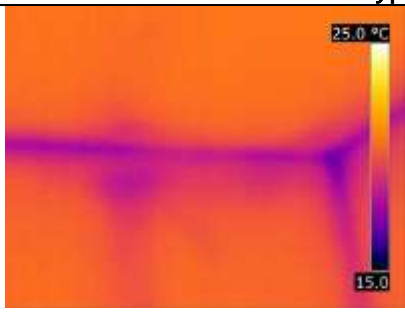


Fig. IR89– Bedroom

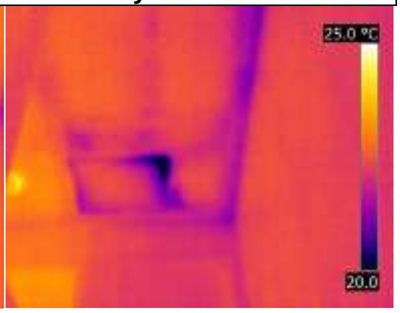


Fig. IR90 – Top of Staircase

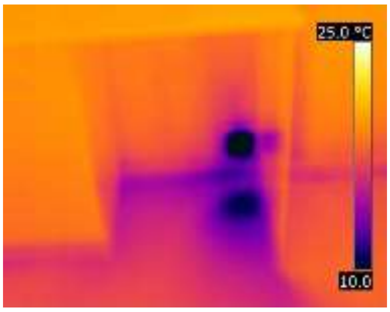


Fig. IR91 – Utility room

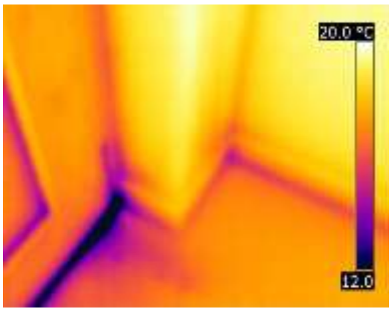


Fig. IR92 - Entrance

Fig. IR93– Bedroom

Comments: The thermograms shown above for plot 20 indicate heat loss around wall/ ceiling and around some pipe work entry points as in IR91. These entry points will be for a washing machine that will need to seal around the pipe work in order to contain air tightness. IR90 shows heat loss near the attic hatch with lower surface temperatures experienced around it too. Heat loss at eaves point on the ceiling spans into the room in images IR88 and IR93. Cold air entering under the main front door in IR92.

Property: Block 7 – Future Affordable 2010 Type of Survey: Internal – Plot 21

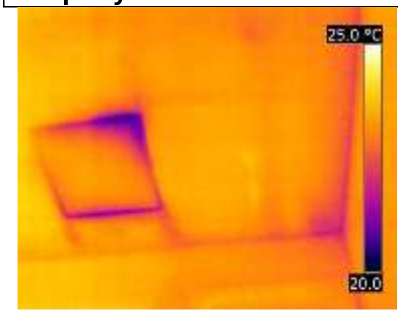


Fig. IR94– Attic hatch - stairs

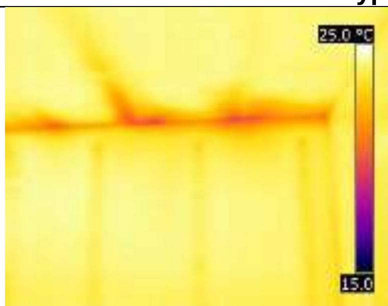


Fig. IR95– Bedroom

Fig. IR96 – Bedroom

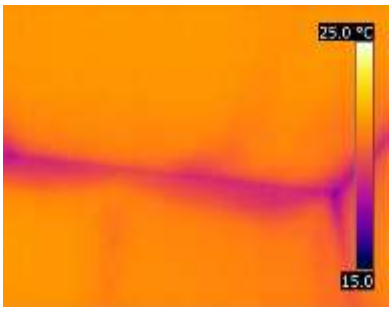


Fig. IR97 – Bedroom

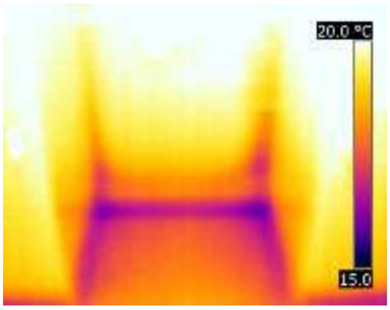


Fig. IR98- Kitchen

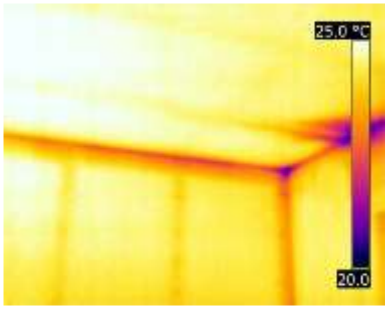


Fig. IR99 – Bedroom

Comments: The thermograms of this dwelling in plot 21 show some similar concerns observed in plots 19 & 20. A common trend has been observed in the attic hatches where heat loss is experienced around the frame edges, see IR94. There are also areas near the eaves of the roof, particularly on the ceilings, where air infiltration and a lack of insulation indicates lower surface temperatures. Although these temperature differences are between 2 & 3 ˚C they are considerable in the performance of the dwelling. Image IR98 shows heat loss at skirting level in the kitchens where cabinets are placed.

Property: Block 8 – Lomond Breathable wall	Type of Survey: External envelope

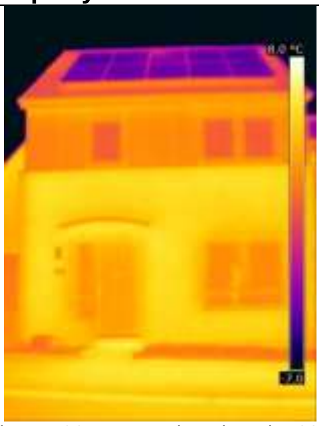


Fig. IR100 – Front elevation plot 23

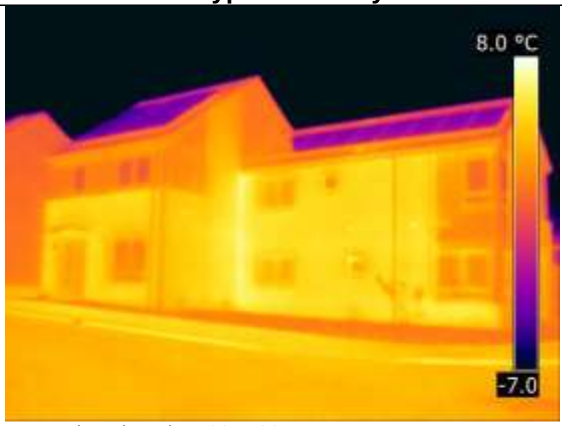


Fig. IR101– Front elevation plots 22 & 23

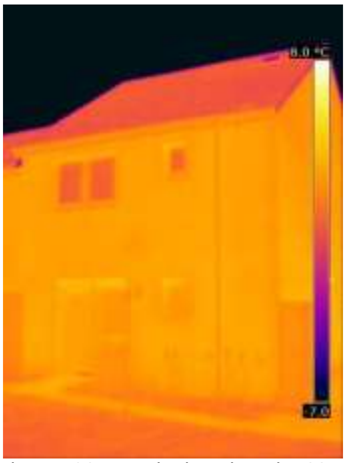


Fig. IR102– Back elevation plot 23

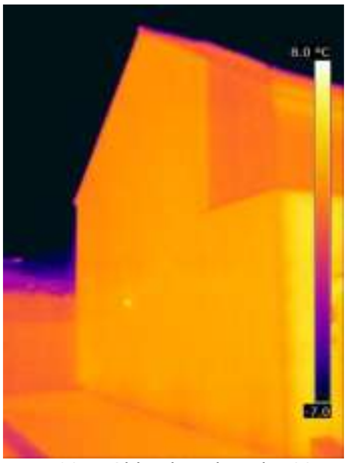
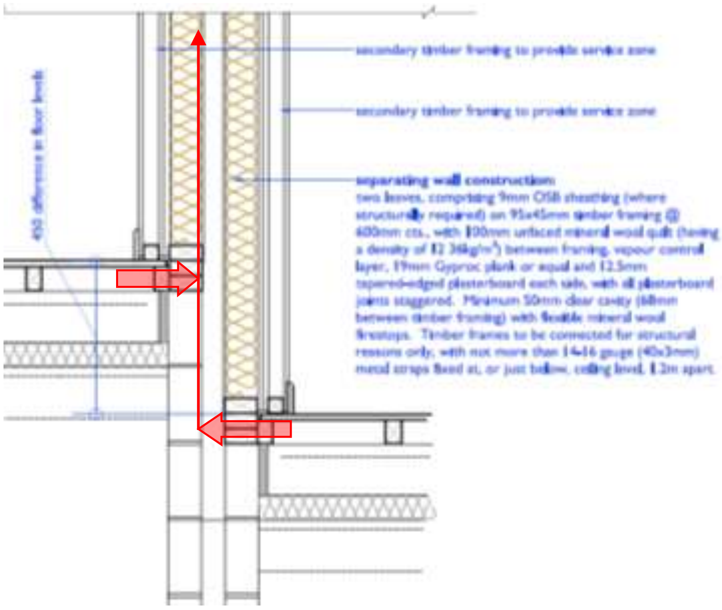


Fig. IR103– Side elevation plot 23

Fig. IR104– back elevation plot 23



Detail 11

Comments: External envelope thermograms show some changes between different wall finishes. This could be due to the different emissivity of the materials. Images IR100 and IR101 show the front elevations of the dwellings where the coloured render shows higher surface temperatures in comparison with the Marley Cedral Weatherboarding. Image IR101 also shows higher surface temperatures at the junction between the two plots. This party wall shows increased temperatures and detail 11 indicates how the design drawing specifies mineral wool insulation on both walls and heat conducting below into the cavity. Concerns appear around the party wall cap on front and back elevation junction.

Property: Block 8 – Lomond Breathable wall Type of Survey: Internal – Plot 23

Fig. IR105– Entrance lobby

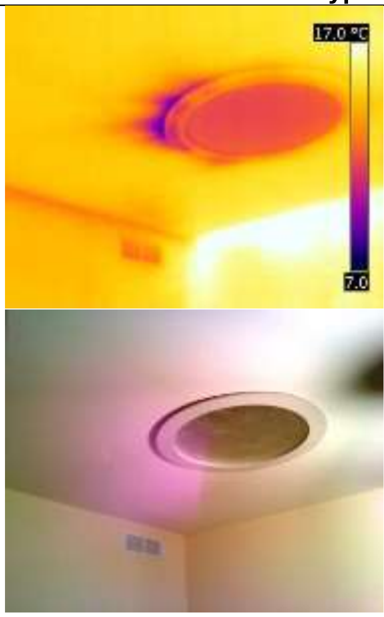


Fig. IR106 – Top of stair first floor

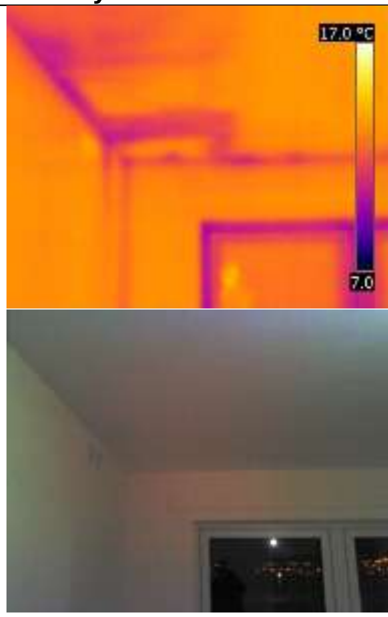


Fig. IR107– Bedroom 2

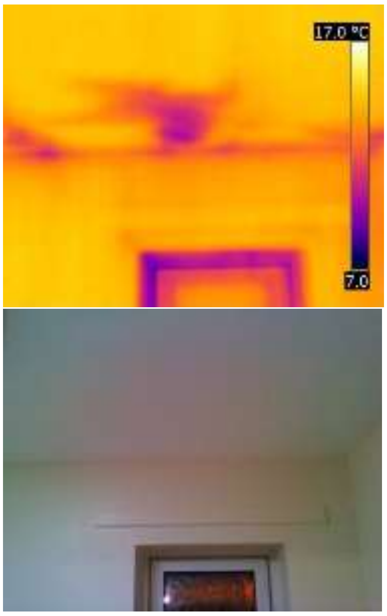


Fig. IR108 – Bathroom up stairs

Fig. IR109 - Bathroom

Fig. IR110– Bedroom 1

Comments: Internal thermograms show some concerning images both in ground and first floors. This area has at skirting level heat loss patches where a thermal bridge or air infiltration is occurring. Images IR105 and IR110 show cold air entering the rooms from northerly orientated breathing wall. Image IR107 shows bedroom 2 which is orientated southwards where no cold air is entering the room. Heat loss is appearing in around the perimeter of the sun-pipe where the frame of the element is permitting colder air to enter. Images IR108, IR109 & IR107 show missing or misplaced insulation on the ceiling level. These are close to the junction between wall/ceiling but also across the ceiling into the room and also in junctions between ceiling and vertical duct work (IR109).

Property: Block 9 – CCG IQ system	**Type of Survey: External envelope**

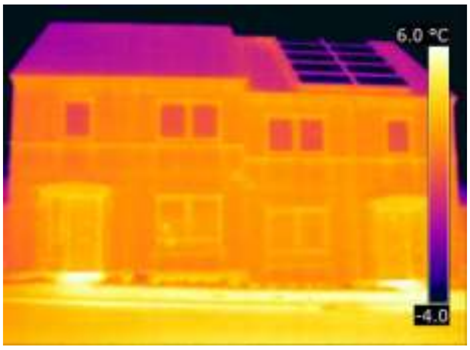


Fig. IR111 – Front elevation plot 24 & 25

Fig. IR111 – Side/ front elevation plot 24

Fig. IR112 – Front elevation plot 25

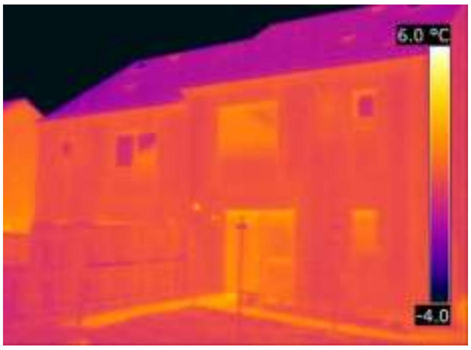


Fig. IR113– Back elevation Plots 24 & 25

Fig. IR114 – Back elevation plot 25

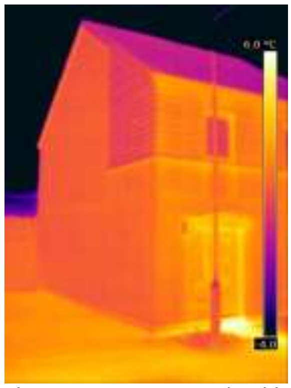
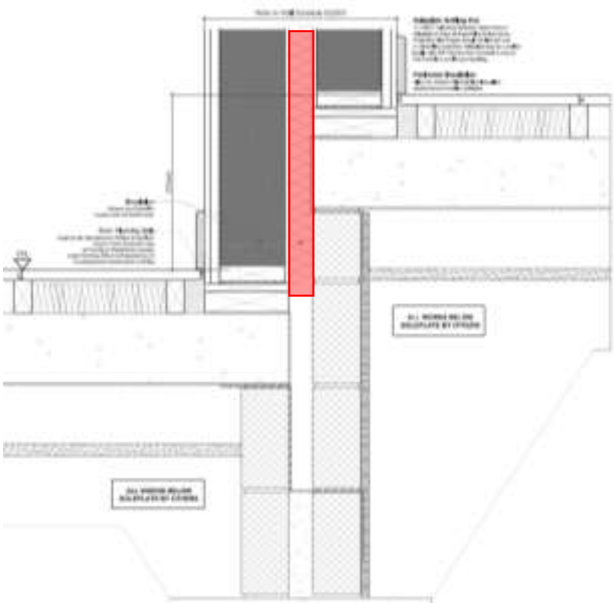
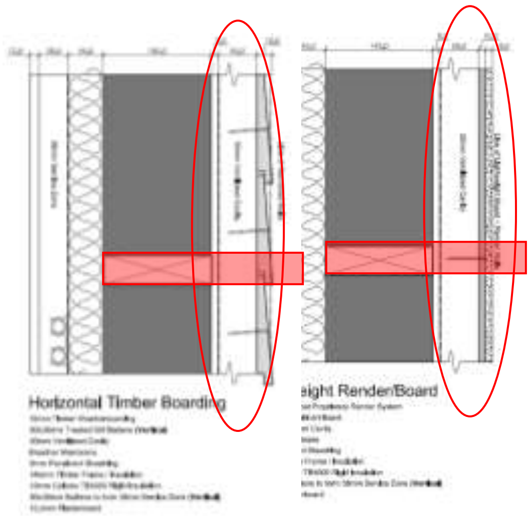


Fig. IR115 – Front/ side elevation plot 25



Detail 12



Detail 13

Comments: The thermograms of these dwellings show some concerns in various elevations. The dwellings have a dual wall finish. The upper front elevation rooms have a weatherboard as a finish and the rest of the rooms have a proprietary render. They both hold a ventilated void behind the finish. Images IR111, IR112 & IR113 show vertical lines with higher surface temperatures. Detail 13 shows the wall timber structure covered internally by insulation which would limit thermal bridging. The weatherboard and render requires a frame system which would be the reason for these cross section higher temperature lines. Detail 12 confirms that insulation in the party wall cavity between the two dwellings benefits by limiting heat loss at the wall junction.

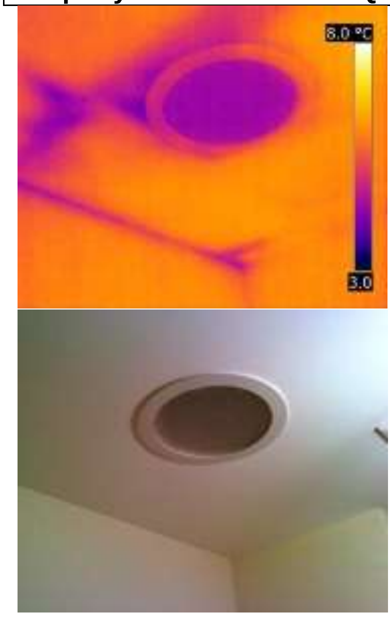


Fig. IR116– Sun pipe top of stairs

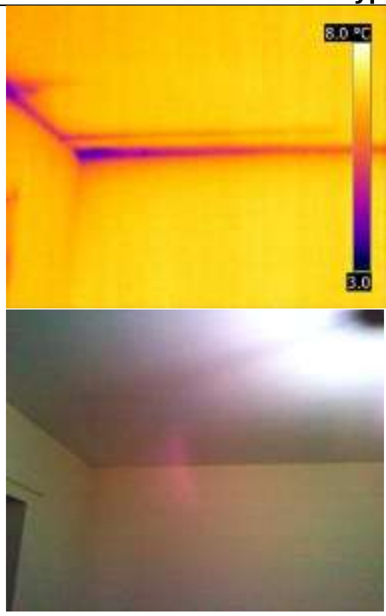


Fig. IR117 – Bedroom 2

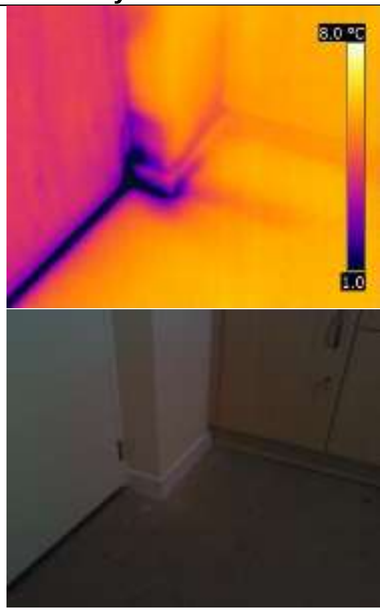


Fig. IR118– Kitchen

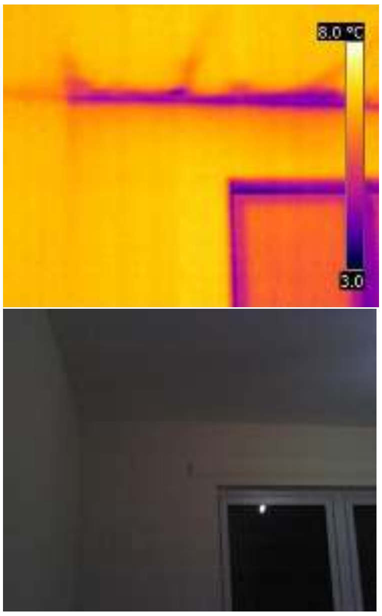


Fig. IR119 – Bedroom 1

Fig. IR120 – Bedroom 3

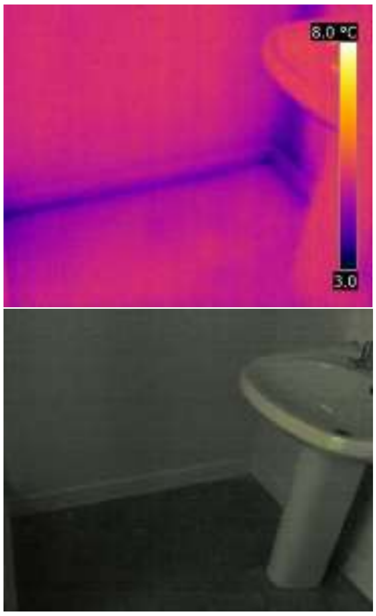


Fig. IR121– Bathroom Ground

Comments: Internally, plot 25 presents some concerns around sun pipes and ceilings close to the roof eaves. Image IR116 shows the sun pipe located at the top landing of the stair case. The detailing around it has highlighted lack of insulation or insulation that is placed incorrectly. Thermogram IR117 shows heat loss appearing close to the wall/ ceiling junction where joists may be creating a thermal bridge and additional colder surface temperatures above the window at the eaves detail. IR119 and IR120 show a similar scenario with lack of or badly placed insulation at the eaves junction with the wall. Thermogram IR121 shows some heat loss at the skirting board level in the ground floor bathroom but what is more concerning is the vertical heat loss appearing on the external wall from a timber structural element or pipe work going upwards to the first floor. Image IR118 shows heat loss at the door edge in the kitchen. This is a common heat loss path where draught proofing is not effective enough.

Property: Block 10 – Bobin Developments - BECO **Type of Survey: External envelope**

Fig. IR122 – Front elevation plots 32 & 33

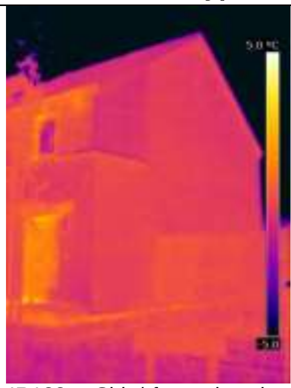


Fig. IR123 – Side/ front elevation plot 33

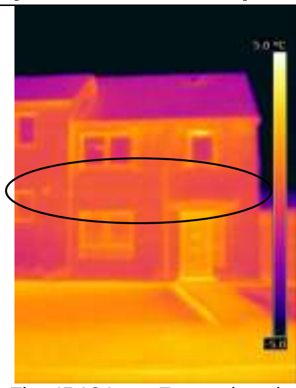


Fig. IR124 – Front elevation plot 33

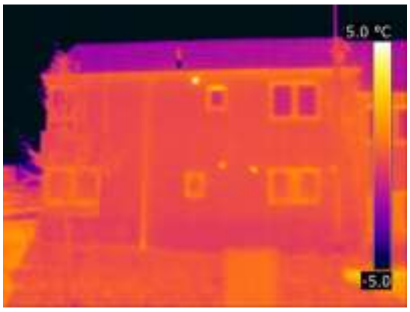


Fig. IR125– Front elevation Plot 32

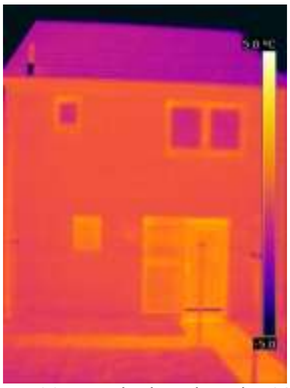


Fig. IR126 – Back elevation plot 33

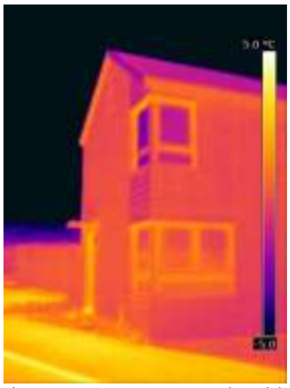
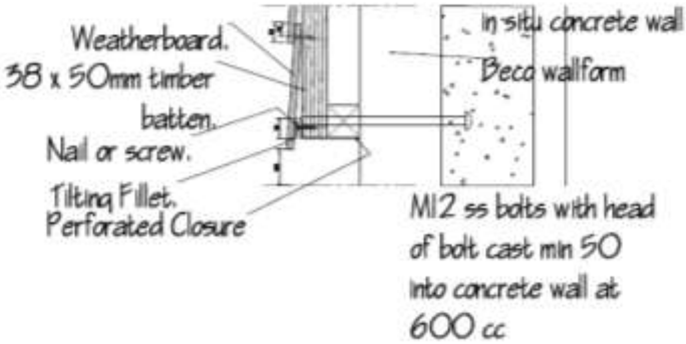
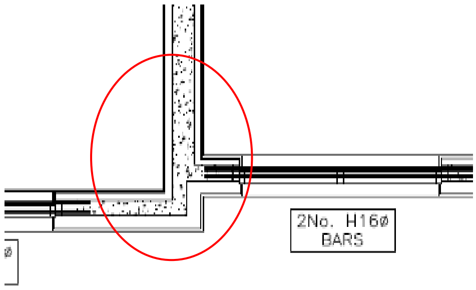


Fig. IR127 – Front/ side elevation plot 32



Detail 14



Detail 15

Comments: The external images show consistent surface temperatures across the envelope with the exception of the party wall junction and front elevation patches with heat loss near the eaves of the roof in plot 33. Image IR122 shows how some heat loss appears vertically where the party wall is positioned in between the two plots. Details of this wall were not available but detail 15 shows the how concrete core wraps round the wall and connects with both plots. This also applies to the insulation of the BECO block. Thermogram IR124 shows some heat loss patches on the weatherboarding in the front elevation of the first floor. These patches appear to be sequential. Detail 14 shows the bolts that are drilled into the concrete.

Property: Block 10 – Bobin Developments – Beco Wallform Type of Survey: Internal – Plot 33

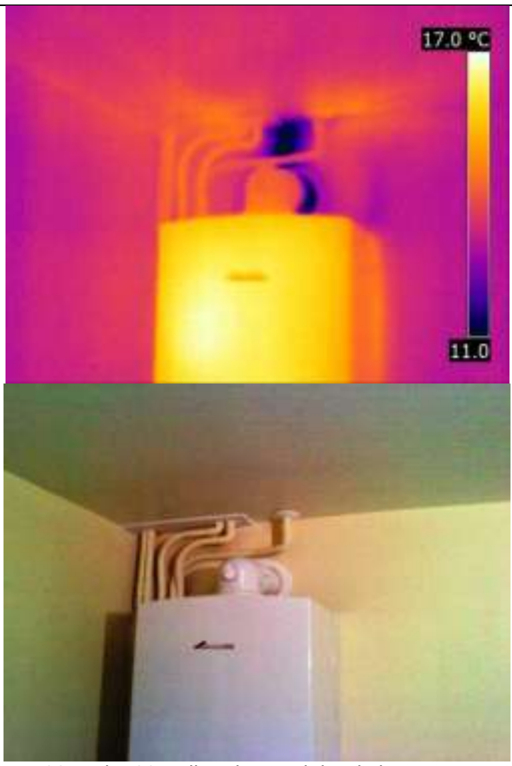


Fig. IR128 – Plot 33 Boiler pipe work in Kitchen

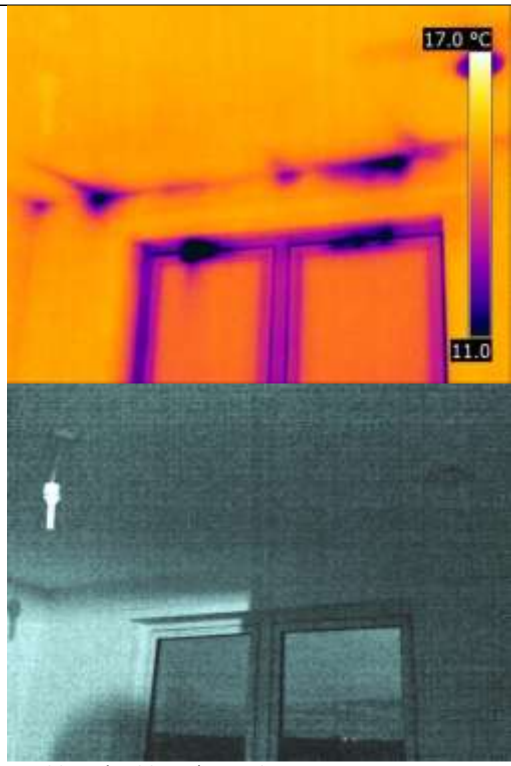


Fig. IR129– Plot 33 Bedroom 2

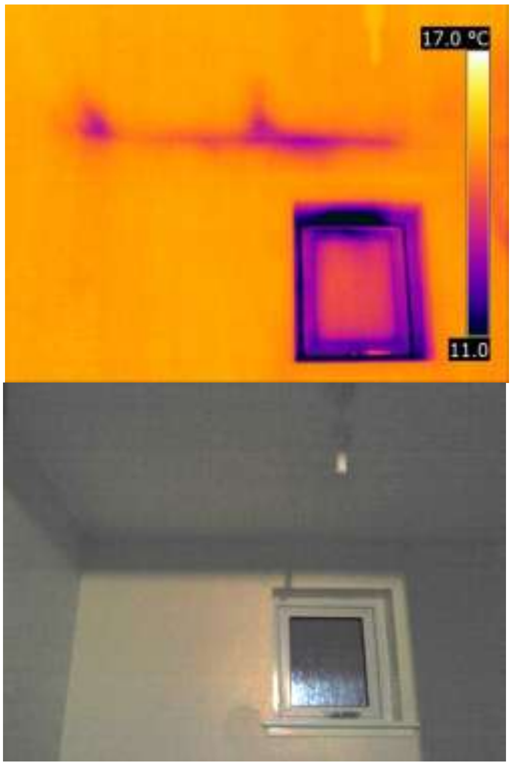


Fig. IR130 – Plot 33 Bathroom

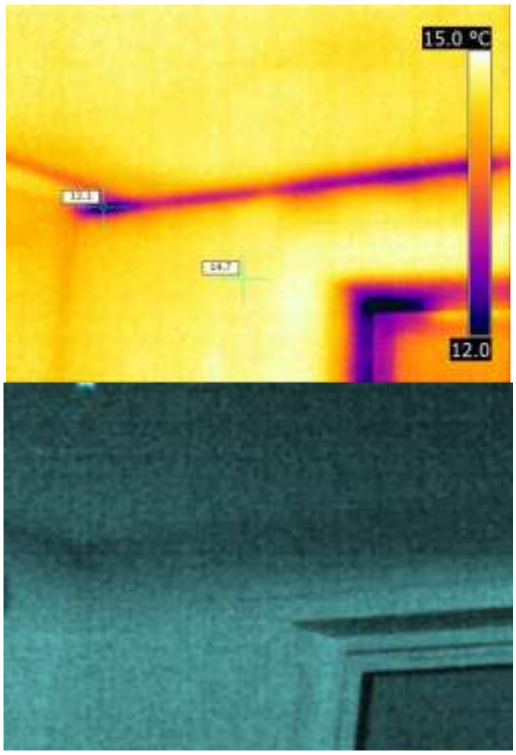


Fig. IR131 – Plot 33 Bedroom 1

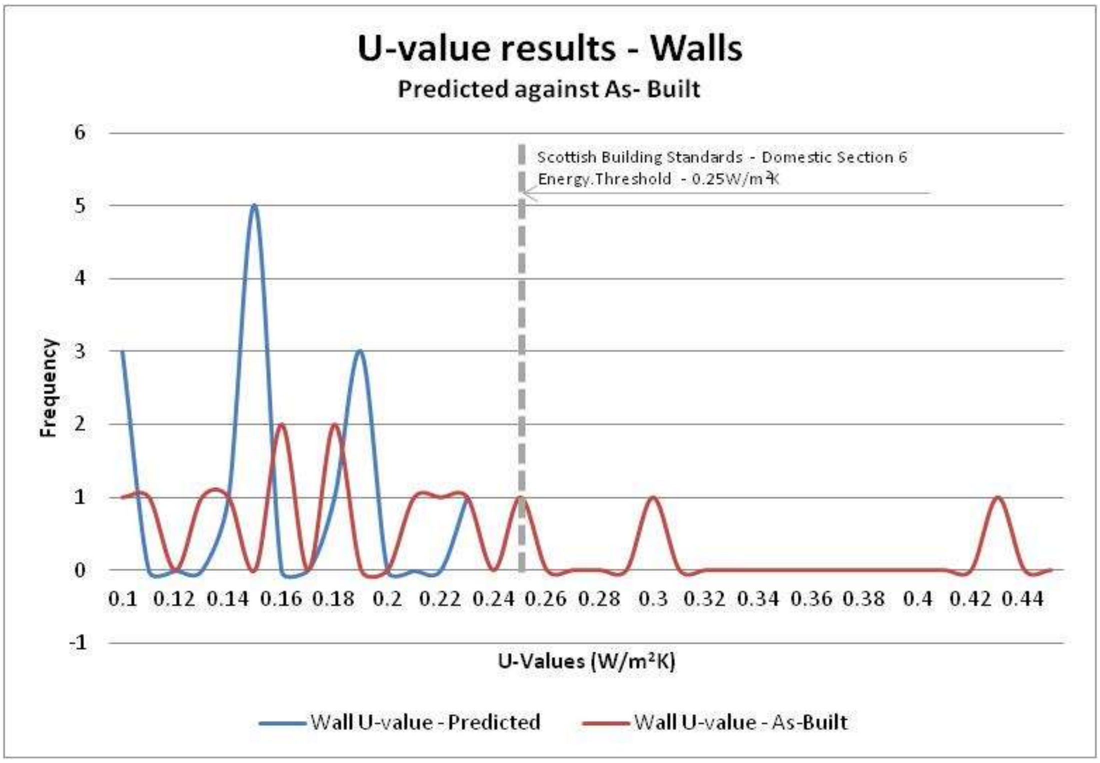
Comments: Internal thermograms of plot 33 show some concerns especially on the ceilings. IR128 shows missing insulation above the flue, which had a larger hole for positioning and was later blocked up. Image IR129 shows heat loss at ceiling level where loft insulation has not reached those areas sufficiently or possibly air infiltration is appearing. IR130 shows a similar example of this. Image IR131 shows the similar eaves ceiling/wall junction but with a greater impact on the corner of the wall where heat loss is experienced beyond the line of the eaves and across a joist or other element creating thermal bridging.

In-situ U-values

Each dwelling type was tested under the methodology explained in the Technical Appendix, page 134 where walls, roof and floors were evaluated for their as-built thermal transmittance. Each system provider has been given codes against which they can identify the U-value results obtained.

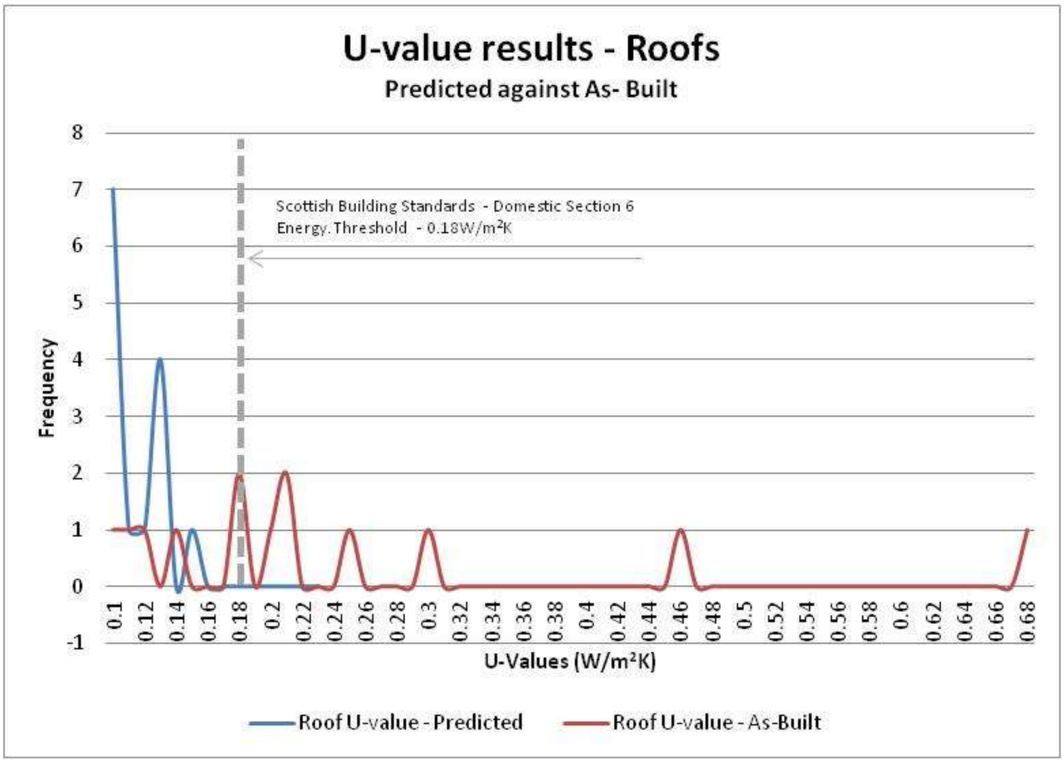
The results table 06 (page166) has been designed in such a way that each system provider with a code can identify their results in an easy and quick way. The codes start with the prefix "LCH" followed by a number for each building component; wall, roof and floor. The table is not designed to be read linearly in accordance with the assigned codes in order to anonymise the data sets as discussed earlier and commensurate with BPE practice. For example; a system provider will be given code LCH01 for the floor: at 0.27 W/m^{2}K; LCH08 for the Wall: at 0.43 W/m^{2}K and code LCH14 for the roof: at 0.46 W/m^{2}K.

Three histogram graphs have been produced to define the frequency of the results in line with the analysed data sets. The graphs highlight a trend line between the frequencies of results of the predicted values against the as-designed field test values.

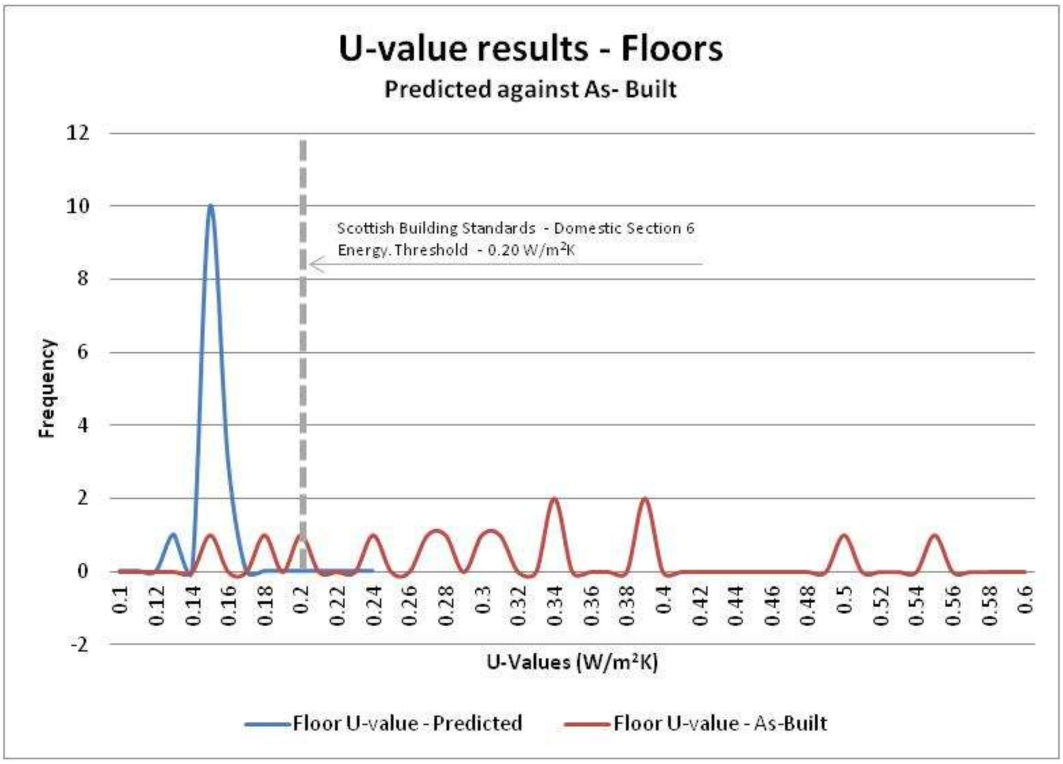


Graph 21 – Frequency analysis of walls U-value results

U-values were generally identified as being above the predicted levels calculated at design stage. From the frequency graphs, it is clear that the predicted values for walls (Graph 23) positioned themselves below 0.2 W/m^{2}K which is lower than the benchmark set by the Scottish Building Standards (SBS 2010) of 0.25 W/m^{2}K with the most frequent value identified as 0.15 W/m^{2}K. If this is compared with the as-built results, a wide frequency range is observed but the majority of values still appear below the 0.25 W/m^{2}K benchmark with a few beyond that benchmark; the highest value reaching 0.43 W/m^{2}K. The floors and roofs present a similar pattern between predicted and as-built measurements. In roofs (Graph 24), the majority of the predicted values fall under 0.15 W/m^{2}K which is below the benchmark of 0.18 W/m^{2}K. The as-built results range between 0.20 and 0.46 W/m^{2}K with a value as high as 0.67 W/m^{2}K. Floors on the other hand (Graph 25), had predicted values below 0.15 W/m^{2}K with few as-built results below the threshold, with values ranging from 0.24 W/m^{2}K to high values between 0.3 and 0.4 W/m^{2}K with some as high as 0.50 W/m^{2}K. All three components demonstrate higher than predicted U-values in the majority of dwellings, highlighting concerns over predicted values in estimating performance and the potential under-performance of elements as reported by BBA & NHBC Foundation (BBA, 2012).



Graph 22 – Frequency analysis of roof U-value results



Graph 23 – Frequency analysis of floor U-value results

Kingdom Housing Association – Housing Innovation Showcase

Results table 06

In situ As-built Thermal transmission values (U-values)

Building code	Floor U-Value result	Wall U-Value result	Roof U-Value result
LCH 01	0.39	0.18	0.25
LCH 02	0.24	0.1	0.68
LCH 03	0.15	0.13	0.18
LCH 04	0.2	0.16	0.2
LCH 05	0.39	0.21	0.1
LCH 06	0.34	0.18	0.7
LCH 07	0.27	0.14	0.11
LCH 08	0.31	0.11	0.3
LCH 09	0.18	0.3	0.21
LCH 10	0.55	0.16	0.18
LCH 11	0.3	0.25	0.14
LCH 12	0.28	0.22	0.21
LCH 13	0.5	0.43	0.12
LCH 14	0.34	0.23	0.46

U-value range (W/(m.K)): Floor 0.1–0.6; Wall 0.1–0.5; Roof 0.1–0.8

Table 3 - In situ As-built Thermal transmission values (U-values)

Sound Insulation Testing

To assess the level of sound insulation of the new build separating floors and walls.

SOUND INSULATION TESTING
DUNLIN DRIVE
DUNFERMLINE
KY11 8EX

Technical Report No. R-5944-EQ-NR

8th June 2012

Kingdom Housing Association

2 Natal Place

Cowdenbeath

Fife

KY4 8HX

For the attention of Bill Banks

Introduction

We were instructed by Bill Banks of Kingdom Housing Association to carry out measurements of the sound insulation of the party floor and party walls between newly built residential apartments at Dunlin Drive, Dunfermline.

The measurements were carried out on the following dates;

- First site visit – 10th March 2012
- Second site visit – 26th April 2012
- Third site visit – 27th April 2012

Measurements were undertaken on the first visit by Nicola Robertson BEng(Hons), PGDip, MIOA and Scott Lothian BEng(Hons), PGDip, MIOA. and on the second and third visits by Nicola Robertson and Emma Quayle BA(Hons).

Wall specification

The location of the wall sections as tested are shown below in Table 1.

Table 1. Dunlin Drive, Dunfermline – Sound Insulation Test - Walls

Block	Source Room	Volume (m^3)	Receiving Room	Volume (m^3)
1 - Powerwall	Plot 4 Bedroom2	35	Plot 1 Bedroom 2	35
	Plot 3 Bedroom 2	35	Plot 2 Bedroom 2	35
2 - Campion	Plot 5 Bedroom 2	35	Plot 8 Bedroom 2	35
	Plot 7 Bedroom 2	35	Plot 6 Bedroom 2	35
3 - Stewart Milne	Plot 12 Bedroom 2	35	Plot 9 Bedroom 2	35
	Plot 11 Bedroom 2	35	Plot 10 Bedroom 2	35
4 - Campion	Plot 14 Front bedroom	40	Plot 13 Front Bedroom	40
	Plot 14 Rear Bedroom	32	Plot 13 Rear Bedroom	32
5 - Cube	Plot 16 Front Bedroom	40	Plot 15 Front Bedroom	40
	Plot 16 Rear Bedroom	32	Plot 15 Rear bedroom	32
6 - Campion	Plot 18 Living room	65	Plot 17 Living room	65
	Plot 18 Rear Bedroom	32	Plot 17 Rear Bedroom	32
7 - Springfield	Plot 20 Kitchen	45	Plot 21 Kitchen	45
	Plot 20 Kitchen	45	Plot 19 Kitchen	45
8 - Lomond	Plot 23 Kitchen	39	Plot 22 Kitchen	61
	Plot 23 Rear Bed	27	Plot 22 Bedroom	61
9 - CCG	Plot 25, Living room	45	Plot 24, Living room	45
	Plot 25, Bedroom 2	33	Plot 24, Bedroom 2	33
10 - Bobin	Plot 33 Front Bedroom	27	Plot 32 Front Bedroom	27
	Plot 33 Living room	40	Plot 32 Kitchen	30

It is understood that the wall constructions as tested were as follows:

Block 1 - Powerwall

The party wall as tested comprised of 64 mm LGS metal studs at 600mm crs. Lined on exposed face with 12 layers 12.5mm tapered edge plasterboard, all joints staggered and taped and filled for jointless finish, 100mm insulation quilt between studs. Wall lined on hidden face (within cavity) with 30mm Powerwall high density quilt/batt (180kg/m3)

Block 2 - Campion:

The party wall as tested consisted of a twin stud timber frame construction with timber studs either side of a cavity. The wall was finished on both room sides with 19mm plank and 12.5mm plasterboard.

Block 3 – Stewart Milne:

The party wall as tested consisted of a twin stud timber frame construction with 89mm timber studs either side of a 63mm cavity (fully filled with 70mm insulation), pre-fitted with 9mm OSB to the cavity side of the party wall panel where required structurally to one leaf only. The wall was finished on both room sides with 19mm plank and 12.5mm plasterboard.

Block 4 - Campion:

The party wall as tested consisted of two leaves of 100mm Porotherm block either side of a 100mm cavity (with 35mm Isover RD35 insulation within cavity), finished to room sides with parge coat, 19mm plank and 12.5mm plasterboard.

Block 5 - Cube:

The party wall as tested consisted of two layers of 15mm Gyproc wallboard, Mineral wool packed between 45 x 25mm treated SW battens, Tyvek Airguard vapour control layer and two 119 SIPS Eco Panels either side of a 50mm cavity.

Block 6 - Campion:

The party wall as tested consisted of an asymmetrical – one leaf 235x38mm stud with insulation between studs and one leaf 89x35mm stud with insulation between studs - timber frame construction with timber studs either side of a cavity. The wall was finished on one room side with 19mm plank and 12.5mm plasterboard and on the other with 19mm plank and 12.5mm plasterboard on 25mm rigid insulation and finally with 12.5mm plasterboard to provide a 25mm service void.

Block 7 - Springfield:

The party wall as tested consisted of 12.5mm plasterboard (untapped) on 19mm plank (staggered joints), 95 x 45 treated Solid Wood frame 100mm APR1200 low density mineral fibre, standard breather membrane or Netlon. 50 mm APR1200 low density mineral fibre rolls fixed to top edge and tacked to bottom, rolls staggered with opposite leaf.

Block 8 - Lomond:

The party wall as tested was a cavity wall construction of two leaves, comprising 9mm OSB sheathing (where structurally required) on 95x45mm timber framing at 600mm cts., with 100mm un faced mineral wool quilt (having a density of 12-36kg/m3) between framing, a vapour control layer, 19mm Gyproc plank or equal and 12.5mm tapered-edged plasterboard on each side, with all plasterboard joints staggered.

Block 9 - CCG:

The party wall as tested was a twin timber frame construction with each leaf separated by a 50mm cavity, fully filled with mineral wool and comprising of 12.5mm plasterboard and 19mm plank plasterboard on a 140mm timber frame incorporating 140mm *Knauf Frametherm40* insulation and sheathed with a layer of 9mm *Panelvent* board.

Block 10 - Bobin**:**

The party wall as tested consisted of 313mm Becofirewall blocks with a 200mm in-situ concrete core finished on both sides with 12.5mm plasterboard on 50x50mm timber strapping.

Floor specification

Table 2. Dunlin Drive, Dunfermline – Sound Insulation Test - Floors

Block	Source Room	Volume (m^3)	Receiving Room	Volume (m^3)
1 - Powerwall	Plot 4 Bedroom 2	35	Plot 3 Bedroom 2	35
	Plot 4 Living room	65	Plot 3 Living room	65
2 - Campion	Plot 5 Bedroom 2	35	Plot 6 Bedroom 2	35
	Plot 8 Bedroom 2	35	Plot 7 Bedroom 2	35
3 - Stewart Milne	Plot 12 Bedroom 2	35	Plot 11 Bedroom 2	35
	Plot 12 Living room	65	Plot 11 Living room	65

The location of the floor sections as tested are shown below in Table 2.
*** Source and receiver room reversed for impact test**

It is understood that the floor constructions as tested were as follows;

Block 1 - Powerwall

The party floor as tested consisted of 18mm chipboard on 45 x 45mm SW battens on 30mm Powerwall high density quilt/batt all on a 100mm Powerwall SIPS panel. The ceiling below consisted of a 100mm Powerwall SIPS panel lined with 12.5mm plasterboard on 25mm resilient bars and 30mm Powerwall high density quilt/batt.

Block 2 - Campion

The party floor as tested consisted of 22mm chipboard and 19mm plank on 70mm resilient battens with 60mm insulation between battens and a 15mm structural deck all on the timber joists. The ceiling below consisted of 19mm plank and 12.5mm plasterboard on 16mm resilient bars.

Block 2 – Stewart Milne

The party floor as tested consisted of 22mm chipboard and 19mm plank on 75mm resilient battens with 25mm insulation between battens and a 15mm OSB structural deck all on the timber joists with 100mm insulation between joists. The ceiling below consisted of two layers of 15mm Fireline plasterboard on 16mm resilient bars.

Equipment used

The equipment used conformed to the requirements of BS EN ISO 140 *Measurement of sound insulation in buildings and of building elements Part 4: Field measurements of airborne sound insulation between rooms* (1998) and *Part 7: Field measurements of impact sound insulation of floors* (1998).

The following items of equipment were used during the measurement:-

Equipment	Serial No.	Date of calibration expiration	Calibration certification no.
Brüel & Kjær Modular Precision Sound Level Meter Type 2260 running Building Acoustics Module Type BZ7204	2120171	09/2013	C1107489
Brüel & Kjær Prepolarised Condenser Microphone Cartridge Type 4189	2431002	09/2013	C1107489
Brüel & Kjær Sound Level Calibrator Type 4231	1780570	09/2013	C1107489
Brüel & Kjær Modular Precision Sound Level Meter Type 2260 running Building Acoustics Module Type BZ7204	2399619	21/10/2013	10027
Brüel & Kjær Prepolarised Condenser Microphone Cartridge Type 4189	2386220	21/10/2013	10026
Brüel & Kjær Sound Level Calibrator Type 4231	2393980	21/10/2013	10025
JBL EON10 G2 Sound Source	13150	n/a	n/a
JBL EON10 G2 Sound Source	13374	n/a	n/a
Norsonic Tapping Machine Type Nor277	2775686	29/09/2013	1180187

Measurement procedure

The sound level meter was calibrated before the measurements at the calibration level of 93.9 dB re 2×10^{-5} Pa at 1000 Hz. The deviation from the previous calibration level was insignificant and within the tolerance for Class 1 sound level meters.

Attended source and receiver room measurements were performed using multiple fixed microphone positions and a two-speaker (uncorrelated) sound source (defined in ISO 140-4:1998 Sections 6.3.2 & 6.3.3).

The following attended measurement procedures were followed during each airborne sound insulation test:

L_1	**Source room L_{eq} measurement: 5 static positions of 6 second duration**
L_2	Receiver room L_{eq} measurement: 5 static positions of 6 second duration
T_2	Receiver room reverberation time measurements: 6 static positions (two source positions)
B_2	1 spatially averaged 30 second receiver room background noise measurement

The following impact sound insulation measurement procedures were followed:

L_2	**1 spatially averaged 30 second receiver room SPL measurement for each location (6 individual tapping machine locations were used)**
T_2	6 receiver room reverberation time measurements (2 speaker positions)
B_2	1 spatially averaged 30 second receiver room background noise measurement

During measurements the background noise was predominantly due to construction activities on site. The background noise levels did not unduly influence the sound insulation result. For rooms overlooking Dunlin Drive vehicle noise was the main background source. Again this did not unduly influence the sound insulation results.

Results

The full airborne sound insulation results of the separating wall constructions are given in Figures 1-20. The single figure sound insulation ratings calculated in accordance with BS EN ISO 717: 1997 are shown in Table 3 relative to the requirements of Section 5 of the Technical Handbook to the Building (Scotland) Regulations 2004.

Table 3. Dunlin Drive, Dunfermline – Sound Insulation Tests - Walls

Block	Source Room	Receiving Room	Airborne $D_{nT,w}$ (Min 53 dB)	Pass/Fail
1 - Powerwall	Plot 4 Bedroom2	Plot 1 Bedroom 2	63	Pass
	Plot 3 Bedroom 2	Plot 2 Bedroom 2	65	Pass
2 - Campion	Plot 5 Bedroom 2	Plot 8 Bedroom 2	62	Pass
	Plot 7 Bedroom 2	Plot 6 Bedroom 2	60	Pass
3 - Stewart Milne	Plot 12 Bedroom 2	Plot 9 Bedroom 2	63	Pass
	Plot 12 Bedroom 2	Plot 11 Bedroom 2	60	Pass
4 - Campion	Plot 14 Front bedroom	Plot 13 Front Bedroom	55	Pass
	Plot 14 Rear Bedroom	Plot 13 Rear Bedroom	53	Pass
5 - Cube	Plot 16 Front Bedroom	Plot 15 Front Bedroom	55	Pass
	Plot 16 Rear Bedroom	Plot 15 Rear bedroom	54	Pass
6 - Campion	Plot 18 Living room	Plot 17 Living room	63	Pass
	Plot 18 Rear Bedroom	Plot 17 Rear Bedroom	60	Pass
7 - Springfield	Plot 20 Kitchen	Plot 21 Kitchen	67	Pass
	Plot 20 Kitchen	Plot 19 Kitchen	66	Pass
8 - Lomond	Plot 23 Kitchen	Plot 22 Kitchen	66	Pass
	Plot 23 Rear Bed	Plot 22 Bedroom	66	Pass
9 - CCG	Plot 25, Living room	Plot 24, Living room	67	Pass
	Plot 25, Bedroom 2	Plot 24, Bedroom 2	66	Pass
10 - Bobin	Plot 33 Front Bedroom	Plot 32 Front Bedroom	56	Pass
	Plot 33 Living room	Plot 32 Kitchen	62	Pass

The results given in Table 3 indicate that the sound insulation of the tested wall constructions have complied with the requirements laid down in the aforementioned regulations.

The full sound insulation results of the separating floor constructions are given in Figures 21-26 (airborne) and Figures 27-32 (impact). The single figure sound insulation ratings calculated in accordance with BS EN ISO 717: 1997 are shown in Table 4 relative to the requirements of Section 5 of the Technical Handbook to the Building (Scotland) Regulations 2004.

Table 4. Dunlin Drive, Dunfermline – Sound Insulation Tests - Floors					
Block	**Source Room**	**Receiving Room**	**Airborne $D_{nT,w}$ (Min 52 dB)**	**Impact $L'_{nT,w}$ (Max 61 dB)**	**Pass/Fail**
1 - Powerwall	Plot 4 Bedroom 2	Plot 3 Bedroom 2	65	53	**Pass**
	Plot 4 Living room	Plot 3 Living room	62	51	**Pass**
2 - Campion	Plot 5 Bedroom 2	Plot 6 Bedroom 2	60	55	**Pass**
	Plot 8 Bedroom 2	Plot 7 Bedroom 2	57	54	**Pass**
3 - Stewart Milne	Plot 12 Bedroom 2	Plot 11 Bedroom 2	63	52	**Pass**
	Plot 11 Living room	Plot 10 Living room	59	53	**Pass**

The results given in Table 4 indicate that the sound insulation of the party floor construction has complied with the requirements laid down in the aforementioned regulations.

Prepared by:

Nicola Robertson ______________________

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Approved by:

Chris Steel ______________________

BSc (Hons), MPhil, MIOA

Witnessed Handover

Prospective residents were invited for a viewing of the property offered for rent in order to establish if they wished to accept the offer. The following is a description of the walkthrough conducted in June 2012.

Figure 10 – Handover procedure

The demonstrator explained to the prospective residents that the viewing would be witnessed by an independent evaluator and permission was obtained for photographs of the process to be taken.

The initial viewing of a two bedroom house was managed by Kingdom Housing Association's Housing Officer, Marie Paterson and Carmen Hunter, Project Development Officer, who both showed the property to a family with a young child. The contractor's representative joined the viewing for the technical demonstration during the event.

The viewing was also attended by a family friend who assisted by interpreting in English/Chinese languages. As the family had little English, Kingdom made arrangements for a professional interpreter to be present however, the interpreter was unable to find the location of the development and in the event, it was the family friend who helped with interpreting the proceedings. The viewing lasted about 45 minutes.

Figure 11 – Handover procedure

Signing the tenancy agreement

Early on during the viewing the prospective resident confirmed that they wished to accept the offer of the house and, with all the necessary documents having been prepared by Kingdom staff in advance, the tenancy was signed during the viewing.

The signing of the tenancy was accompanied by advice covering the following:

- Summarising contents of tenancy agreement, ending tenancy including period of notice , antisocial behaviour, arrears, service charge
- permissions if resident wishes to make material changes in the house, keeping pets, erecting sheds, planting, being away from home for a long holiday, repairs and complaints.
- Eligibility for housing and child benefit and procedure for applying
- Buying second hand furniture and cooker / location of a second hand store / sourcing second hand furniture via websites such as Gumtree /local newspapers.

Figure 12 – Demonstration of heating

Demonstrating Systems

Figure 13 – Explanation of terms of tenancy agreement

The viewing commenced from the living room with discussion over **Feed in Tariff (FiTs)**. It was explained that residents needed to understand that reimbursement of money from FiTs would be made to Kingdom and that excess electricity would be sold to the grid. At this point demonstration included pointing to electrical sockets, telephone and TV aerial, operating windows, including how to operate the safety hinge and how to open/lock/unlock rear door into the garden.

This was followed by demonstration of the **central heating programmer** and the demonstrator explained that the programmer can be set to turn itself on and off at different times of the day - depending on preference and this was followed by a physical demonstration - day by day - how to change time and day on the programmer, followed by advice that the programmer can be left on 'auto' or if the heating is not needed, the CH function of the programmer should be turned off. This was followed by demonstration of how to set hot water function and how to change the time settings depending on preference. This demonstration was followed by looking at the **thermostat** to explain that it regulates temperature in the house.

Next followed demonstration of an in-home **energy display system** by explaining that its display was based on a traffic light system with green indicating 'ok' energy use, 'orange' indicating 'warning' and 'red' advising to try and reduce energy use. Residents were advised not to turn it off to allow Kingdom to monitor energy use remotely for the purpose of research.

Figure 15 –Explanation on how to use the heating programmer

Figure 14 - Demonstration how to regulate hot water in the shower

It was also made clear that full instructions on how to operate the programmer are included in the **Resident Handbook**.

The demonstration then moved upstairs where the following technologies were explained in detail: operation of an electric shower, fire alarm and carbon monoxide detectors. This part of the viewing concluded by explanation of how to report **defects**, emergency repairs and advice on **Kingdom's targets** for attending to **emergency, reactive and routine repairs**.

GLOSSARY

Air Permeability: The physical property used to measure the air tightness of a building. It is representative of the leakiness of a building with respect to air. The higher the air permeability, the leakier the building. Air permeability is defined as the air leakage rate per external envelope area of the building at a reference test pressure difference of 50 Pa for the inside of the building relative to the outside. The units of measurement are m3/(h.m2). This is airflow in metres cubed per hour through the building envelope per metre-squared of external envelope area. Air permeability is measured using a blower door.

Air Tightness Testing: Air tightness testing is the procedure to trace any unwanted drafts and uncontrolled airflow through a dwelling. Too much air leakage leads to heat loss resulting in higher CO2 emissions.

'As-built' Performance: Describes performance that has been re-calculated using measured post-construction data applied to the original SAP calculation to give an estimated actual performance of the dwelling.

'As-designed' Performance: Describes the predicted performance during the design stage using SAP.

Building Fabric: The building fabric is a critical component of any building, since it both protects the building occupants and plays a major role in regulating the indoor environment. Consisting of the building's roof, floor slabs, walls, windows, and doors, the fabric controls the flow of energy between the interior and exterior of a building.

Dwelling Emission Rate (DER): The DER is the carbon emission rate for a dwelling as calculated using the national calculation methodology (SAP). The units of measurement are kgCO2/m2.a. This is kilograms of carbon dioxide emitted from the building per metre squared of floor area per annum.

Heat flux Measurements: Heat flux is the rate of heat energy transfer through a given surface, measured in W/m2. Heat flux sensors allow measurement of direct heat flow through various elements of the building fabric.

Mechanical Ventilation: Is a system of fans and ducts used to extract stale air and bring fresh air into a building. Mechanical ventilation can include the recovery of waste heat from the outgoing air, which is used to pre-heat the incoming air - Mechanical Ventilation with Heat Recovery (MVHR).

Standard Assessment Procedure (SAP): SAP is the national calculation methodology used to calculate the energy performance of new dwellings. The model was originally developed by the Building Research Establishment (BRE) and has been continually adapted to reflect changes in the requirements of the Building Regulations. The latest version is SAP 2009, which was updated to reflect the changes in the most recent building regulations in England, Wales, Scotland and NI.

Target Emission Rate (TER): The TER is the regulatory target carbon emission rate for a dwelling as calculated using the national calculation methodology (SAP). The units of measurement are kgCO2/m2.a. This is kilograms of carbon dioxide emitted from the building per metre squared of floor area per annum.

Thermal Bridge: A thermal bridge is created in an external building element when there is a pathway for heat flow through the element that avoids or short-circuits the designed insulation layer. Thermal bridges occur at junctions between elements such as wall corners. These are called geometric thermal bridges. Repeating thermal bridges occur in regular patterns such as the case of conductive steel wall ties penetrating through an insulation layer in a wall cavity. Non-repeating thermal bridges will arise due to specific design features such as a combined steel window or door lintel that will bridge the insulation layer.

Thermal Imaging: A non-invasive means of observing and diagnosing the condition of dwellings through temperature differentials. It can be used to check for high heat loss paths in dwellings. It can also assist in identifying building features that create thermal bridges, to check or prove insulation continuity, to find hidden leaks, and a source of damp in a dwelling. Thermal imaging can be used to evaluate and verify improvements and remedial works made to the fabric of dwellings subsequent to problems being diagnosed.

Thermograms: Display surface temperatures in a range of colours. With skilled interpretation, thermograms of heated buildings can show comparative heat loss through different elements of the building envelope and thermal weaknesses.

Thermal Performance: Each 'element' of the building envelope - a wall, a roof, a floor, a window or a door - has a role to play in minimising heat loss. The insulating effect of each of these elements is measured by its U-value.

U-value: A measure of the flow of heat through a building element such as a wall, floor or ceiling. The lower the U-value, the better the insulating ability of the building element. The units of measurement are W/m2K. This is Watts of heat flow per metre squared area of building element per degree Kelvin temperature difference between the two sides of the building element.

REFERENCES

Report

1. Behaviour Change and Energy, Department of Energy and Climate Change
2. Building Post Occupancy Evaluation of the Quarries for Dunedin Canmore Housing Association
3. Changing Household Energy Behaviours: Key Findings From A Review Of Applied Research, Tamsyn Wilson and Liz Hawkins, Scottish Government Built Environment Research
4. Climate Change Behaviours Research Programme 2010-12, Scottish Government (2011)
5. Domestic Ventilation Compliance Guide, (2010 Edition)
6. Good Homes Alliance Monitoring Programme 2009-20011 Technical Report
7. International Review of Behaviour Change Initiatives, February 2011
8. Living With Environmental Change (LWEC) (2009)
9. Low & Zero Carbon Homes: Understanding the performance challenge, NHBC Foundation, (2012)
10. Motivating Sustainable Consumption: A Review of Evidence on Consumer Behaviour and Behavioural Change Jackson, (2005)
11. New Psychology of Leadership: identity, influence and power, Reicher,(2010)
12. NHBC Standards 2014 Chapter 3.2, Accessed at: **http://nhbcnews.co.uk**
13. The Psychology of sustainable Behaviour, Minnesota Pollution Control Agency, 2009
14. The Rebound Effect Report, The UK Energy Research Centre (UKERC), http://www.ukerc.ac.uk/support/ReboundEffect
15. Review of overheating in highly insulated homes in the UK, NHBC Foundation project, (2012).
16. Scottish Environmental Attitudes Survey Report, Scottish Government by Ipsos Mori 2008 **http://www.scotland.gov.uk/Resource/Doc/280711/0084578.pdf**
17. Synthesis Review of the Public Understanding Research Projects, Defra (2007)
18. Technology Strategy Board (September, 2010), Building Performance Evaluation, Domestic Buildings – Guidance for Project Execution
19. Tipping Point or Turning Point? Social Marketing & Climate Change, Ipsos Mori (2007)
20. What Works in Behaviour Change Event, Scottish Government **http://www.scotland.gov.uk/Resource/Doc/175356/0112485.pdf**

Technical Appendices

1. BBA Technical Report No 1 (2012), An investigation into the effect of air movement on the thermal performance of domestic pitched roof constructions, BBA, NHBC Foundation.
2. BSI (2001) Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method, BS EN 13829: 2001, BSI
3. ATTMA (2007) Technical standard 1 – Measuring air permeability of building envelopes, Issue 2, ATTMA – note that this is based on BS EN 13829.
4. CIBSE (2000) Testing buildings for air leakage, CIBSE Technical Memorandum 23, CIBSE, London
5. Hart, J.M. (1991) ‘A practical guide to infra-red thermography for building surveys’, BRE Paper 176, BRE, Watford
6. CIBSE. (2006). *Energy assessment and reporting method - TM22* (p. 32).
7. BSI (1999) Thermal performance of buildings – Qualitative detection of thermal irregularities in building envelopes – Infrared method, BS EN 13187:1999, BSI.
8. Doran, S. (2000) Field investigations of the thermal performance of construction elements as built, BRE Report 78132, BRE Watford
9. Baker, P. (2008) In situ u-value measurements in traditional buildings – preliminary results, Report to Historic Scotland, Glasgow Caledonian University
10. Hukseflux (2010) Application and specification of heat flux sensors, Hukseflux, Delft, Netherlands
11. ISO (1994) Thermal insulation -- Building elements -- In-situ measurement of thermal resistance and thermal transmittance, ISO 9869: 1994
12. Scottish Building Regulations (2011), Scottish Building Standards section 6 Energy. Section 6.2.4, 3.14 & 3.14.2

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