

One Brighton

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

Innovate UK project number	450009
Project author	Good Homes Alliance
Report date	2014
InnovateUK Evaluator	Tom Kordel (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
5 apartments	Brighton, Sussex	Multi-story apartments	2008 - 2010
Area	Construction form	Space heating target	Certification level
Various (see report)	Reinforced concrete with Thermoplan infill walls	<30 kWh/m ² per annum	2006 <i>Building Regulations</i>

Background to evaluation

One Brighton is a mixed-use development comprising residential blocks with office and community space. Five apartments were monitored, with fabric testing and an occupant survey. The buildings have an efficient thermal envelope, and use sustainable construction materials and low-energy appliances. Biomass and gas boilers and MVHR systems provide heat. A PV array was estimated to generate up to 7600 kWh per annum. Design targets for carbon emissions were less than 25 kgCO₂/m² per annum, with electrical consumption less than 45 kWh/ m² per annum. Intensive monitoring of five occupied apartments was carried out for between 15 and 20 months.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes

The results from One Brighton revealed that a fabric-first approach to building design can result in a significant reduction in energy demand for space heating compared to the building stock. The designed performance of the fabric at One Brighton was slightly better than that required to meet the minimum Fabric Energy Efficiency Standards (FEES) for zero carbon homes targets in 2016. The measured carbon intensity for delivered communal heat at 0.5 kgCO₂/kWh was ten times that predicted, and twice that which would have been expected had the development used individual gas boilers as the main heat source. Emissions were related mainly to high distribution losses, high pumping energy and the use of the back-up communal gas boiler in preference to the communal biomass boiler.

Occupant survey type	Survey samples	Structured interviews
BUS domestic	Various. See report (page 42)	Yes

Winter and summer occupant surveys were conducted on 172 dwellings (i.e. six months apart), generating response rates of 35% and 30%. The results from the first BUS survey showed that the majority of residents found the living conditions to be healthy and satisfactory. Around 80% of residents who responded indicated that the building met their needs. At the time of the first survey, comfort conditions in winter were thought to be better than in summer. The main health issues reported were related to noise, dust, pollution, air dryness, and the heating and ventilation systems. The results from the summer survey showed that most people remained satisfied and comfortable. Noise and antisocial behaviour were negative issues. In general, people were satisfied with space and layout.

Avante Housing Development

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Innovate UK project number	450011 (related to 450077 and 450078)
Project lead, authors, and client	School of the Built Environment, Oxford Brookes University, CA Sustainable Architecture, and Four Walls for Crest Nicholson PLC
Report date	August 2015
InnovateUK Evaluator	Tom Kordel (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
150 (2 plots sampled)	Maidstone, Kent	Private & social housing	2007 - 2011

Area	Construction form	Space heating target	Certification level
85.2 m ² (Sample)	Timber panel	52.3 kWh/m ² per annum	EcoHomes (Excellent)

Purpose of evaluation

The two-storey houses and flats over garages were a mixture of open-market, shared ownership and affordable houses. The houses were equipped with Mechanical Ventilation with Heat Recovery (MVHR) and used a structurally insulated timber panel system (SIPS) construction. The study investigated the as-built performance of the building compared with design predictions, the interaction of residents with their homes, and their comfort through the seasons, and the potential for improvements in the developer's business processes to produce better performing homes.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP 2005)	No	No

Homes were constructed using SIPs and were designed for high tightness and thermal insulation. Simple gas central heating systems with an MVHR unit were installed. The study covered final construction stages and early occupancy and therefore no monitoring of operational energy use was completed and therefore findings in relation to the energy strategy are limited. The SIP panels were believed to function well, but analysis of the party wall in the co-heating test showed significant heat loss. It was concluded that the cavity between the house walls was not properly filled with insulation and sealed, leading to air movement and heat loss from the cavity. The airtightness was shown to be 5.82 m³ (m².h), above the target of 5 m³ (m².h). The MVHR unit was tested through on site flow rate measurements and was found to be significantly lower than that specified by the system designer. The usability of the heating and hot water controls was not intuitive and users needed instructions to use it properly. The MVHR system was not intuitively understandable, labelling and annotation was confusing, and the control panels difficult to use.

Occupant survey type	Survey sample	Structured interview
Domestic BUS	42 of 135 (31% response rate)	N/A

Generally, the occupants were very satisfied with the housing development overall and were particularly appreciative of the location, spatial, layout and appearance of the homes. However, a number of issues were identified in relation to usability and environmental conditions.

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Innovate UK project number	450014 Related study: 450070 (phase 2)
Project author	Leeds Beckett University for the Gentoo Group
Report date	2013
InnovateUK Evaluator	N/A

No of dwellings Two 2-bedroomed terraced bungalows	Location Houghton-le-Spring	Type Terraced bungalows (one end and one mid-terrace)	Constructed 2011
Area 66 m ²	Construction form Pre-fabricated timber-frame	Space heating target N/A	Certification level CSH Level 4

Background to evaluation

The two chosen bungalows form part of a development of 28 bungalows. 25 of the bungalows were terraced units (8 end-terrace 17 mid-terrace), with the remaining 3 bungalows being detached. All 25 terraced bungalows on the development were designed to PassivHaus standards and either *Code for Sustainable Homes* (CSH) Level 4 or 5. Eighteen dwellings had solar thermal systems installed. In addition, five dwellings with solar thermal systems also had PV systems to enable them to achieve Level 5 of the CSH.

Design energy assessment No	In-use energy assessment N/A	Sub-system breakdown N/A
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A significant attention to detail was given to airtightness, with considerable care taken to ensure continuity of the air barrier membrane around openings, such as windows. However, gaps, some quite considerable, were observed between the sole plate and the damp-proof course. Tears were also observed in the foil-faced membrane used as an air barrier, resulting in discontinuity of the air barrier. The sills at all of the openings were not protected from the elements resulting in the mineral wool insulation used to fill these sections becoming saturated. Where services penetrated the external layer of bitroc, no attempt appeared to be being made to seal the penetration. Some of these issues were resolved before handover. The tested mean air permeability values of the two dwellings were 0.89 m³ (m².h) @ 50 Pa and 1.31 m³ (m².h) @ 50 Pa.

Occupant survey type BUS domestic	Survey sample 21 of 27 (77.7% response rate)	Structured interview N/A
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Results showed that occupants found the air movement in the properties to be too still during both summer and winter, with additional concerns about air being excessively humid in summer. One possible reason for this could be incorrect use of the MVHR system, which should have provided sufficient fresh air to the dwelling. Some residents had been confused by the advice to keep windows closed to improve MVHR efficiency, and interpreted it as an instruction to not open windows. Overall, the consensus was that the dwellings were of high quality, with residents enjoying living in them and happy with their performance.

The Old Apple Store, Stawell

Phase 1 study

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Innovate UK project number	450015
Project author	Oxford Institute for Sustainable Development: Low Carbon Building Research Unit
Report date	2011
InnovateUK Evaluator	Ian Mawditt (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
Five	Stawell, Somerset	Detached and terraced	2009
Area	Construction form	Space heating target	Certification level
Various. See report	Timber frame	29.5 kWh/m ² per annum	CSH level 5 (SAP 2005)

Background to evaluation

The objectives of the BPE study involved collaborative sub-studies undertaken by the designers, developer and researchers which covered the development process from inception through to early occupancy. The study involved performance assessment of the openpanel timber frame fabric, assessment of occupant satisfaction in relation to orientation, open planning and daylighting. The study examined the design process and the initial design intentions for The Old Apple Store as well as the rationale behind any changes made during the development and construction process. A technical study focused on a 120 m² terraced house (No. 2).

Design energy assessment	In-use energy assessment	Sub-system breakdown
N/A	N/A	N/A

The target of CSH level 5 with zero carbon emissions for heating and lighting was to be achieved by utilising a super insulated timber frame construction with low air permeability, 2.04 kWp photovoltaic panels and solar thermal water heating. Additional water and space heating was provided by a 1 kW wood pellet burner and all houses have rainwater harvesting systems for toilets and washing machines. The research found a significantly better than assumed Standard Assessment Procedure (SAP) value for heat loss and thermal bridging elements, a better heat loss for the external fabric of a tested home than originally predicted by SAP, good occupant satisfaction with the housing in relation to orientation, open planning and daylighting, and satisfaction with overall comfort conditions, with perceived positive health benefits from the detached units.

Occupant survey type	Survey sample	Structured interview
N/A	N/A	Yes

A structured interview was conducted with the occupants in one of the properties. The occupants found it very easy to live in, with well-balanced environmental conditions. They were pleased with the renewable energy systems (solar hot water and photovoltaic panels) as the initial earnings they got from the PV array almost matched the cost of the electricity they used. They were not satisfied with the handover and information pack received; they felt it was not particularly organised, put together in a hurry and was not thorough enough. The occupants found the mechanical extract system to be relatively poor; it ran constantly and could not be adjusted. Overall, there was very poor control of the ventilation system.

Cross Lane Development

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

No of dwellings 22 properties: 18 tenanted, 4 in shared ownership*	Location Royston, Barnsley	Type 2 detached, 20 semi-detached*	Constructed 2011
Area 82 - 120 m ²	Construction form Timber frame	Space heating target N/A	Certification level CSH Level 4

Background to evaluation

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

Design energy assessment Yes	In-use energy assessment No	Sub-system breakdown No
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The houses were supplied with grid electricity and a 2.4 kWp photovoltaic array, designed to supply up to 1938 kWh of electricity per annum. Heating was by mains gas-fired condensing boiler and radiators. A detailed analysis of the water harvesting system was conducted. The design and construction audit did not reveal any significant changes between the as-designed and as-built. The designed SAP for Plot 5 was 93 whereas the reviewed SAP figure remained at 93. The air permeability test prior to testing was 6.15 m³ (m².h) @ 50 Pa. The post testing air permeability was 5.96 m³ (m².h) @ 50 Pa. The heat loss coefficient was 103.12 W/K (design value: 107.41 W/K, reviewed design value was 108.58 W/K).

Occupant survey type BUS Domestic	Survey sample 11 of 18 (61 % response rate)	Structured interview Yes
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Air conditions in the summer were humid and stuffy, whereas for winter its was too still. Temperature fluctuations were evident in the winter. This may have been due to the air tight nature of the house and heat losses as identified. The occurrence of light in the building, either natural or artificial edged towards 'too much'. Interviews were undertaken with residents in six properties at Cross Lane.

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Innovate UK project number	450023 Related study: 450049 (phase 2)
Project author	Cambridge Architectural Research Ltd for bere:architects
Report date	2011
InnovateUK Evaluator	Jason Palmer (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
Single	London (Camden)	Detached 2-storey house	2010
Area	Construction form	Space heating target	Certification level
101 m ²	Prefabricated timber frame	<15 kWh/m ² per annum	PassivHaus

Background to evaluation

The structure of the house consists of larch and spruce prefabricated elements made in Austria. It has 280 mm of Rockwool Flexi insulation in floor and walls, with 380 - 400 mm of insulation in the roof, and an air tightness membrane stapled and taped throughout. Calculated U-values for roof, floor and walls vary from 0.07 to 0.14 W/m²K. The house has a heat loss parameter of 35 ±15 W/K for both ventilation and fabric losses and 33.4 ±12 W/K for fabric losses alone. It achieved an air tightness test result of 0.53 m³ (m².h) @ 50 Pa. Low carbon technologies include solar hot water collector, MVHR, and rainwater harvesting.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes

PHPP calculations estimated total annual energy use of 97 kWh/m² per annum (compared with 120 kWh/m² per annum required to achieve PassivHaus certification). MVHR power consumption was measured at 42 W at 130 m³/h, 30 W at 99 m³/h, and 23 Watts at 72 m³/h compared with standard testing. Sensors showed that the solar thermal system was not generating as much thermal energy as expected. Examination on the roof showed that the installation was incorrect: the design specified that the collector be installed flat with tubes running East-West whereas it was installed with tubes running North-South. The air tightness test indicated 0.53 m³ (m².h) at 50 Pa, better than the design target of 0.6 m³ (m².h) at 50 Pa. A co-heating test identified a total heat loss of 35 ±15 W/K, beating the design target.

Occupant survey type	Survey sample	Structured interview
BUS Domestic	1 person	Yes (2 people)

The occupants were satisfied with the MVHR, noting that it is responsive and easy to use. They prefer the PassivHaus concept of heating through heat recovery to a conventional system as the house is always warm. During winter, temperatures are considered to be stable and always sufficiently high, and are usually kept in the 20 - 22°C range. Mechanical ventilation is only adjusted by using the boost ventilation control in bathroom, only occasionally after showers. There were no reported problems with humidity. The mechanical ventilation is quiet and there are no complaints from the occupant.

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InnovateUK project number	450040 Related study: 450013 (Phase 1) ²
Project author	Leeds Beckett University for Joseph Rowntree Housing Trust
Report date	2014
¹InnovateUK Evaluator	Ian Mawditt (Contact via www.bpe-specialists.org.uk)

²Johnston, D., Miles-Shenton, D., & Farmer, D. (2015). Quantifying the domestic building fabric 'performance gap.' *Building Services Engineering Research and Technology*. 36(5). 614–627. <https://doi.org/10.1177/0143624415570344>

No of dwellings	Location	Type	Constructed
Six	New Earswick, York	Mixed	2011
Areas	Construction form	Space heating target	Certification level
Various (see report)	Hemcrete timber-frame system	N/A	Level 4 Code for Sustainable Homes

Background to evaluation

This report outlines the findings obtained from an in-use performance and post occupancy evaluation study undertaken on a small mixed-tenure development of six dwellings. The development comprised two 4-bed detached bungalows for supported living, and four 4-bed terraced family dwellings for rent or shared ownership. Due to monitoring issues, data is incomplete in many areas, limiting the ability of the research team to draw confident conclusions with regard to environmental conditions and energy use. However, internal conditions in both intensively monitored dwellings suggested possible areas for improvement.

Design energy assessment	In-use energy assessment	Sub-system breakdown
No	No (Equipment failures)	No (Equipment failures)

One bungalow and one terraced dwelling were subjected to intensive in-use monitoring of electricity consumption disaggregated by end-use. However, heat meter and pulse meter failures and problems with access to the homes hampered data collection and analysis. Physical tests included air-pressurisation tests, thermographic surveys and MVHR duct flow measurements. The bungalow achieved a mean air permeability of 4.89 m³ (m².h) @ 50Pa, a slight decrease from a test undertaken in 2011. Dwelling 4 (mid-terrace) achieved a mean air permeability of 7.00 m³ (m².h) @ 50Pa, a slight improvement from a test undertaken in 2011. The MVHR systems in both dwellings appeared to be significantly unbalanced. Less intensive monitoring was carried out on the four remaining dwellings.

Occupant survey type	Survey sample	Structured interview
BUS domestic	4 of 6 (66% response rate)	No

Feedback from residents in the BUS survey showed dissatisfaction with their energy usage (both heating and electricity), the mechanical ventilation and heat recovery system, and the fact that a number of the issues that they had identified within the home had been outstanding for a significant period of time. The indoor air quality issues identified by the residents were reinforced by the MVHR duct flow measurement results. General feedback was positive, with the majority of responses returning either 'green' or 'amber' mean scores on the BUS semantic differential scales.

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InnovateUK project number	450049 Related study: 450023 (Phase 1)
Project author	UCL and RMIT for bere:architects
Report date	2014
¹InnovateUK Evaluator	Jason Palmer (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
Single	London (Camden)	Detached 2-storey house	2010
Area (TFA)	Construction form	Space heating target	Certification level
101 m ²	Prefabricated timber frame	<15 kWh/m ² per annum	PassivHaus

Background to evaluation

This report covers a two year evaluation of a PassivHaus certified a two-bedroom, two storey, south-facing single family detached house. See the Phase 1 report for structural details of the house and its engineering services. The Phase 2 study involved the analysis of two years-worth of monitored data. The study also included the design and testing of a new long-life ventilation system filter concept developed to facilitate easy changing of filters without third parties needing to enter the property.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes

The Phase 2 BPE air tightness test indicated 0.71 m³ (m².h) at 50 Pa, below the design target of 0.6 m³ (m².h) at 50 Pa. Angled window heads were considered the culprit for the decline in airtightness over time, as the top of the window cannot be made as airtight as is ideal, and the window is less strong than a rectangular window. The tilt-and-turn windows had been roughly treated, evidenced by a broken metal component in the closing mechanism of one tilt-and-slide window. Rough treatment of the window mechanisms was also seen during construction. A second co-heating test identified a total heat loss of 56 ± 5 W/K. The second test was considered more reliable than the Phase 1 test due to more appropriate weather conditions. The solar thermal system was found not to generate the expected thermal energy due to installation deficiencies.

Occupant survey type	Survey sample	Structured interview
BUS Domestic	2 persons	Yes (2 people)

The residents were generally very satisfied with all aspects of thermal comfort and general house performance. The occupants reported a good air quality throughout the year with winter and summer conditions rated as the highest possible level of satisfaction. Air was noted as odourless, fresh (slightly less in summer) and with good moisture content (not dry or humid). Both in winter and summer, air was considered still. Lighting and noise were overall rated satisfactory although the comments noted the bathroom to be too dark and that the gaps under the doors allowed for noise between the rooms.

Malmesbury Gardens

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Innovate UK project number	450050
Project lead, authors, and client	Swindon Council, Oxford Brookes University
Report date	April 2015
InnovateUK Evaluator	xxx (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
13 (2 plots sampled)	Swindon	Terraced houses	2011

Area	Construction form	Space heating target	Certification level
94 m ² (typical)	Timber frame with solid external walls and Hempcrete	N/A	Code for Sustainable Homes (5)

Purpose of evaluation

Malmesbury Gardens was a social housing scheme intended to provide an innovative approach to affordable mixed-tenure housing design, procurement and finance. It consisted of 13 houses built to Code for Sustainable Homes Level 5 criteria. All homes achieved SAP rating A for both energy efficiency and environmental performance. Two houses had a co-heating test, infrared thermography, air permeability testing, in-situ U-value measurement test, review of commissioning processes, observation of the handover process, a BUS questionnaire survey, a walkthrough and interviews with the occupants. The construction was based on the application of Hempcrete. Hempcrete was cast into a timber frame to achieve high thermal mass levels in combination with optimized U-Values. The airtightness target of 2 m³ (m².h) was not met.

Design energy assessment	In-use energy assessment	Sub-system breakdown
SAP A (99)	SAP B (88) recalculated	Yes (both plots)

The primary heating system was based on exhaust air heat pumps. The NIBE Fighter 410P heat pumps used the warm air inside the dwelling as its primary heat source, drawing the heat energy via the ventilation system. In addition, the heat pump is supplemented with solar pre-heat which supplies hot water to the unit, thereby reducing the amount of electricity consumption by the heat pump’s compressor. The heat pumps serve underfloor heating systems. Most of the houses did not have the heating system adjusted correctly and were given instructions of how to use it more efficiently. Not all tenants had read the Home User Guide resulting in a lack of knowledge about the system’s operation. The MVHR system in both plots were found to be unbalanced resulting in increased energy use, noise and draughts. The systems were recommissioned.

Occupant survey type	Survey sample (two plots)	Structured interview
BUS (domestic)	13 and 19 (Responses: 9 and 11)	N/A

The houses performed well compared to other surveyed UK houses. Variables that fell significantly below the BUS benchmarks were air quality during summer (which appeared to be drier than expected), control over cooling, and noise levels from outside and in between the rooms. Occupants in both houses found the electricity bills were high. They were not satisfied with the heat pump performance.

Community In A Cube

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InnovateUK project number	450052
Project author	Leeds Beckett University for the Good Homes Alliance
Report date	2013
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Single apartment	Middlesbrough	Flat	2011
Area (TFA measured)	Construction form	Space heating target	Certification level
42.9 m ²	Concrete frame	N/A	Building Regulations

Background to evaluation

The apartment studied formed part of a zero carbon, residential-led, mixed-use development comprising 80 residential units and retail/leisure space. The apartment building adopted the BioRegional and WWF International 10 One Planet Living principles (Bioregional Quintain, 2012²). The apartment was heated using a communal biomass-fuelled boiler. The scope of the project was limited to the post-construction and initial occupation stages and consisted of physical tests alongside occupant satisfaction analyses.

²BioRegional Quintain (2012). *One Planet Living*. London, Bioregional Quintain. Available from <http://www.bioregional-quintain.com/one-planet-living>

Design energy assessment	In-use energy assessment	Sub-system breakdown
Partial	No	No

Physical tests and energy analysis included a co-heating test air-pressurisation tests, a SAP check, design and construction review, thermographic survey, heat flux measurements, and an installation and commissioning review of systems and services. However, difficulties were encountered while measuring the total heat loss for the apartment, which was outside the control of the research team. Although the apartment tested was found to be of average airtightness by prevailing UK standards it was leakier than would normally be the case with MVHR. The MVHR system was not performing as intended and was probably not commissioned *in situ*. Heat flux measurements also revealed that, with the exception of the windows, the external elements failed to perform close to their design specification. Limited commissioning data was available.

Occupant survey type	Survey sample (all apartments)	Structured interview
BUS domestic	3 of 57 (5% response rate)	With building manager

Many apartments were unoccupied during the time allocated for BUS questionnaire surveying. Furthermore, the majority of occupied apartments were inhabited by temporary overseas workers, who were attending a six-month training course in the local area. As a result, there was a very poor return rate. Discounting temporary workers, at the time of BUS distribution there were nine permanent occupants. This improved the return rate to 33%, but the sample size was still too small to be considered broadly informative.

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InnovateUK project number	450054
Project author	ECD Architects for Hanover (Scotland) Housing Association Ltd
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Six	Livingston	One and a half storeys	2010
Area	Construction form	Space heating target	Certification level
Areas not reported	Timber frame	N/A	Scottish <i>Building Regulations</i>

Background to evaluation

The homes were designed for low maintenance and long lifespans, with a choice of materials and flexibility for future use being crucial to the concept. Natural Building Technologies was selected as the preferred choice of construction with timber frame, exterior wood fibre solid walls, breathable render and hemp insulation. The dwellings incorporated a natural ventilation strategy in place of MVHR, and the use of natural breathable construction materials.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP)	Yes (DomEARM)	Yes (not reported)

Heating and hot water provision were provided by conventional domestic condensing combi-boiler systems. Energy use assessments were carried out on representative properties: a mid-terrace and end terrace dwellings. Energy use data was run through the DomEARM engine to provide comparisons with the in-built benchmarks. Mid-terrace consumption: Electricity 31.4 kWh/m² per annum, gas 79.0 kWh/m² per annum. End terrace consumption: Electricity 40.5 kWh/m² per annum, gas 88.6 kWh/m² per annum. **Note: All detailed energy data, including gross and/or treated floor areas, was reported in an appendix which is missing from the published InnovateUK report.**

Occupant survey type	Survey sample	Structured interview
BUS domestic	11 of 15 (73% response rate)	No

The overall summary of the main issues in the BUS survey indicated that the dwellings scored similar to, or better than, scale midpoints and the benchmarks of comparative dwellings on the BUS database. The scores were variable, but most respondents noted a stable summer and winter temperature. However, the responses suggest that while the houses are prone to overheating in the summer and difficult to keep cool, they perform better in winter. There appeared to be a year-long issue regarding the dryness of the air. This was considered a function of the inherent airtightness of the construction.

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InnovateUK project number	450055
Project author	Glasgow School of Art for Glasgow Housing Association
Report date	2013
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Four	Glasgow	Semi-detached	2010
Areas	Construction form	Space heating targets	Certification level
Not reported	2 Clay block 2 Timber frame	Not reported	Not reported

Background to evaluation

The Glasgow Houses were prototype designs using passive principles along with tried, tested, simple and low maintenance technologies to reduce heating and hot water bills for tenants. The aim was to provide a very thermally efficient exemplar houses that could be delivered on a large scale throughout the city. The design incorporated a 'Thermoplan' clay block or timber frame, with external insulation, highly insulated roofs, high-performance windows, thermal mass, airtight construction, sunspaces, solar thermal hot water collectors, mechanical ventilation heat recovery (MVHR), low energy lighting, and high efficiency appliances.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP review)	Simulated only (no details)	No

The project included a series of six early-occupancy studies that used varying occupancy regimes to evaluate the performance of the houses and users perceptions of comfort and environmental quality under varying conditions. Two pressure tests were conducted. There was said to be a 'significant' increase in the level of air permeability over the intervening 18 month period. During the pilot study the CO₂ levels in both houses were found to be high. The system was investigated by the manufacturer and re-commissioned. Solar thermal systems were investigated. In some cases solar thermal pipework insulation was found to be sub-standard. Comparison of the MVHR systems in both houses identified differences in performance. This was likely due to issues with duct routing and failures in the (enclosed) air delivery system.

Occupant survey type	Survey sample	Structured interview
Student developed	N/A	N/A

The eccentric nature of this Phase 1 study required that specific occupant surveys were developed to deal with the short-term occupation for the four dwellings (2 plots) by the student volunteers. This was a variation to the more standard use of BUS questionnaires in BPE studies. Details are not provided.

SHINE Zero Carbon (East Midlands)

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Innovate UK project number	450067
Project lead, authors, and client	PS Sustainability Ltd
Report date	2013
InnovateUK Evaluator	Fionn Stevenson (Contact via www.bpe-specialists.org.uk)

No of dwellings Six terraced dwellings, three single apartments	Location East Midlands	Type Single terraced building	Constructed 2011
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Area 50 m ² per dwelling	Construction form Insulated concrete	Space heating target 25 kWh/m ² per annum	Certification level SAP 2005 (EPC to SAP 2009)
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Purpose of evaluation

The BPE project assessed the performance of the Insulating Concrete Formwork (ICF). It achieved a very high standard of air tightness (1.8 m³ (m².h) @ 50 Pa), thermal insulation (U-value 0.15) and acoustic isolation DnTw + Ctr dB 59 between dwellings. The project also assessed the solar thermal collectors, air-source heat pumps, and biofuel combined heat and power system. Excess heat from the solar collectors and CHP is used to generate warm air that heats an underground thermal store. The thermal store was intended to provide inter-seasonal storage, enabling summertime heat generation to meet wintertime space heating demand.

Design energy assessment Yes	In-use energy assessment Yes	Sub-system breakdown No
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The space heating energy consumed by the tenants was measured over the year 2012, and derived an average figure of 23 kWh/m² per annum for the dwellings. This is very close to the design intent of 25 kWh/m² per annum, and indicated that overall the building fabric performed to specification. There was some difficulty in modelling the building's heating system, which uses a combination of CHP, solar collectors, and air source heat pumps (ASHP). The primary heating system was modelled as a 'Community Heating Scheme', which incorporated boilers and CHP. However, it was not possible to add the ASHP as an additional heating system. Overall site electrical energy usage (non domestic heating energy) was found to be roughly in line with BREDEM-8 estimation.

Occupant survey type BUS (domestic)	Survey sample N/A	Structured interview N/A
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The BRE report contains very little detail on survey methodology and statistics. The design intent for thermal comfort and air quality was reportedly achieved. The tenants were said to be pleased with the performance of the development, with the BUS satisfaction index in the high 80% percentile range. Tenants reported overall satisfaction with the air quality in the summer months, but some tenants reported stuffiness.

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InnovateUK project number	450070 Related study: 450014 (Phase 1)
Project author	Leeds Beckett University for the Gentoo Group
Report date	2015
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Six	Houghton-le-Spring	Terraced bungalows	2011
Area	Construction form	Space heating target	Certification level
66 m ²	Pre-fabricated timber-frame	N/A	Level 4 Code for Sustainable Homes

Background to evaluation

The BPE report outlines the findings obtained from an in-use performance and post-occupancy evaluation study undertaken on six 66 m² 2-bedroomed terraced bungalows. All have solar thermal systems installed on their South-facing roof slopes. Dwelling 7 was chosen to be intensively monitored. As it is of the same size, shape and of very similar form to Dwelling 1 studied in Study 450014, the post-construction test results relating to that dwelling were considered likely comparable.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes (one dwelling)

Intensive in-use monitoring of one dwelling covered electricity consumption disaggregated by end-use, namely MVHR, lighting, and appliances including cooking devices. The total amount of heat supplied for space heating, heat supplied as top-up for the hot water cylinder, and heat supplied by the roof-mounted solar collector to the hot water cylinder were measured. Cold water supplied to the hot water cylinder (equivalent to total domestic hot water consumption) was also monitored. The main finding was the identification of an overheating risk in the dwelling, exacerbated by the dwelling's inability to purge unwanted heat without increased night-time ventilation. The pressurisation tests revealed that the air permeability of the dwelling had degraded since practical completion.

Occupant survey type	Survey sample	Structured interview
BUS domestic	4 of 7 (57 % response rate)	Yes

General feedback was positive. Residents found the air in the dwellings to be stuffy, dry and still in both summer and winter, with winter regarded as the poorer season for air quality. The air was monitored as being dry at times, however, particularly during winter when residents open their windows less often due to the cold, thus reducing the introduction of outside air. Both natural and artificial lighting were deemed to be 'too much'; although the research team believed that residents regarded this response and others like it as positives. **Students: see explanatory note on this topic on Page 20.**

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InnovateUK project number	450073
Project author	Glasgow School of Art, Mackintosh Environmental Architecture for Research Unit (MEARU) Architecture + Design Scotland
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Eight	Milton of Leys, Inverness	Various (see p.13)	2010
Areas	Construction form	Space heating targets	Certification level
Various (see p.13)	Various (see p.13)	Various	Scottish Building Regulations

Background to evaluation

Scotland's Housing Expo held in 2010 was an event showcasing innovative sustainable housing. The purpose of the Expo was to promote best practice in design with the aim of making sustainable features commonplace. A BPE study was undertaken on eight dwellings: four were social rented homes and the remaining dwellings were owner-occupied. The dwellings were from four different plots (two dwellings on each plot), each having particular features and design approaches. The study examined the relationships between design intentions and predictions, users' experiences and perceptions, and environmental and energy performance.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP assessment)	Yes (Detail is dwelling dependent)	Yes (SAP)

An assessment was made of each dwelling's in-use performance against the design expectations. This was determined using the Standard Assessment Procedure (SAP) prediction tool. However, as-built SAP assessments were not conducted. **Note: Individual SAP assessments produced by the various design teams were reported in appendices which were redacted by InnovateUK prior to publication. More information may be available on request from MEARU.**

Occupant survey type	Survey sample	Structured interview
BUS domestic	29 of 45 (64% response rate)	Yes

Semi-structured interviews were developed to discuss the handover process with the occupants. These aimed to understand the level of advice and support each household had received when moving in to their homes and to understand issues the occupants worried about. Occupants were questioned over their ability to operate and control heating and hot water systems and whether the heating was affordable. The survey also prompted discussion over sound performance and the ventilation systems. The BUS results are available at <http://portal.busmethodology.org.uk/Upload/Analysis/yp2nevx2.214/index.html> (as of January 2020).

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Innovate UK project number	450077 Related CHP study: 450078 (Phase 1)
Project author	UCL and Crest Nicholson Operations for Crest Nicholson Plc
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Three	Woolston, Hants	3-storey terraced houses	2012
Areas	Construction form	Space heating targets	Certification level
103.3 m ²	Cavity masonry	See report	Building Regulations, 2006

Background to evaluation

This report provides the results of the in-use performance analysis and post-occupancy evaluation of three monitored dwellings constructed as part of the first phase of Centenary Quay development. The performance of the district heating system and the CHP plant installed was assessed as part of the Phase 1 study.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP)	Yes	Yes

Temperatures recorded for the monitored dwellings show higher risk of overheating than predicted in the as-built *Building Regulations* compliance calculations (as-built SAP). All bedrooms in one dwelling and the second floor bedroom in all dwellings experienced overheating during the measurement period. The operational performance of the district heating system and the combined heat and power plant was disappointing with respect to overall energy centre efficiency, system power-to-heat ratio and heat distribution efficiency. The carbon intensity of delivered heat at Centenary Quay was also more than double what would be expected from individual gas-fired condensing boilers. CO₂ concentrations in most liveable spaces were lower than 1500 ppm for more than 90% of the monitoring time. Measurements of low extract rates in all monitored dwellings suggested that the mechanical ventilation systems failed to deliver their designed performance.

Occupant survey type	Survey sample	Structured interview
BUS domestic	24 of 168 (14 % response rate)	Yes

Note: BUS report not included and hyperlink now defunct. Interviews carried out with the residents in the monitored mid-terraced houses showed overall, satisfaction with the new homes. They particularly like the design, layout and space the houses provided. They were also generally content with the indoor thermal comfort conditions, although gender differences in perceived thermal comfort were found. Residents in two monitored dwellings raised concerns about high heating bills. Window trickle vents were found permanently blocked in two dwellings with paper blinds and closed in another dwelling in winter to prevent draught.

Centenary Quay fabric and district heating performance study

Phase 1 study
Post construction and early occupation

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Innovate UK project number	450078 Related CHP study: 450077 (Phase 2)
Project author	UCL and Crest Nicholson Operations for Crest Nicholson Plc
Report date	2013
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Multiple	Woolston, Hants	Terraced houses	2012
Areas	Construction form	Space heating targets	Certification level
103.3 m ²	Cavity masonry	See report	Code for Sustainable Homes Level 3

Background to evaluation

This report provides the results of the as-built performance of the building fabric and services, and also to understand how occupiers interacted with their homes during the first few months of occupation. The performance of the district heating system and the CHP plant was assessed. The strategy was expected to deliver total carbon dioxide savings over *Building Regulations, Part L, 2006* of between 40-44%.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP review)	Partial (heating)	No

Co-heating tests were performed on one end-terrace town house. Pressure tests were conducted on two terraced dwellings with repeat tests over a period of three months. Flow measurements were performed on mechanical extract ventilation systems in three dwellings. Infra-red thermal imaging was undertaken during the co-heating tests. *In situ* heat flux measurements were performed on external walls, party walls and ceilings during the co-heating test. Semi-structured interviews and walkthroughs were carried out with residents of three dwellings. The physical handover process and handover documentation were evaluated. The SAP calculations for a small number of dwellings and the likely impact of observed as-built factors on calculated emissions were also assessed.

Occupant survey type	Survey sample	Structured interviews
BUS domestic	25 of 168 (15% response rate)	Yes (3 dwellings)

The results of the Building Use Studies (BUS) survey and customer interviews showed that, overall, the residents of Centenary Quay were satisfied with their new homes. In particular they liked the house design, room layouts, location and general levels of comfort. The responses for internal temperature showed a high level of satisfaction in winter with most residents considering the temperature to be neither too hot nor too cold. However, the responses for summertime temperature were much more variable, with a high proportion of residents saying that the dwellings were too hot in summer.

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InnovateUK project number	450081
Project author	Glasgow School of Art, Mackintosh Environmental Architecture Research Unit (MEARU)
Report date	2015
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Types	Constructed
Three	Dunoon	Semi-detached	2010
Areas	Construction form	Space heating targets	Certification levels
Low energy: 110 m ² PassivHaus: 95 m ²	Timber frame	See Table 7.3, p.86	Scottish <i>Building Regulations</i> and PassivHaus

Background to evaluation

The Tigh-Na-Cladach (Gaelic meaning 'Houses by the Shore') development is located one mile south of the town of Dunoon in the Scottish county of Argyll and Bute. The BPE project studied one PassivHaus home and two low-energy homes. The Tigh-Na-Cladach dwellings performed significantly better than the UK average and approached best practice. The PassivHaus dwelling was the first in Scotland at the time.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes (See p.86 for detail)	Yes

Air-tightness was found to far exceed the *Building Regulations*/design stage targets of 10 m³ (m².h) for the low energy dwellings. The PassivHaus dwelling was just under the PassivHaus target of 0.6 m³ (m².h) and slightly over the design target of 0.5 m³ (m².h). Significant problems were found with mechanical ventilation with heat recovery systems (MVHR) and the air-to-air source heat pumps (AASHP), which had to be corrected and/or replaced. Energy consumption varied significantly across the dwellings, mainly as a function of user behaviour. The heat pump in the PassivHaus dwelling was found to achieve an average COP of 3.49 in heating mode. The COP quoted by the manufacturer was 4.0. In Scottish weather, a supplementary heat source may be required to meet thermal comfort needs.

Occupant survey type	Survey sample	Structured interview
BUS domestic	See report	Yes

As-designed aspects of the affordable low-energy homes were, on the whole, achieved. The health design intended by the architects was considered successful on the basis that there were no negative health issues noted in survey scores or comments. The PassivHaus had a number of problems post-occupancy and these were reflected in BUS responses. (Students and researchers: see additional notes on Pages 10 and 55 relating to BUS survey data interpretation.) Occupant diaries were maintained across all surveyed dwellings.

Ancion Court

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Innovate UK project number	450083
Project author	Connect Housing/Kiwa
Report date	2014
InnovateUK Evaluator	Fionn Stevenson (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
Two flats assessed	Marsden	2 bed apartments	2011
Area	Construction form	Space heating target	Certification level
63.7 m ² and 55.5 m ²	Block construction	Flat A: 2633 kWh per annum Flat B: 1941 kWh per annum	CSH Level 4

Background to evaluation

Ancion Court was a new development in West Yorkshire consisting of 14 flats (13 occupied dwellings and a communal area). The properties were constructed to Level 4 of the *Code for Sustainable Homes* (a 25% reduction in dwelling emission rate) compared with the target emission rate. Flats A and B were modelled under SAP calculations) leading to a target emission rates of 31.7 and 31.1 respectively. The properties are heated two ground source heat pumps rated at 33.3 kW and 7.5 kW respectively. Monitoring was carried out to enable the performance of the heating and hot water systems to be analysed.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes

The field trial results found a greater requirement for space heating energy than the calculated SAP assessments predicted, (15% higher for flat A and 41% for Flat B). However, they also show a higher internal temperature by approximately 3-4°C. The researchers suggested that the temperature difference alone could account for a 20 to 30% increase in energy required to maintain the internal temperature. Energy use by lighting was also higher than predicted in SAP assessments, with recorded values at least 50% higher than estimated. Artificial lighting was found to be required for the majority of the time for rear-facing ground floor flats, which was not predicted in the SAP assessments. The air tightness of the dwellings measured 4.72 m³ (m².h) and 7.66 m³ (m².h) for Flats A and B respectively.

Occupant survey type	Survey sample	Structured interview
BUS domestic	13 of 13 (100 % response rate)	Yes

A Building Use Study (BUS) was carried out approximately 12 months after the residents first moved into the development. All of the properties in the development were approached and all willingly completed the survey. Overall the air quality was considered satisfactory in both summer and winter. The air was thought to be odourless, but also dry and still. Several residents commented that the air was stuffy and they needed fans to create air movement during hot summer months. Control of heating, lighting (both natural and artificial) and cooling within the properties were by far the most criticised aspects of the development.

Lancaster co-housing development (Forgebank)

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Innovate UK project number	450095
Project lead, authors, and client	University of Sheffield and Leeds Metropolitan University for Lancaster Co-housing Development
Report date	2013
InnovateUK Evaluator	N/A (Contact via www.bpe-specialists.org.uk)

No of dwellings	Location	Type	Constructed
Six	Lancaster	Detached	2012
Area	Construction form	Space heating target	Certification level
N/A	Full-fill masonry cavity	15 kWh/m ² per annum	PassivHaus & CSH Level 6

Purpose of evaluation

The scope of the project was limited to the post-construction and initial occupation stage. Lancaster Co-housing development was a 41 dwelling affordable community housing project, comprising a range of dwelling types. 35 of the dwellings were within the co-housing scheme. All dwellings on the development were designed to Passivhaus standards, Lifetime Homes and Level 6 of the Code for Sustainable Homes. The project covered the post-construction and initial occupation stage and consists of a combination of physical tests alongside occupancy studies. These included co-heating tests, air-pressurisation tests, SAP check, and design and construction review, and occupant interviews and walkthroughs.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Partial	No	No

The key findings from the project were that the housing construction and occupancy performance largely fulfilled the design intentions. Measured heat loss for the test dwelling of 47.1 W/K compared with a predicted heat loss coefficient of 39.0 W/K – a difference of just over 8 W/K. The dwelling tested was exceptionally airtight with a value of just less than 0.6 m³ (m².h) @ 50 Pa. Design, construction, installation and commissioning procedures were all very thorough indicating that a Passivhaus helps to close the traditional performance gap that exists in housing. The occupants are exceptionally satisfied with their homes overall, although there are a number of improvements that could be made to the user handover, guidance, and usability of environmental controls

Occupant survey type	Survey sample	Structured interview
BUS survey on 6 households	36 of 36 (100 % response rate)	Yes

A Building Use Studies (BUS) survey was undertaken. 36 responses were obtained out of 36 questionnaires delivered (100%). Overall, the results produced were excellent. Residents are very positive about this development and how well it performed. The eight summary variables covering air, comfort, design, perceived health, lighting, needs, noise and temperature are all higher or better than the UK 2011 BUS housing benchmarks.

Thames Valley Houses

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Innovate UK project number	450096
Project author	Low Carbon Building Group, Oxford Brookes University, for Thames Valley Housing Association.
Report date	2014
InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
2 dwellings	Feltham, Middlesex	House 1: 128 m ² 4-bed, mid-terrace House 2: 146 m ² 5-bed, detached	2012
Area	Construction form	Space heating target	Certification level
128 m ² and 146 m ²	Timber frame	N/A (has a SAP analysis)	CSH Level 4

Background to evaluation

A two-year in-use BPE study of two social housing dwellings. The social housing scheme of 10 council houses was built to *Code for Sustainable Homes* Level 4, with an average 'as designed' dwelling Target Emission Rate (TER) of 9.01 kgCO₂/m² per annum. All dwellings have mechanical ventilation with heat recovery (MVHR) systems with summer bypass mode and thermal sensors. Gas condensing-boilers supply energy for heating and hot water. Electricity is generated by solar PV. The research covered user behaviour in relation to an innovative combination of passive low energy features, the usability and effectiveness of the micro-generation solutions and key control elements and an investigation of the construction costs.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Partial

The envelope consists of external walls with a U-value of 0.21 W/m²K and aluminium windows with double glazing with a U value of 1.6 W/m²K. The envelope was designed to achieve an air permeability of 3 m³ (m².h) @ 50 Pa. In both case study houses, the measured air-permeability values were around 6 m³ (m².h) @ 50 Pa which was double the design target of 3 m³ (m².h) @ 50 Pa, leading to higher ventilation heat losses. Air-leakage pathways identified during the initial walkthrough revealed that design air tightness levels had not been achieved. Mains electricity use in both case study houses was lower than the UK average dwelling, but much higher than the CSH level 4 and *Part L* benchmarks.

Occupant survey type	Survey sample	Structured interview
BUS domestic	8 of 10 (80 % response rate)	Yes

The survey revealed a positive opinion towards the houses, with air quality and comfort being the most appreciated elements. All elements scored high above scale midpoints and above the benchmarks. Respondents felt that the facilities provided meet their needs very well and that the houses were comfortable overall. Temperatures during summer were generally regarded as quite comfortable but less so in winter. Lighting levels appeared to be satisfactory overall. Natural light scored within the benchmark, with the majority of the people finding it adequate (neither too little nor too much).

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InnovateUK project number	450097
Project author	Glasgow School of Art, Mackintosh Environmental Architecture Research Unit (MEARU) for Dormont Estate
Report date	2015
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Constructed
Four	Lockerbie	Semi-detached	2011
Areas	Construction form	SAP v9.81 rating	Certification level
2-bed units: 87 m ² 3-bed units: 103 m ²	Off-site timber frame	2-bed units: 93 (A) 3-bed units: 92 (A)	PassivHaus

Background to evaluation

The development studied involved eight new build-houses, comprising four 2-bed and four 3-bed 2-storey, semi-detached dwellings designed to the PassivHaus standard. The BPE study was undertaken on four dwellings: two 2-bed cottages and two 3-bed cottages. The design and procurement processes were regarded as exemplary. The BPE monitoring involved non-invasive testing of the building fabric to provide an indication of construction quality. Each dwelling underwent two air permeability tests while *in situ* U-value tests were undertaken to the roof and wall in one dwelling Thermographic surveys were undertaken in all dwellings.

Design energy assessment	In-use energy assessment (SAP)	Sub-system breakdown
Yes (details in Figure 2.7, p.9)	Yes (details in Figure 2.7, p.9)	Partial

Space heating was achieved through mechanical ventilation with heat recovery (MVHR), and water heating by wood stove and solar thermal systems. SAP predictions were said to be fairly accurate for energy consumption, but not for energy costs, which were between 3 and 4 times higher, due mainly to inaccurate unit costs within SAP. The most difficult aspect on site was achieving the required level of airtightness. The plumbing and electrical works were contractor design packages and proved the most problematic post-completion. Apart from issues associated with occupants' understanding of the active services, the main issue for occupants was overheating.

Occupant survey type	Survey sample	Structured interview
BUS domestic	7 of 8 (87% response rate)	Yes (plus occupant diaries)

Overall, the houses were well received. The only significant issue for occupants appeared to be overheating in the summer. Note: Researchers and students should be wary of the data interpretations from the BUS survey, as there appears to be some misunderstanding of the statistical data that was derived from very small (local) samples. The local responses from each survey respondent are more insightful than the BUS scores aggregated from the individual dwellings (i.e. from local, specific contexts). The reported contradictions between the averaged scores and individual free-text responses therefore need to be read with some caution.

Sinclair Meadows Community Village

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InnovateUK project number	450099
Project author	National Energy Foundation for the Three Rivers Housing Association
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings²	Location	Type	Constructed
1 dwelling, 1 flat	South Shields	Terraced houses and flats	2012

²Areas	Construction form	Space heating targets	Certification level
107 m ² and 66.5 m ²	Timber frame, hemp insulation	Dwelling: 8.3 kWh/m ² per annum Flat: 6.4 kWh/m ² per annum	Code for Sustainable Homes Level 6 (SAP 2005)

Background to evaluation

The BPE study assessed the performance of the Sinclair Meadows Carbon Negative social housing project in Tyne and Wear which intended to be a carbon neutral development. The development was designed as mixed-use, with twenty one dwellings including nine each of three-bed terraced houses and a three-storey apartment block containing twelve two-bed apartments/flats. The development incorporated a biomass-fuelled communal district heating system to provide space heating and hot water. In addition 85 kWp solar photovoltaic (PV) panels generated electricity. Rainwater was harvested for toilet flushing and gardening.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes (SAP)	Yes	Yes

One terraced house and one flat were analysed. The predicted net carbon emissions were -6.26 kgCO₂/m² per annum for the house and -2.85 kgCO₂/m² per annum for the apartment. The designed heat loss parameter for the house and apartment was very low at 0.51 W/m²K and 0.59 W/m²K respectively. The annual requirement for delivered heat energy for both dwelling types was dominated by that for domestic hot water, which accounted for around 80 per cent of the heat requirement. The net efficiency of the biomass-fuelled boiler was 82.2 per cent compared to the manufacturer's quoted efficiency of 93.6 per cent. The overall system efficiency for delivery of heat to the dwellings was 20.3 per cent. Measured temperatures indicated overheating in the bedrooms in both dwellings during the summer.

Occupant survey type	Survey sample	Structured interviews
BUS (domestic)	17 of 21 (81 % response rate)	Yes, various

Residents reported many positive experiences of their new homes and scores compared well against BUS benchmark datasets. Overall comfort, perceived health and needs met all scored in the 99th percentile. The flats performed much better in winter than during summer. While in the winter the residents appreciated the ability of the flats to retain heat, during warmer periods 80 per cent of residents said that dwellings were too hot in the summer, reportedly due to high levels of solar gain. Over a third of residents stated that they were unable to control cooling. **Users note: inappropriate use of histograms for reporting BUS data (page 62).**

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

No of dwellings	Location	Type	Constructed
Two	Bicester	Mid and end-terrace	2012
Areas	Construction form	Space heating targets	Certification level
Mid terrace: 123 m ² End terrace: 88 m ²	Steel frame	See report	CSH Level 4

Background to evaluation

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

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

The case study dwellings were assigned an 'as designed' Dwelling Emission Rate of 11.53 kgCO₂/m² per annum, equating to 92 (A) for the mid terrace dwelling and 91 (B) for the end terrace. An as-built SAP assessment generated an 'as built' assessment of 88 (B) for the mid terrace and 86 (B) for the end terrace. The reason of the deviation was located in the discrepancies between the roof areas, wall areas and floor heights that were used in the provided SAP in comparison to the architectural drawings. Higher air permeability rates were also measured in the dwellings at an average 5.5 m³ (m².h), above the as-designed values of 3 m³ (m².h). Thermographic testing revealed a number of thermal anomalies. Some parts of the heating systems were initially not working in both properties.

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

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

Seager Distillery Housing

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Innovate UK project number	450102
Project author	AECOM for Galliard Homes
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings 20 (3 detailed, 9 in less detail)	Location Deptford, London	Type Apartments	Constructed 2011
Apartment area Various: 35 - 74 m ²	Construction form Reinforced concrete	Space heating targets Various (see SAP analyses)	Certification level Building Regulations, 2006

Background to evaluation

The project involved the performance assessment of the redeveloped Seager Buildings in Deptford. The site comprised a large number of apartments with a smaller proportion of commercial space. There were two phases to the residential scheme. Phase 1 of 173 apartments was complete and occupied prior to the study. Phase 2 was completed during the study period and comprised 130 apartments and a basement car park. The InnovateUK study focused on Phase 1 of the residential space. Three flats from the Norfolk House apartment block were used for detailed evaluation.

Design energy assessment Yes	In-use energy assessment Yes	Sub-system breakdown Yes (12 dwellings)
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The main heat source was a gas-fuelled 100 kW combined heat and power (CHP) plant supplemented by a 800 kW biomass boiler and two conventional gas boilers. The apartments were ventilated using individual MVHR units. The project assessed energy performance, the efficiency of the district heating system, incidence of any overheating in the apartments, and the occupant experience and levels of satisfaction. The dwellings were tested for air permeability, and insulation tested using thermography. Actual air permeability was more than 50% better than in design-stage SAP. The heat for space heating and DHW consumed by the three apartments analysed in detail was 40 to 65% less than predicted by SAP. All three flats analysed in detail experienced periods of summer overheating against the CIBSE *Guide A* criteria. Electricity use varied widely.

Occupant survey type BUS (domestic)	Survey sample 27 of 58 (47% response rate)	Structured interview Yes
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Only the 11 surveys from a second wave of surveys could be used to carry out the analysis as the data were captured at the same time and were therefore comparable. **Readers note: the explanation of the BUS colour coding is not correct. See note on Page 27. This misunderstanding affects much of the subsequent analysis.** However the results suggest that the occupants perceived the flats to be too hot. The occupants also rated airflow as being still in summer and winter as well as the air being quite dry during the winter. Written feedback and face-to-face meetings were held with occupants from the three dwellings studied in detail.

Murray Place

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InnovateUK project number	450104
Project author	Hanover Housing Association
Report date	2014
¹InnovateUK Evaluator	N/A

No of dwellings	Location	Type	Mid-terrace (MT) End terrace (ET) Flat	Constructed
Three	Barrhead, Glasgow			2010
Areas (TFA)	MT: 93.1 m ² ET: 75.4 m ² Flat: 75.8 m ²	Construction form	Actual space heating	Certification level
		2 Timber frame 1 Masonry (the flat)	81.3 kWh/m ² per annum 175.3 kWh/m ² per annum 120.4 kWh/m ² per annum	Scottish <i>Building Regulations</i>

Background to evaluation

The Murray Place development comprised 16 two-bedroom amenity houses for older people. The housing design was developed with reference to the *Green Guide to Housing Specification* and the principles embodied in *EcoHomes*. Three dwellings were selected for BPE study: a mid-terraced two-story house with timber frame construction, a top floor flat with masonry construction, and a single story cottage flat with timber frame construction. The BPE project studied a range of design features including the breathing wall construction with Warmcell insulation, and the active solar strategies.

Design energy assessment	In-use energy assessment	Sub-system breakdown
Yes	Yes	Yes

The breathing wall construction of the timber-frame dwellings performed within design expectations, despite a change in specification on site. There was some evidence that the vapour permeability reduced moisture, but other temperature and ventilation conditions masked this. No evidence of insulation slumping was apparent, although thermal integrity was compromised by some missing and misplaced insulation. The U-values of the masonry construction were poorer than design values. Energy consumption was higher than SAP calculations in terms of regulated energy, although hot water consumption was lower. Two years of data is available for electrical and gas consumption, solar hot water production, domestic hot water consumption, and sub-metered electrical consumption for up to six sub-circuits in the dwellings.

Occupant survey type	Survey sample	Structured interview
BUS domestic	9 of 15 (60% response rate)	Yes

Generally the occupants were satisfied with their homes, the location, and the orientation. However there were common concerns over the solar thermal systems and questions over whether they were working. After two years occupation only one of the households knew how to set the heating programmer, but admitted that they had only learnt how to do this recently. Students and researchers note: additional comments on the interpretation of BUS survey results are on pages 48 and 49.

BUS results are available at <http://portal.busmethodology.org.uk/Upload/Analysis/ichljgnr.hgv/index.html> (accessed January 2020)