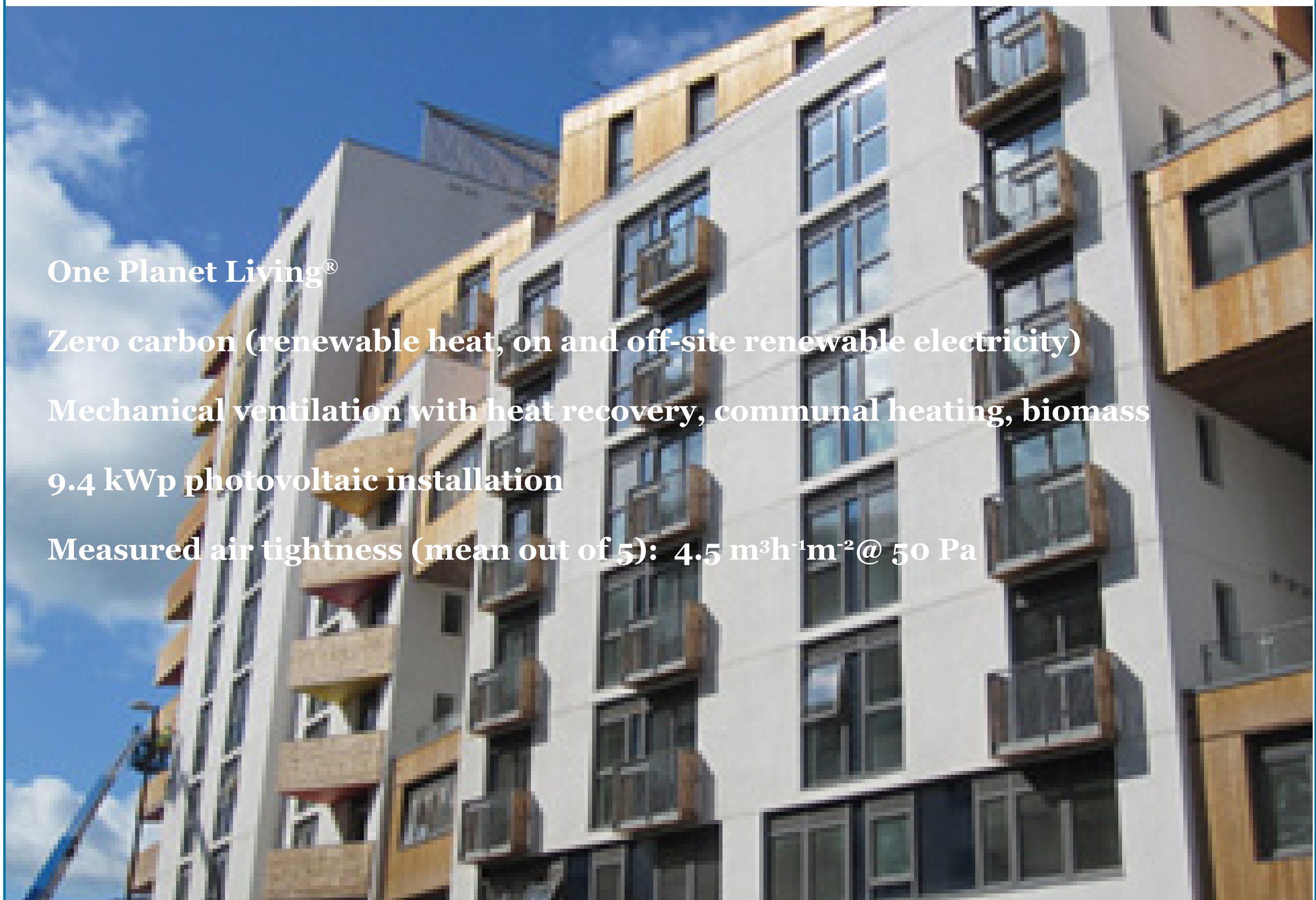
BUILDING PERFORMANCE EVALUATION CASE STUDY ONE BRIGHTON



One Planet Living®

Zero carbon (renewable heat, on and off-site renewable electricity)

Mechanical ventilation with heat recovery, communal heating, biomass

9.4 kWp photovoltaic installation

Measured air tightness (mean out of 5): 4.5 $m^3h^{-1}m^{-2}$@ 50 Pa

Building Performance Evaluation Team

Good Homes Alliance

University College London

Technology Strategy Board

Driving Innovation

The project reported here is part of the Technology Strategy Board's Building Performance Evaluation programme and acknowledgement is made of the financial support provided by that programme. Specific results and their interpretation remain the responsibility of the project team.

This case study presents the findings of a Building Performance Evaluation (BPE) project that investigated the post-construction and in-use performance of the One Brighton development. The evaluation was carried out by University College London (UCL), funded by the Technology Strategy Board's (TSB) Building Performance Evaluation programme.

Five identical occupied one-bedroom apartments (referred to as A, B, C, D and F) were evaluated. Site-wide communal data was also analysed.

The results from One Brighton show that a fabric first approach to building design can result in a significant reduction in energy demand for space heating. Fabric testing showed only limited degree of underperformance compared to design intent.

However the communal heating system and MVHR systems were found to be underperforming. The measured carbon intensity for delivered communal heat was found to be ten times greater than predicted. Summer overheating in the bedrooms of the 5 dwellings was also identified.

Design and Construction

One Brighton was developed by CNBQL Limited on the larger New England Quarter site, a regeneration scheme adjacent to Brighton station. It was constructed between 2008 and 2010 in a Design and Build (D&B) arrangement.

The development is mixed-use, with 172 dwellings, 925 m^2 of community space and 1134 m^2 of commercial space. The homes at One Brighton are a mixture of studio, 1, 2 and 3-bed apartments, with 30% being affordable. The development primarily consists of two blocks: one 11-storey block (Brighton Belle) containing 109 dwellings, and one 8-storey block containing 63 dwellings (Pullman Haul). The community and commercial spaces are located on the ground floor.

It was designed in accordance with a set of ten values based on the One Planet Living Principles. A green caretaker works on site to assist the residents with the energy, lifestyle and sustainability aspects of the development.

External walls are made up of a reinforced concrete frame with 240mm infill of Thermoplan blocks. The walls are externally clad with 100mm wood fibre insulation boards, bonded to the blocks and concrete frame. The walls have a breathable render on the outside and a wet-applied mineral plaster finish to the inside, creating an airtight but vapour permeable and breathable wall. Summer time temperatures were designed to be limited by façade design, exposed thermal mass and night-time heat purge through the ventilation system.

Heating and hot water are provided by a communal heating system with a biomass boiler and back-up gas boiler. The communal heat distribution system is connected to Heat Interface Units (HIUs) in each apartment for instantaneous space heating and Domestic Hot Water (DHW) production.

Space heating within the apartments is delivered by warm air provided through the MVHR system. Thus warm air is only directly provided to the living room and bedrooms, which receive fresh supply air.

There is a 9.36 kWp photovoltaic (PV) array on the roof of Pullman Haul building. The panels are linked to the private wire network for the development.

The predicted fabric and services performance figures are listed below.

Table 1. Design Targets

Air permeability [design target]	5 $m^3h^{-1}m^{-2}$@ 50Pa
U-value: walls [UCL calculated]	0.21 W/m^2K
U-value: roof [as-built SAP]	0.19 W/m^2K
U-value: windows, whole [UCL calculated]	0.8 W/m^2K
Y value [as-built SAP]	0.08 W/m^2K
Biomass boiler efficiency [as-built SAP]	85%

Real Performance

A Coheating test was carried out on one unoccupied apartment. The apartment used was a mid-floor corner flat. The measured 19 W/K discrepancy indicates that there may be problems with both the assumptions used for the design estimate and the performance of the as-built fabric. For example, the wall U-values used did not include the presence of hidden structural reinforced concrete columns.

In-situ U-value measurements were carried out at two locations on the external wall. It is thought that the most likely explanation for the measured difference is that the north east sensor was located at or close to a concrete column.

The design air permeability for all apartments at One Brighton was 5 $m^3h^{-1}m^{-2}$@ 50Pa. All five tests met the design target. However, it should be relatively straightforward to achieve an air permeability of 5 $m^3 h^{-1} m^{-2}$ @ 50Pa and below with apartments that have solid concrete floors and ceilings, and wet plastered wall finishes. In this respect, the results were somewhat disappointing. Current advice in Part F 2010 for dwellings with MVHR systems is 3 $m^3h^{-1}m^{-2}$ @ 50Pa in order to maximise the energy benefits of heat recovery.

The table below compares the fabric design targets with the measured values. Overall the dwellings, as constructed, are fairly airtight and insulated, but U-values perform worse than the design targets.

Table 2. Real fabric performance

	Predicted	Measured
Heat loss coefficient	36.7 W/K [UCL calculated]	55.7 W/K
Air permeability	5 $m^3h^{-1}m^{-2}$ @ 50Pa [design target]	4.17-4.84 $m^3h^{-1}m^{-2}$ @ 50Pa 4.5 $m^3h^{-1}m^{-2}$ @ 50Pa [mean]
Wall	0.21 W/m^2K [UCL calculated]	0.23 W/m^2K [south east wall] 0.32 W/m^2K [north east wall]

Indoor temperature

Monitoring of indoor environmental conditions showed that in all cases, the internal temperatures were higher than the standardised assumptions in the SAP2005 calculation, which use a mean internal temperature of 19.5°C.

The maximum bedroom temperature in the summer reached 32.5°C in F, and the peak living room temperature in the summer reached 36.1°C in C. While some extended overheating in the living room of F was found, the bedrooms of all five dwelling regularly exceed the 26°C threshold.

Energy consumption

Electricity use is dominated by plug-in appliances. While the amount of electricity used for appliances is fairly similar for all apartments, there are big differences for the MVHR systems. In A and C the MVHR energy use is very low, while in B, D and F it constitutes around 40% of total electricity use. It appears that A and C have the MVHR system turned off for most of the time. The annual electricity consumption in all five dwellings is well below the OFGEM ‘typical medium’ UK electricity use for all dwellings of 3300 kWh (OFGEM 2010).

The total communal heat input to the monitored apartments ranged from a low of only 7.4 kWh/m^2 for C, to a high of 68.7 kWh/m^2 for B. The highest space heating use was in B, while the highest DHW use was in F. There are clearly big differences in the way that the residents heat their homes and in how they use DHW.

The direct energy costs for the monitored One Brighton apartments were still around 40% cheaper than the average UK gas-heated dwelling (not even taking into account One Brighton heat provision costs which include maintenance of the HIU).

System performance

Data on the commissioning of heating and ventilation systems at One Brighton was limited. No test results or performance data were found for the biomass boiler, PV array, or MVHR systems. It is thought that the design flow rates for the MVHR were determined by the space heating load rather than fresh air requirements. Inspections of the MVHR system showed poorly taped connections and gaps in the duct joints, constricted, damaged or crushed flexible ductwork, excessively dirty MVHR filters, and many of the intake and exhaust terminal vents on the external walls are located above the windows of the dwellings in recesses protected by a louvre, with the intake and exhaust terminals separated by only around half a metre - this will increase the risk of recirculation.

Flow rate measurements in the apartments revealed that while in all cases the systems failed to meet the commissioning target total boost flow rate, most easily meet the regulatory ventilation requirements. The reduced flow rate compared to the design target should be expected to have little impact on air quality, but may affect the ability of the warm air system to deliver the designed heat output.

Specific Fan Power (SFP) at different fan speeds was calculated for one installation, varying from a low of 3.5 W/l/s in trickle mode up to a maximum of 6.2 W/l/s in boost mode. These values are very high relative to a typical modern domestic MVHR system, which would be expected to be less than 1 W/l/s when installed correctly.

Measurement of MVHR air temperatures found that in summer there is very little difference between extract and supply temperatures indicating that the automatic summer bypass is not functioning as expected.

Communal heat output was mostly supplied by the gas backup boiler, with heat from biomass only accounting for 34% of total heat output. The design and regulatory expectation was that close to 100% of heat should have been provided by the biomass boiler, with the gas backup only being used for shutdowns due to maintenance or equipment faults. Clearly, there have been significant issues with the reliability of the biomass boiler.

The heat losses from within the plant room and distribution network were calculated to be 58.8%, which is equivalent to a distribution efficiency of 41.2%. The default value for community heating in SAP 2005 gives a distribution efficiency of 95%. Actual losses were therefore eight times those assumed in the as-built SAP calculations.

The mean annual yield of the PV array was found to be 10,252 kWh/a. The expected yield for the PV array was calculated using SAP 2012 (BRE 2013) to be 10,694 kWh/a, which is reasonably consistent with the measured long term average, indicating that the panels are performing well.

Carbon emissions

The measured carbon emission factor for delivered heat at 0.50 $kgCO_2$/kWh was ten times the 0.05 $kgCO_2$/kWh calculated using the design assumptions . The carbon intensity of heat delivered by individual gas condensing boilers in each apartment would be expected to be 0.24 $kgCO_2$/kWh (allowing for a system efficiency of 87%) - half the measured emissions of the communal system at One Brighton.

The total measured carbon emissions of 632 tCO_2/a does not compare favourably with design expectation for emissions of around 250 tCO_2/a, given in the One Brighton sustainability action.The difference in expected and real carbon emissions is due primarily to the operation and losses of the communal heating system.

BUS survey

Residents were asked to complete the survey on two occasions – first, during the winter of 2011, and then during the summer of 2012. Results from the first 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. The results from the second BUS survey showed most people remained satisfied and comfortable. In general, people were still satisfied with the space and layout of the building.

A wide range of factors were mentioned that worked well. These included the apartment layouts, allotments, bike storage facilities, building location, the green caretaker, and thermal insulation. Examples of things that were perceived to be not working as expected included poor acoustic insulation, the intercom system and the heating/ventilation system. Of concern was overheating during the summer, with 75% of occupants reporting that it was either hot or too hot.

Key Findings and Lessons

- 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 measured heat loss coefficient was low in comparison to regulatory targets, but was around 50% higher than predicted. This was partly because the designed assumptions had neglected to include the concrete columns in the wall.
- The measured air permeability values were all less than the design target of 5 $m^3h^{-1}m^{-2}$. However it should have been possible to achieve lower levels of air leakage given the use of concrete floors, high performance glazing and the lack of cavities in the construction.
- The MVHR system flow rates were not meeting the design specifications, which will reduce the effectiveness of the MVHR system in heating mode. However the measured flow rates exceeded the minimum regulatory requirements for fresh air under Part F.
- Issues found with the condition of the ventilation systems included: the kitchen extract vents were located too close to the cooker and hob, and were found to be contaminated with fat deposits; the filters that were examined were dirty; the terminal intake and exhaust vents on the outside of the building were sited very close to each other increasing the risk of recirculation; the measured SFP of the One Brighton MVHR units was very high compared to a efficient SFP value of around 1.2 W/l/s (Wingfield 2011). The impact of such poor SFP values can be seen in the electricity used to run the MVHR systems where the annual electricity consumption for the MVHR units constituted around 40% of measured total electricity use in these apartments.
- Monitored temperature data indicated that the summer bypass (heat exchanger bypass) is not operating as intended. Thus it is not expected that free-cooling is being supplied by the MVHR systems monitored.
- There have been continued reliability issues with the biomass boiler. The contribution of the biomass boiler to overall communal heat output was around 34% - most of the heating was supplied by the back-up gas-fired boiler. This, in addition to high distribution losses, increased the carbon emissions related to heat delivered by the communal heating network significantly.
- Summer overheating was found in the bedrooms of the monitored dwellings. This was unexpected as the MVHR systems were specified with a high flow rate free-cooling mode which, and the dwellings have a high amount of exposed thermal mass.
- Actual carbon emissions for delivered communal heat for the whole site were ten times that predicted, and twice that which would have been expected had the development used individual gas boilers to heat the apartments. The factors giving rise to the high emissions were related mainly to the use of the backup communal gas boiler in preference to the main biomass boiler and high distribution losses.
- Overall the results from the BUS surveys show a relatively high level of satisfaction with the development. The main issues identified were summer overheating, and the occupants have issues with the maintenance and functionality of the MVHR system.

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