GHA Monitoring Programme 2011-13: Technical Report

One Brighton

Results from Phase 2: Post-occupation testing of sustainable new homes

Acknowledgements

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Front cover image:

One Brighton

Good Homes Alliance Monitoring Programme 2011-13:

Technical report: One Brighton

Results from Phase 2: Post-Occupation Evaluation

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1 Introduction

The Good Homes Alliance Monitoring Programme aims to measure and monitor the performance of high-level sustainable, new build homes. The programme consists of the following research phases:

1. *Post-construction testing:* testing the thermal efficiency of the building shell
2. *Monitoring in Use*: analysis of in-use data about energy and water consumption, and temperature and Internal Air Quality (IAQ) conditions.
3. *Post-occupation evaluation (POE):* analysis of resident and user behaviour patterns, comfort and satisfaction levels and perceptions.

This document reports on the results of the monitoring in-use and post-occupation evaluation carried out at the One Brighton development by the University College London team, as part of the GHA monitoring programme.

Monitoring equipment was installed in one apartment in October 2011. Information on total monthly consumption of water, heat and electricity was obtained from the managing ESCo at One Brighton.

Under this evaluation programme, data was recorded through October 2012. However data is data is still being recorded and analysed in this apartment under the Technology Strategy Board's (TSB) Building Performance Evaluation (BPE) Programme. Under this programme additional parameters are being analysed in 4 additional apartments. Thermocouples have been fitted measuring ventilation duct air temperature, in addition to window sensors to better understand and characterise the ventilation system operation, in conjunction with occupant use of the windows for fresh air and control indoor temperatures. Biomass consumption and PV generation are also being analysed. These results will be made available in a separate case study once the TSB programme has completed.

A 'walkthrough' and in-depth interviews with occupants and members of the One Brighton design team were also carried out. Similarly, residents of the One Brighton development were surveyed using the Building Use Survey (BUS), in addition to a second survey designed to enable quantification and apportionment of building performance to occupant behaviour. Copies of the BUS were delivered in January 2011 and June 2012.

The ‘walkthrough’ took place in July 2011. Core design team members and those involved with the monitoring and testing of One Brighton, together with the Green Caretaker, were invited to visit One Brighton and view an occupied flat, the allotments, the biomass boiler and the waste management facilities. A Q&A session was then facilitated by a UCL team member.

Figure 1. One Brighton

The apartment being monitored is situated on an intermediate floor of the Brighton Belle block at One Brighton (Figure 1). The apartment has a surface area of 45.84m^2, consisting of a hallway, one bedroom, a bathroom and living room area comprising an open kitchen, a small dining space and lounge. The living room area has a floor area of 21.14m^2 and the apartment a floor to ceiling height of 2.65m. The apartment is North-West orientated and has 9.24 m^2 of exposed external wall and 5.88 m^2 of windows (including a glass door in the living room for access to a small balcony). The apartment is occupied by a woman in her 30s, who is out most of the day as she works in another city.

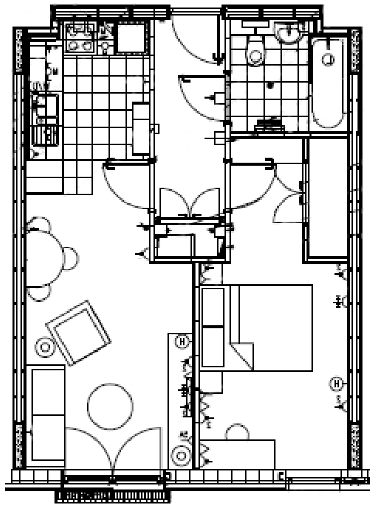


Figure 2. Apartment layout being monitored

1.1 The Development

One Brighton is a mixed use neighbourhood developed by Crest Nicholson and BioRegional Quintain in a joint venture. The project is promoted as one of the country's first environmentally and socially sustainable 'One Planet Living' communities. The development offers a range of residential accommodation, community and commercial/office space. The development comprises 172 homes (eco-studios, 1-bed, 2-bed and 3-bed units), around 1,000 m^2 of community space, and approximately 1,200 m^2 of commercial/office space.

1.1.1 Design Principles

The apartments at One Brighton have been designed following a set of 10 key design principles based on the 10 One Planet Living Principles (Desai, 2010).

1. Zero Carbon: Reducing carbon dioxide emissions by optimising building energy demand and supplying from zero carbon and renewable resources
2. Zero Waste: Reducing waste arising, then reclaiming, recycling and recovering
3. Sustainable transport: Reducing the need to travel and providing sustainable alternatives to private car use
4. Sustainable and local materials: Materials chosen for buildings and infrastructure to give high performance in use with minimised impact in manufacture and delivery
5. Sustainable and local food: Consumption of local, seasonal and organic produce, with reduced amount of animal protein and packaging

6. Sustainable water: Reduced water demand with rain and waste water managed sustainably
7. Natural habitats and wildlife: Existing biodiversity conserved and opportunities taken to increase ecological value
8. Culture and heritage: Cultural heritage acknowledged and interpreted. Sense of place and identity engendered to contribute towards future heritage
9. Equity and fair trade: Create a sense of community. Provide accessible, inclusive and affordable facilities and services
10. Health and happiness: Promote health and wellbeing. Establish long-term management and support strategies

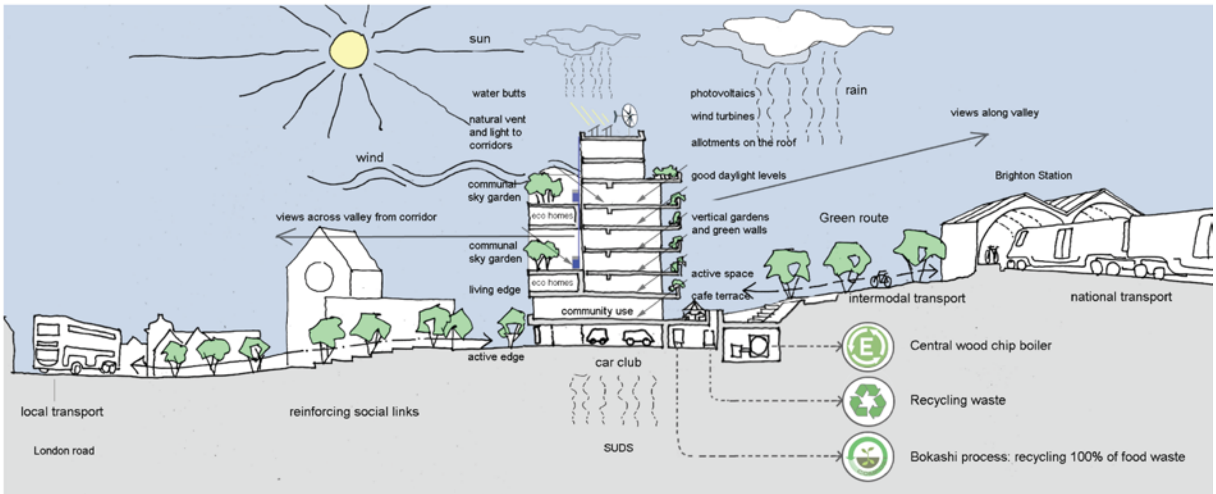


Figure 3. Some of the sustainable design principles used in the One Brighton development

1.1.2 Design Standards and Specifications

Table 1. Outline design specification

High thermal performance standards of built form	Insulation levels to be in excess of 2006 Building Regulation minima by 15%, in-line with achieving maximum credits under relevant EcoHomes criteria. Proposed external wall construction had U-value of 0.21 W/m^2K (40% above 2002 Building Regulations) and window U-value of 1.3 W/m^2K (sufficient to preclude unwanted cold downdraughts)
	Window surface area for residential elements to be

	greater than 0.15% of floor area
	Target for air tightness of $5m^3h^{-1}m^{-2}$ @ 50 Pa. This compares to Building Regulations (ADL1a2006) maximum of $10m^3$ $m^3h^{-1}m^{-2}$ @ 50 Pa.
Energy efficient appliances and fittings	Provide A-rated appliances in homes and information to occupants on purchasing energy-efficient goods
	Energy efficient light fittings specified internally and externally to secure maximum relevant EcoHomes and BREEAM credits, and to help ensure efficient lights are used in perpetuity
Low/zero carbon energy generation	Centralised renewable energy system providing a carbon-neutral solution
Heating and hot water	Biomass-fuelled boiler coupled to accumulator with back-up gas boiler. Summer time temperatures to be limited by façade design, exposed thermal mass and night time purge by ventilation unit
Electrical	PV power generation via array of small-scale building-mounted systems
	Commitment to feasibility study investigating twinning development with new larger-scale wind turbine array in Brighton area
	Remainder of electrical demand met via ‘green tariff’ supply contract between renewable utility provider and community trust with sub-metering via private wire to individual residents (currently exploring approach via ‘opt out’ of 28 day rule). REGO

	(Renewable Energy Guarantee of Origin) certified 'green tariff' selected to support the creation of new renewable capacity.

1.1.3 Design Targets

- Net zero carbon development in use
- CO_2 emissions from homes (as defined by EcoHomes) to be 25kg CO_2/m^2
- ***Space heating demands < 30 kWh/m^2/annum***
- ***Hot water < 45 kWh/m^2/annum***
- ***Electrical consumption < 45 kWh/m^2/annum***
- U-values 30% below Building Regulations (ADL1A 2006)."
- Low energy lighting and appliances, drying spaces and good daylighting
- Low carbon, low impact concrete frame and infill design
- Monitoring through an established ESCO – energy services company

1.2 Conclusions

1.2.1 Key findings

- Infra-red images taken both from the outside and the inside of the building show little evidence of thermal bridging, and the Coheating test that was undertaken in one apartment shows a measured heat loss that is, within margins of error, consistent with design expectations. Consistent with the high levels of insulation achieved at One Brighton, the BUS survey showed high levels of satisfaction with the apartments in winter.
- In general the building meets the occupants' needs, as a high percentage of residents thus indicated.
- There is clear evidence of a tendency to overheat at One Brighton. Primary determinants of overheating are solar heat gains through fabric and fenestration, fabric heat loss and thermal mass, ventilation and control of internal heat gains.
- External noise from busy streets appears to be a factor that limits window opening in hot weather.

1.2.2 New technologies

- The mechanical ventilation with heat recovery (MVHR) system presented challenges in their design stage and later installation. Designers responded to the lack of space in the apartments by placing the MVHR above the ceiling in the bathroom. This severely limits access for maintenance and replacement of filters, and may in the longer term affect indoor air quality and operational life of the system.
- The introduction of new technologies has been a continuous challenge to the Green Caretaker. He has been forced to deal with issues and ultimately experiences, which unfortunately cannot easily be transferred. This became critically important when the original building manager moved on.

1.2.3 What worked well

- The Green Caretaker has been a key player in the success of One Brighton. He has helped to continuously communicate to residents the ethos and purpose and functions of the green systems of the development.
- Facilities such as the *Allotment and bike store are areas* are a great success in the project and seem to be loved by residents.
- Heat use is dominated by the use of hot water, with proportionally very little heat used for space heating. Despite low space heating usage, recorded internal temperatures in the apartment during cold months were most of the time above comfort levels (between 19^{o}C and 25^{o}C). This demonstrates that the building fabric is providing good thermal insulation.
- In general OB performs above average in terms of heat energy use and exceeds targets. In many ways, One Brighton performs better than expected, and appears as an adequate alternative for future sustainable developments.

1.2.4 What did not work well

- Communal heating system
- Some residents had the expectation that the ventilation system also functions as a cooling system. This points to a failure in the handover procedure. Confusion on the part of occupants about the function of the MVHR system in summer is likely to lead to disappointment.
- Significant internal heat gains come from heat distribution systems. These cause raised temperatures in circulation spaces. Additional heat gains come from uninsulated components of the HIU within apartments.
- Commissioning of systems such as the MVHR units is essential in a project like One Brighton. In this case the MVHR was not commissioned as indicated by the manufacturer. Commissioning was limited to a simple physical record of its installation in each apartment.
- Electricity used by the MVHR is proportionally high. It equates to approx 30% of the overall electricity consumed in the apartment, reaching almost 40% in summer.

- Parts of the One Brighton development are exposed to significant levels of solar radiation. External shading, or window systems that incorporate effective protection against solar gain, would have been beneficial in reducing heat gain and overheating.

1.2.5 Areas for future work

- Control of summer overheating in highly insulated dwellings, particularly in apartment blocks, requires as careful attention to insulation of heating systems as to the building envelope. A survey of the integrity and continuity of insulation on the communal heat distribution system could be undertaken.
- All those who attended the walkthrough enjoyed the experience and the presentations and focus group discussion that followed. Most communicated that they had not been involved in this type of feedback session for previous projects that they had worked on and felt that it was a valuable experience. This suggests that more wash-up meetings or project feedback sessions, where BPE findings are presented to the design and construction team, could be of high value and help transmit in-use performance knowledge. This could potentially go some way towards closing the performance gap.

2 Building Construction

2.1 Building Fabric

The external walls consist of a concrete frame with an infill of NBT Thermoplan blocks, and are externally clad with wood fibre insulant and rendered – the system is a two-layer, single skin load-bearing wall system. The honeycombed blocks are planed top and bottom during manufacture, enabling them to be laid with thin bedding joints of adhesive to produce a single skin, robust, weather and airtight structural wall, which is vapour permeable (airtight and breathable). The blocks interlock on the vertical face and require no vertical mortared joints, with the thin horizontal mortar joint having a negligible impact on the overall fabric performance. The frame and 240 mm infill blocks are wrapped externally with insulation of compressed interlocking T&G 100mm wood-fibre boards and rendered (Figure 4). The wall system as a whole is designed to be inherently free of thermal bridging and convective bypasses.

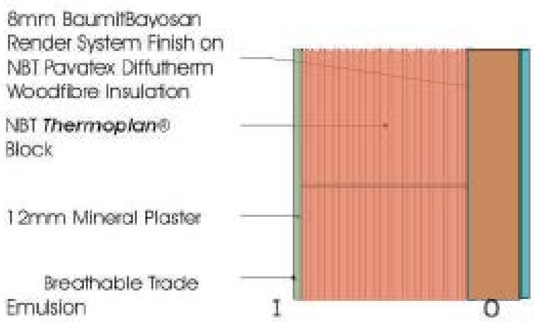


Figure 4. External wall construction detail One Brighton development

2.2 Building services

To achieve the Zero Carbon principles, the One Brighton design combines good thermal design, energy efficient appliances and fittings, and on and off-site renewable generation technologies.

Space heating and hot water demand at One Brighton is provided by a centralised biomass boiler coupled to an accumulator with a back-up gas boiler. A communal heating system then distributes this heat to heat exchanger units in the flats.

The summer time temperatures were designed to be limited by the façade design, exposed thermal mass and night-time air purge using the ventilation unit. The requirements of the Approved Document F for Ventilation were designed to be met by the installation of MVHR system to provide adequate fresh air in the flats.

The MVHR systems also provide the space heating requirements through a water-to-air heat exchanger sited within the MVHR unit, downstream of the main air-to-air heat recovery heat exchanger.

2.2.1 Ventilation

The ventilation strategy for all apartments at One Brighton uses Mechanical Ventilation with Heat Recovery (MVHR).

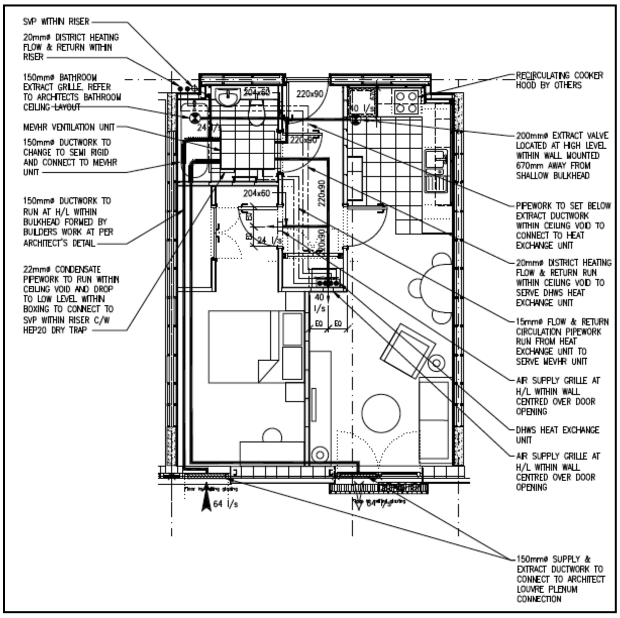


Figure 5. Drawing layout of ventilation and heating system in apartment N^{o}36

The system was designed to work with an air permeability of 5m^{3}h^{-1}m^{-2} @ 50 Pa, which was lower than the Building Regulations requirement of 10m^{3} m^{3}h^{-1}m^{-2} @ 50 Pa (2006 Building Regulations) and with the approved document F 2006. The system contains supply terminals for bedrooms and living rooms and extracts terminals from bathrooms and kitchens.

Figure 6.Illustration of MVHR Xcell 600 installed in ceiling of bathroom

The MVHR system used was Xpelair Xcell 600 with a stated heat recovery efficiency of 70%. The MVHR is controlled by a FX07 controller which provides 5 options of fan speed control (automatic, off, permanently running at low, medium and high speed). Boost mechanical extract ventilation is provided by the operation of light switches within the bathrooms and on operation on the cookers within the kitchens.

Figure 7. FX07 MVHR control

2.2.2 Ventilation commissioning

The ventilation flow rates recommended for commissioning in the boost mode in apartment 36 are shown below.

Table 2.Ventilation flow rates for the MVHR in boost mode

	Lounge (supply)	Kitchen (extract)	Bedroom (supply)	Bathroom (extract)	Total supply and extract
l/s	40	40	36	36	76

Even though there is no record of an official commissioning of the MVHR at One Brighton, a spot check was carried out. Measurements were taken using a TSI Aircone Flow Hood. Three readings in the highest speed as given by the control (Figure 7), which is not boost mode, were taken per supply and extract terminals and the average calculated. Flow rates recommended for commissioning of the MVHR at its highest speed setting (76 l/s) are presented in Table 2. As can be seen in Table 3, the ventilation flow rates measured for supply are higher than those measured in the extracts (more air is being supplied than extracted). It was also found that the ventilation rates measured are significantly lower than the recommended commissioning value, reaching almost 60% lower rates than recommended commissioning values.

Table 3.Ventilation flow rates measured in the apartment, Brighton Belle

	Lounge (supply)	Kitchen (extract)	Bedroom (supply)	Bathroom (extract)
l/s	29	17	27	15

2.2.3 Space heating

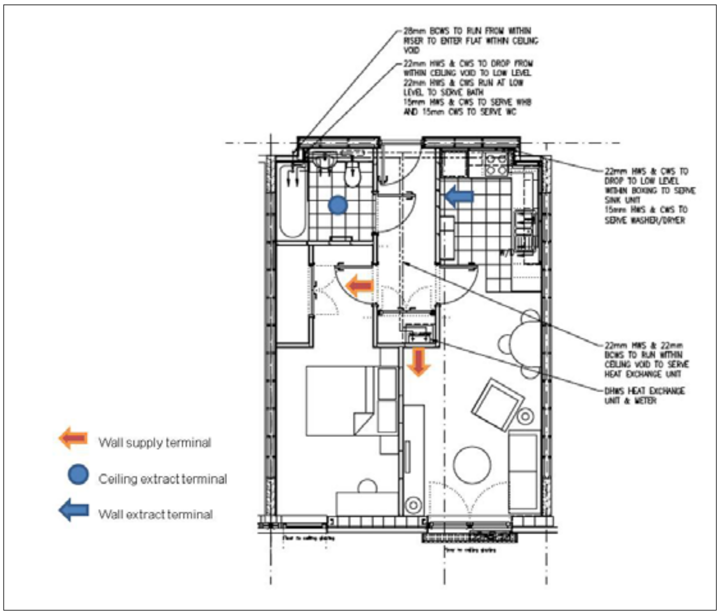


Figure 8. Drawing layout of hot and cold water services in apartment and location of supply and extract terminals

A biomass boiler was installed to provide all space heating and hot water requirements for One Brighton, including the commercial, community and residential spaces, via a Low Temperature Hot-Water (LTHW) flow-and-return heat distribution system. A gas-fired standalone back up boiler was installed for operational use when the biomass boiler is shut down for maintenance. In addition to the boiler plant, two 10,000 litre storage vessels were installed to provide additional heating during period of high heating requirements.

The heat distribution system at One Brighton consists of horizontal distribution from the main boilers at basement level, vertical distribution in a set of risers, and finally horizontal distribution at high level in corridor ceilings to the heat exchanger units located in each apartment. The heat exchanger units, also referred to as Consumer Interface Units (CIUs) or Heat Interface Units (HIUs), installed are Switch2 Mini CIU.

The CIU contains two circuits: one to provide domestic hot water to taps and showers and one to provide space heating. Space heating within the apartments is delivered by the MVHR located within the bathroom ceiling. It provides warm air into bedrooms and living rooms via the wall mounted air valves. The heat is supplied via a secondary heating flow and return service from the CIU into the LTHW coil within the MVHR unit to heat up the air.

In operation, the biomass boiler has had technical failures and there has been difficulty with the quality of the fuel supply. As such, the gas-boiler, although designed as back-up, has often provided all or most of the heating requirement.

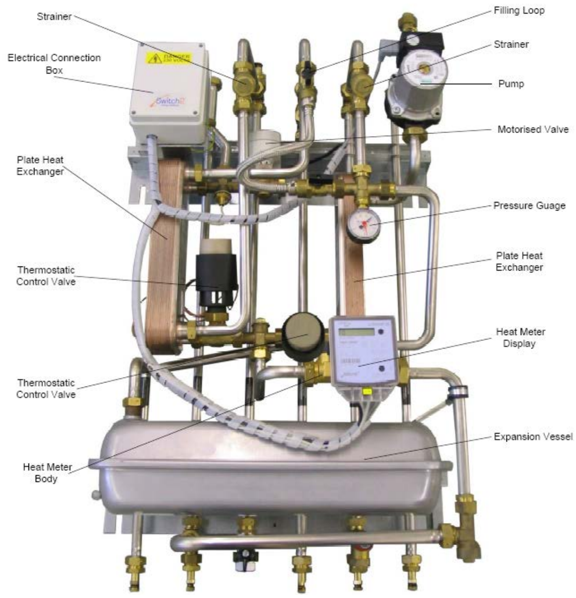


Figure 9. Switch2 Mini Consumer Interface Unit (Switch2 technical details, 2007)

2.3 Key findings

- The supply and extract rates measured in the apartment are considerably different to those recommended for the commissioning of the MVHR in apartment N^{o}36. The lower air flow rates can be associated with poor indoor air quality due to a lower air change rate, and therefore have an impact on the health of residents. This could also lead to problems of humidity and mould growth, especially in the bathroom due to the low extract rate measured.
- No record of the commissioning of the ventilation systems at One Brighton was available. The low ventilation rates measured by UCL highlight a key issue at One Brighton, which probably is a problem that affects a good number of apartments - measurements were taken in 5 apartments and all had low ventilation rates.
- The ventilation system seems to be a recurrent problem, being mentioned not just by the design team but also by residents. There is a lack of understanding of the function, proper operation and maintenance of the system. Given the implication that the MVHR may have for the internal environmental conditions of a building and its effects (for good or bad) on the health of its residents, it is recommended that the design, installation and commissioning of MVHR systems be undertaken thoroughly, and that systems be maintained, and periodically re-commissioned over their lives. Guidance on all of this is widely available, of varying quality. The best we have seen in English is still the Canadian Standard:

  CSA (1991) *Residential Mechanical Ventilation Systems*, CAN/CSA-F326-M91 (R2010). http://shop.csa.ca/en/canada/energy-efficiency/cancsa-f326-m91-r2010/invt/27003241991/

  The Passivhausinstitut produces superb material, though mostly in German. http://www.passipedia.de/passipedia_de/zertifizierung/passivhausgeeignete_komponenten/zertifizierung_von_lueftungsgeraeten

  Organisations such as the AECB, the Passivhaus Trust and BRE provide guidance oriented to the UK – see for example, the AECB's Passivhaus Guide. Encraft have recently produced a very good guide in English - among other things, this covers access for maintenance – something that was not well done at One Brighton:

http://www.encraft.co.uk/wp-content/uploads/2012/08/Viewpoint-August-2012-MVHR-Designing-and-implementing-a-robust-and-effective-ventilation-system3.pdf

Note that the above is not intended to be an exhaustive list.

3 Occupant surveys (BUS) and interviews

3.1 Methodology

Residents were surveyed using the Building Use Survey (BUS) during the winter of 2011 and summer of 2012. In addition, a Behaviour Survey was used, designed to assess the behaviours related to reducing heat, water and electricity use. This survey enables quantification and apportionment of building performance to occupant behaviour. The first BUS survey and Behaviour Survey were undertaken as part of a UCL MSc dissertation (Bainbridge, 2011).

A ‘walkthrough’ and in-depth interviews with occupants and members of the One Brighton design team were also carried out. The ‘Walkthrough’ took place earlier in July 2011 at One Brighton. Core design team members and those involved with the monitoring and testing of One Brighton, together with the Green Caretaker, were invited to visit One Brighton and view an occupied flat, the allotments, the biomass boiler and the waste management facilities. A Q&A session was then facilitated by a UCL team member.

Access to One Brighton was pre-arranged with the help of Crest Nicholson, Bioregional Quintain and the Green Caretaker. An introduction letter, information sheet and a paper copy of the survey were delivered to each resident’s post box early in January 2011 and June 2012. In addition, posters were displayed in communal areas and an advertisement in the community newsletter was placed to promote the survey. Residents were provided with drop-off points for the completed surveys. Entry into a prize draw in vouchers for a local food and natural products cooperative was offered as an incentive.

A call was made on each of the 172 flats at One Brighton to encourage people to fill out the surveys. The occupants (approximately 140 flats in the winter and 125 flats in the summer) were spoken to directly to explain and introduced to the survey. This involved visiting the development a considerable number of times, mainly during the evenings, lunchtimes and weekends. A variety of posters were also produced, some which stated the probability of winning prizes to stimulate interest in the project. Due to an initial low response rate (for both surveys) in "month" the surveys were reposted to everyone who had not completed the questionnaire.

The BUS survey includes a section relating to summer and winter comfort. It is an acknowledged feature of the method that responses to surveys may differ at different times of the year. Since results of a survey can only be regarded as a snapshot in time, two surveys were conducted. The first survey was conducted during the winter of 2010/11, which probably included the coldest December for more than a century (based on the Central England Temperature Series – the available data for Brighton only goes back to 1959). For the second year running, heavy snow had fallen in Brighton. Although the second survey was carried out at the beginning of summer there was a general perception of a mild summer with temperatures lower for a normal June. A total of 62 completed surveys were returned from 60 apartments in the first survey, representing a 35% response rate. In the second survey however a total 51 completed surveys were returned from 50 apartments representing 30% response rate. Table 4 details the breakdown of responses for both surveys. All collected data was treated in accordance with the Data Protection Act and is subject to a quality control procedure.

Table 4. Survey response breakdown based on period, building and apartment type

		Brighton Belle					Pullman Haul				
		Total	Apartment type				Total	Apartment type			
Period			ES	1	2	3		ES	1	2	3
Winter 2011	Number of surveys returned	41	4	15	22	0	21	1	12	7	1
	Percentage of dwellings in each building & breakdown of response rate	36%	10%	36%	54%	NA	33%	5%	57%	33%	5%
Summer 2012	Number of surveys returned	29	5	9	11	0	21	2	11	4	4
	Percentage of dwellings in each building & breakdown of response rate	26%	20%	36%	44%	NA	33%	10%	52%	19%	19%

3.2 BUS survey - January 2011

The results from the BUS indicate that according to occupants' opinions, One Brighton delivers healthy and satisfactory living conditions in 70 to 80% of apartments. 82% of residents indicated that the building met their needs. Comfort conditions in winter are better than in summer.

A wide range of factors was mentioned that work well including: layout, allotments, bike storage, location, bins, the green caretaker, insulation and transport links. Examples of things that do not work included: noise insulation, lack of car parking, the intercom system and the heating/ventilation system.

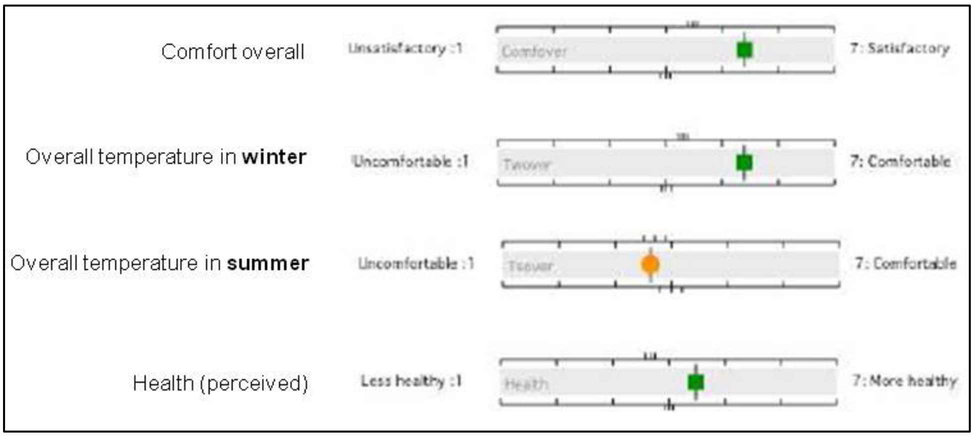


Figure 10. General results of the BUS survey carried out in January 2011

No evidence of damp was seen or reported. Air quality was generally reported to be dry or even too dry – this is consistent with physical measurements and is to be expected given the generally high internal temperatures recorded in all apartments. In general, residents are satisfied with the lighting regime; however, 37% indicated that there is more than enough artificial lighting (particularly in the corridors). Despite the orientation of some flats not being optimum for desirable day lighting conditions due to plot constraints, only 24% reported too little daylight.

The main issue in summer appears to be overheating; 75% of occupants reported that it is hot or too hot (it is worth noting that in Brighton, August 2011 was around 2°C cooler than the heat wave of August 2003, which suggests that the development is at significant risk of overheating during a heat wave). Main health issues reported were regarding noise, dust, pollution, air dryness, and the heating and ventilation system. Nevertheless, 84% indicated that there had been no changes or perceived health effect while living at One Brighton. Residents are satisfied with the lighting installation and only 24% reported low daylight levels.

Some of the negative aspects of the survey are related to services costs. Many occupants considered that energy costs were higher than in their previous accommodation. Nevertheless, the unit energy price comparisons carried out by Bainbridge (2011) suggested that mainstream unit energy prices do not differ substantially from One Brighton. In the case of electricity, the unit price for 100% renewable energy is on the low side. Other comments strongly oppose the standing charge (for full maintenance of all systems) which residents perceive to be too expensive. It is not clear if residents considered the costs of maintaining and replacing their previous systems when making the cost comparison with the system at the building (Bainbridge, 2011).

3.3 BUS Survey - June 2012

Results from the second BUS survey showed that most people are satisfied and comfortable at One Brighton. The location of the site is valued highly and cited positively by residents throughout the survey (Figure 11). More than 50% of residents made positive comments about the location of the site, mostly regarding the convenience to local amenities. Location appears to be the most important factor for lifestyle change too. However some residents do cite noise and antisocial behaviour as negative issues related to the location of the site. In general, people are satisfied with the space and layout of the building.

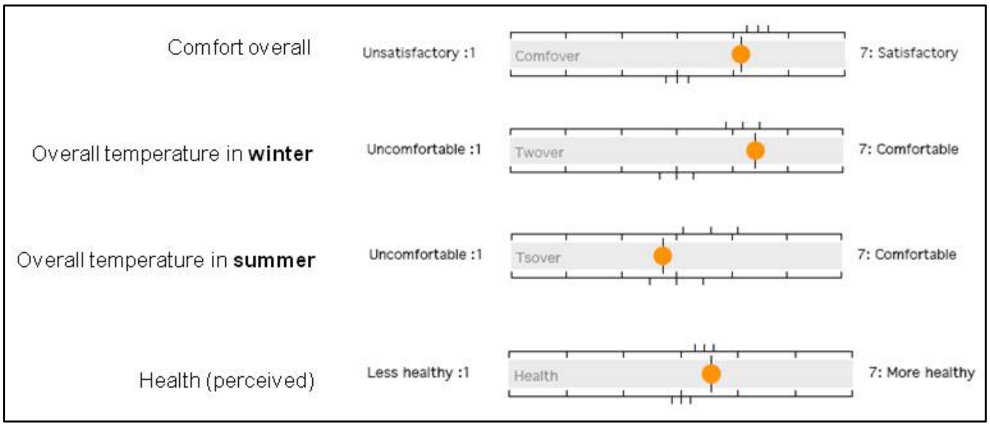


Figure 11 General results of the BUS survey carried out in June 2012

However, control over the internal environment (temperature and noise) in particular is an issue. Despite most residents living at the site for more than a year, more than half report dissatisfaction with the control of the heating system, which seems to be an issue mainly during warm days. When it is hot outside there is not much that residents can do. Overall, residents perceive that they have less control over the temperature than in 2011. The option of opening windows is limited due to the noise and pollution from the surrounding area. Comments also indicate that the air from the ventilation system can be dusty and dry, causing other air quality associated problems.

Another negative aspect reported potentially points to an inadequate ventilation system. 47% of residents reported dissatisfaction with the stuffiness of the air (43% in winter, a 25% increase on 2011). This issue may be related to the cleaning and maintenance of filters. Feedback suggested that access to filters is problematic but also that residents understood they were not responsible for changing the filters.

External noise affects how effectively flats are naturally ventilated, and therefore the quality of the internal environment. Noise disturbance and its associated consequences appear to be one of the main drivers that residents perceive to reduce their health.

There are fewer negative comments regarding the lack of parking compared with the previous survey. It seems One Brighton residents have changed their lifestyle with a reported increase in walking and use of public transport.

The results from this survey were discussed with the Green Caretaker at the site in order to explore other issues not mentioned in the BUS. In general he thought that the BUS results painted an accurate picture of the situation at One Brighton. He also commented that having processed the waste at One Brighton, very little evidence (visual & olfactory) of fresh food preparation was noted. However packets from ready prepared food were in abundance. This observation, albeit anecdotal goes against the grain of one of the aims in the sustainability action plan which was for 25% of the food consumed on site to be from local sources. It is also important from an ecological footprinting perspective as 26% of ecological resources are attributed to food. This topic could benefit from further study, particularly if the open plan layout of the kitchen/living area (or elevated temperatures) has some effect on eating habits and food choices. On the other hand this could be a symptom of modern urban living (Bainbridge, 2012).

3.4 Comparing the two BUS surveys

Table 5 shows the differences in levels of satisfaction from responses (n=63) given in 2011 and responses (n=51) given in 2012. Values are calculated from the results of the BUS questionnaire. The questions are summarised, with an indication of the Likert scale extremes (Bainbridge, 2012).

Table 5. Comparison of levels of % dissatisfaction between 2011 &2012

	QUESTIONS	2011	2012	2011-2012
THE RESIDENCE OVERALL	LOCATION: UN/SATISFACTORY	2	4	-2
	SPACE: ENOUGH/ NOT ENOUGH	16	26	-10
	LAYOUT: SUITABLE/ NOT SUITABLE	3	16	-13
	STORAGE: ENOUGH/ NOT ENOUGH	28	38	-10
	APPEARANCE: POOR/GOOD	5	10	-5
	NEEDS: VERY POORLY/VERY WELL	2	10	-8
WINTER COMFORT	TEMPERATURE OVERALL	16	12	4
	TOO HOT-TOO COLD	20	23	-3
	TEMP STABLE- VARIABLE	43	35	8
	AIR STILL- DRAUGHTY	66	55	11
	AIR DRY- HUMID	50	46	4
	AIR FRESH- STUFFY	18	43	-25
	AIR ODOURLESS- SMELLY	7	11	-4
	CONDITIONS OVERALL	22	31	-9
SUMMER COMFORT	TEMPERATURE OVERALL	49	43	6
	TOO HOT-TOO COLD	50	53	-3
	TEMP STABLE- VARIABLE	42	25	17
	AIR STILL- DRAUGHTY	54	59	-5
	AIR DRY- HUMID	52	52	0
	AIR FRESH- STUFFY	46	47	-1
	AIR ODOURLESS- SMELLY	10	24	-14
	CONDITIONS OVERALL	43	47	-4
NOISE	NOISE OVERALL:UN/SATISFACTORY	29	37	-8
	NOISE BETWEEN ROOMS: TOO	34	34	0
	NOISE NEIGHBOURS: TOO LITTLE/MUCH	47	45	2
	NOISE FROM OUTSIDE: TOO LITTLE/MUCH	54	53	1
LIGHT	LIGHTING OVERALL:UN/SATISFACTORY	15	10	5
	NATURAL LIGHT: TOO LITTLE/MUCH	22	22	0
	ARTIFICIAL LIGHT: TOO LITTLE/MUCH	22	20	2
				0
COMFORT	ALL THINGS CONSIDERED COMFORT:UN/SATISFACTORY	7	18	-11
HEALTH	LESS HEALTHY- MORE HEALTHY	16	18	-2
CONTROL	HEATING: NO CONTROL/FULL CONTROL	40	58	-18
	COOLING: NO CONTROL/FULL CONTROL	50	67	-17
	VENTILATION: NO CONTROL/FULL	30	48	-18
	LIGHTING: NO CONTROL/FULL CONTROL	13	18	-5
	NOISE: NO CONTROL/FULL CONTROL	45	49	-4
DESIGN	DESIGN: UN/SATISFACTORY	15	17	-2

It should be noted that 50% of those who responded in 2012 also responded in 2011. Although in general the differences are not large, it does appear that occupants are less satisfied in 2012. We can tentatively propose some possible reasons for this. It could be that in 2011 the building and its occupants were still in their "honeymoon period" having just recently moved in. Respondents had not yet had much experience of life at One Brighton (54% of respondents had lived at the site for less than one year). Whereas in 2012, 88% of the respondents have lived at the site for more than one year. Comparison of comments about parking and recycling between 2011 & 2012 suggest that residents are adapting to their new environment. It was originally hypothesised that satisfaction levels in summer would be notably lower because the survey was conducted after a warm spell in 2012. However this is not borne out by the data. Respondents in 2012 indicate that they have less control of the ventilation, cooling & heating system than in 2011. This is perhaps contrary to what it would be expected, given that occupants have had time to get used to the controls.

3.5 Behaviour survey results

The behaviour survey was used to calculate "behaviour scores" for water, heat and electricity use. Higher scores translate to a more efficient behaviour (i.e., reduced resource consumption). These scores were then compared with water, heat, and electricity use. No convincing correlations were observed. This is accounted for by the large variability of the data, the small sample size (especially when datasets are subdivided), the heterogeneous nature of the residents (students, families, commuters, couples, etc.) and their occupancy patterns.

Table 6.Percentage response from occupants at OB to a selection of questions from the behaviour survey (Bainbridge, 2011, UCL MSc dissertation)

Question	Percentage of Responses			
General Questions	disagree	neutral	agree	did not answer
I consider myself to be environmentally friendly	0	24	62	15
I consider my behaviour to be energy efficient	4	20	62	15
I consider my house to be energy efficient	2	13	67	18
Living in an 'efficient' house means that I don't need to think about saving energy and water to be environmentally friendly	36	15	27	22
Water use Questions	disagree	neutral	agree	did not answer
In the UK we are using more water than we can source sustainably (without harming the planet)	11	51	38	0
The (water) fixtures, fittings and appliances in this house are efficient	7	18	75	0
I try to keep my personal cleaning time to a sensible level and take showers, not baths	16	18	65	0
I would feel good if I/we used less water than other apparments at One Brighton	13	47	40	0
I feel pressure to reduce water consumption through the media and government etc.	36	40	24	0
I could use less water from taps, showers and appliances (washing machine etc) if I thought about it	15	40	45	0
Heating Questions	disagree	neutral	agree	did not answer
I know how to change the thermostat and radiator valve settings throughout the house	9	20	71	0
I have optimised my thermostat and radiator valve settings for the way that I use the house	24	29	45	2
I would feel good if I knew I/we used less heating and hot water than other appartments at One Brighton	7	49	44	0
I feel pressure to reduce heating consumption through the media and government etc.	40	33	25	2
Reducing my heating and/or hot water consumption from its current usage will reduce my comfort	33	24	42	0
I can make myself comfortable in the home through other means than heating	4	24	73	0
In the future I could easily make changes to reduce my heating/hot water consumption	28	46	26	0
Electricity Questions	disagree	neutral	agree	did not answer
It is inconvenient to turn things off when I'm not using them	58	16	25	0
I think there are people in the UK who use far more electricity than I do	4	7	89	0
Any electrical reduction effort I make is offset by those who use excessive amounts of electricity	27	38	35	0
I would feel good if I knew I used less electricity than other homes at One Brighton	9	35	56	0
If I knew where I could reduce my electricity consumption I would make the effort to do so	9	22	69	0

As observed in Table 6, 25% (heating) to 69% (electricity) of occupants would be willing to make changes to reduce their resource use. Approximately 38% of respondents did not feel pressure to reduce water and heating use, while 35% believed that any electricity savings they made would be offset by other users. However, between 40% – 56% indicated that they would feel “good” if they knew they used fewer resources than other homes. Only 7-13% disagreed.

3.6 Interview with residents

Five residents were selected for in-depth semi-structured interviews using Technology Strategy Board Building Performance Evaluation programme questions. Interviews included the resident of apartment 36, being monitored as part of this study. Findings from these interviews were also presented to the design team focus group. Three of these residents were owner-occupiers and two tenants lived in rented accommodation.

A summary of observations and key findings from each of the resident interviews are presented below.

Table 7. Resident interview summaries

Resident A:	Most Likes	Most Dislikes	5 Key Points
Home Owner	Quality of finishes and community feeling	Balcony, letter boxes on ground floor + warm cold water	1. Warm cold water from cold taps
			2. Entry system directed to mobile phone with confusing interface
			3. Balcony not large enough to stand on
			4. Sockets wired wrong for relevant appliances
			5. MVHR – filters – not easy to change and unclear who is to change them
Quotation	*‘there is a slight user interface issue here – do I have to say hello – are they hearing me now – and it is hello, hello in front of me – every time I have let someone in it has been quite confusing’ - when referring to the door-entry system*		
Resident B:	Most Likes	Most Dislikes	5 Key Points
Home Owner	Location, aesthetics + roof terrace	Summer temperature +	1. Confusion about heating system control i.e. control of MVHR

		waste management	2. Balcony doors designed so it is difficult to install curtain rail
			3. Lamps (light bulbs) only available from specialist suppliers
			4. Summer temperature too hot
			5. Living space combined with kitchen makes it slightly small
Quotation	*'I mean there are things – design things – I did not mention that things are designed badly like that door – it has been designed so you can't actually fit a curtain rail' about balcony window doors'*		
Resident C:	Most Likes	Most Dislikes	5 Key Points
Home Owner	Location and modern design	Kitchen in living area	1. Kitchen in living area
			2. MVHR - filters
			3. Services management and cost
			4. Washer-drier
			5. Waste management
Quotation	*'the first thing that comes to mind is yes I would like the little kitchen area separate from the lounge and that it is difficult for me, like I said when people do come I do find it difficult cooking in front of people, that is a big adjustment for me' about kitchen area*		
Resident D:	Most Likes	Most Dislikes	5 Key Points
Tenant	Location	Temperature in winter + cost and quality of services	1. Temperature in winter too cold
			2. Acoustics – could hear noise from underground garage
			3. Cost and quality of services
			4. Electrical installation – sockets wired incorrectly
			5. Bins located outside window

Quotation	*'well for two weeks Moat was closed there was nothing I could do and I wasn't the only one in that predicament and you could see that it was a problem because the ground floor and the corridor was so cold, but it you went to the third floor – second, third or fourth floor - you could see the difference in heat ' about heating*		
Resident E:	Most Likes	Most Dislikes	5 Key Points
Tenant	Location	Cost and quality of services + kitchen in living area	1. Cost and quality of services
			2. MVHR – filters – never installed and difficult to change
			3. Acoustics can hear noise from underground car-park
			4. Temperature in winter too cold
			5. Kitchen in living area + storage capacity in kitchen cupboards
Quotation	*cos there are so many issues with it – cos there are so many things and problems … – and it has won all these awards and why? To my mind it seems to be more of a marketing tool rather than anything else' about the development as a whole*		

Key observations from occupant interviews can be summarised as follows:

3.6.1 Mechanical Ventilation with Heat Recovery:

- MVHR units had been installed in the bathrooms above the bath and behind a closed hatch. This made it very difficult for access to change filters and for maintenance. One of the residents reported that no filter had actually been fitted in the MVHR unit when the unit was installed and this was only discovered once a maintenance team came around to change the filter eighteen months after it was first occupied.

3.6.2 Cost of services

- The residents living in rental accommodation both complained about the high level of the service charges.

3.6.3 Cold temperatures

- Uncomfortable and cold flats in winter, together with issues of external noise were also reported. The complaint of cold flats could be linked to misunderstandings about how to operate control systems but also to the fact that the thermostats were installed in a location in the small hallway, which potentially had the capacity to heat up more quickly than the other areas in the flat, due to heat from lighting and to heat gains from the district heating heat interface unit (HIU), installed in the hall cupboard. It is likely that heat loss from the district heating system is also responsible for the high temperature of water from the cold water taps in the flat of occupant A – but without further investigation, it is not possible to say where in the system this heating occurs.

3.6.4 Electrical features

- There were a couple of complaints relating to the positions of some electrical sockets which did not apparently correlate well with appliances. There were also comments about light fittings which used low energy compact fluorescent lamps, which were only available from specialist suppliers at considerable cost.

3.6.5 Other observations

- Related to the depth of kitchen cupboards and design of some of the other details which were considered to be too tight to allow for storage or proper functioning of windows. All residents but one commented on the installation of the kitchen in the living area which was considered to be a potential noise problem, for example if using the washing machine whilst watching television, but also a space/function issue if entertaining guests.
- Some of the issues highlighted above are potentially related to residents learning to deal with their new accommodation; issues such as the installation of the MVHR units in inaccessible places and the difficulty in understanding the control dials for these units may have potentially had a more fundamental bearing on the successful operation of these apartments.

3.7 Design team feedback

A design team 'walkthrough' inclusive of a focus group discussion and presentations were held at the One Brighton development. These activities were funded under the Technology Strategy Board Building Performance Evaluation programme. This provided an opportunity for core members of the project's design and delivery team to visit the completed development and discuss the delivery process and some key findings from Coheating test, the BUS survey and interviews conducted with residents of the development. Those attending were provided with an itinerary for the day and informed that their discussion would be filmed.

Representatives from most of the companies involved in the project attended the meeting, making a total of six supported by four representatives from UCL. People attending the meeting were from Feilden Clegg Bradley, Bioregional Quintain Ltd., Crest Nicholson, MLM group, and One Brighton.

3.7.1 Activities undertaken

The flat visited was chosen from five flats owned or occupied by residents of the development who had agreed to have an interview about their experiences of living in the development. Following the visit to the flat, the walkthrough commenced with visits to the on-site allotments, boiler/plant room and waste management facilities. These visits were led by the 'Green Caretaker'.

After the walkthrough the design team reconvened for presentations and focus group discussions. Individual follow-up interviews were conducted with all the respondents who attended the event, together with a representative from the building services consulting engineers and the director from one of the project developers who previously did not attend the walkthrough. These interviews were also filmed and transcribed. The findings from the interviews together with feedback from the walkthrough are presented below.

3.7.2 Design team feedback summary

- All those who attended the walkthrough enjoyed the experience and the presentations and focus group discussion that followed. Most communicated that they had not been involved in this type of walkthrough feedback for previous projects that they had worked on and felt that it was a valuable experience.

- One of the main client representatives explained that most of the key investors in the development had never actually visited the site.
- Visits to the plant room, allotments and waste facilities were hosted by the Green Caretaker who had been specifically employed to manage the site. All were impressed with the facilities shown and by the Green Caretaker. It was felt that the development could not correctly function without his input.
- The presentations that were made by UCL outlined findings from Coheating tests, the BUS survey and interviews with five residents from the two blocks that make up this development. These presentations were well received and helped to stimulate a broader discussion about the design and delivery processes and the final product.
- Day-to-day management of the site caused some of the areas of discomfort or conflict within the development, since services such as cleaners, who were employed as external contractors, did not necessarily deliver services as specified or anticipated by residents. There were also found to be discrepancies in delivery of services between the private tenanted block and the rented accommodation.
- Some of the site's facilities such as the allotments and bike sheds were found to be very well used and loved, but others, such as the car-sharing facility, were not well used. This was attributed to the fact that the development is located very close to transport hubs for trains and buses and close to general facilities within Brighton, so it was not essential. The design of the green hanging wall garden was also found not to work as planned due to the fact that it needs constant watering and maintenance, for which the caretaker does not have the time. Facilities such as the roof garden and sky gardens were liked but less well used than the allotments.
- Issues were highlighted in relation to the procurement of the MVHR units, which apparently were not delivered to specification to the site.
- The biomass boiler design was also apparently difficult due to lack of understanding of the systems by the design team which were exacerbated by limited information provided by UK representatives of the Austrian supplier and a lack of English language information about the product.

- Additional costs were associated with the biomass boiler installation since infrastructure designed to support it was designed to accommodate a lower physical weight than the actual weight of the boiler which was delivered to site. This potentially shows a lack of attention to detail design from engineers and suppliers.
- Problems with fuel supply for the biomass boiler were also highlighted as an issue relating to its overall function as were instances where the fire brigade had had to be called out to attend 'apparent' fires in the fuel store which were caused by smoke feeding back through the fuel supply auger due to inconsistency of the woodchip fuel supply. Overall it was also noted that the biomass boiler did not function for a considerable percentage of the time, causing the system to revert to the gas boiler. The fuel for the boiler was/is sourced locally and there were issues in obtaining this fuel at a consistent quality. All the above problems probably relate to the fact that the use of biomass boilers in conjunction with district heating and local biomass fuel supply is relatively new in the UK. As a result, supply chains are underdeveloped, and there is a lack of design and construction expertise.
- Other areas of the design process that were discussed in the focus group were the use of new construction technologies such as the hollow clay 'ziegel' blocks from Germany and the fact that the contractors had to learn to use these and that the engineers and design team did not trust initially the technology due to lack of experience with it. UK insurers were also reluctant to support the use of this new technology. To get around this problem, an insurer from Zürich was hired who had knowledge of continental European construction techniques and was willing to support the project.
- Other general issues of concern were linked to the installation of other building services such as lighting and door entry systems. Difficulties in achieving the correct light levels via PIR lighting control of corridors were noted as an issue. The original set-up of the PIR systems resulted in the lighting remaining on all night. Similarly, it was noted that door entry calls, which were supposed to be routed to the mobile phone of a resident, were actually ending up at Gatwick airport.
- All those interviewed felt that on the whole the finished product had met with design intentions, but that there were discrepancies in relation to performance of the biomass boiler, MVHR systems and some of the design strategies such as the use of post-

tensioned slabs as a means of delivering a low air-permeability building (due to tolerances relating to calculated deflections).

- Another area of concern that came up particularly during discussion with the architects was that space planning of the dwellings was largely controlled by the estate agents and letting agents for the development; in other words to those whose concerns related only to maximising profit on sale of properties in the development rather than provision of maximum best space for occupants.
- An area of interest noted by one of the clients was the fact that the mechanical and electrical engineering design team changed from the initial design phases through to the final delivery of the project – this occurred due to the fact that the initial engineers employed had expertise in concept delivery but not site delivery and vice versa.
- One Brighton has been felt to have been a success and the design team is proud to have been part of it. All those who participated in the walkthrough and interviews felt there had been good team co-operation during the project and all were happy to have taken part in the walkthrough process which they perceived as having been useful and productive. There was a feeling that all would be interested in taking part in similar processes in the future.

3.8 Key findings

- Overall the results from the BUS surveys show a generally high level of satisfaction with the development. One Brighton performs well against other commercial and domestic developments in terms of user satisfaction and comfort. Nevertheless it has to be noted that although an extensive benchmark dataset exists for commercial buildings which contains data from 450 sites around the world (The One Brighton data from 2011 was compared to this commercial benchmark dataset), the domestic benchmarking dataset is in its infancy.
- Currently the domestic benchmark contains data from 8 surveys of properties including the data from the survey carried out in 2011, in the two buildings at One Brighton (Brighton Belle and Pullman Haul). The nature of these other 6 properties is not known. They could be single semi-rural new build dwellings built as part of a social housing scheme with a dozen residents or a 1970s urban tower block with 2000 residents.

Therefore although the second BUS survey was analysed according to a residential benchmark, little insight can be gained by comparing One Brighton against 5 other unidentified buildings which could potentially have completely different characteristics.

- In general the building meets the occupants' needs, as a high percentage of residents thus indicated.
- One Brighton delivers healthy and satisfactory living conditions for most occupants.
- Comfort conditions in winter are better than in summer.
- The main issue in summer appears to be overheating.
- Despite identical building specifications satisfaction perceptions differ between the two buildings which comprise the development.
- Comments from the design team and residents indicate that there are some filter maintenance issues and unfamiliarity with the workings of the ventilation system which may lead to reduced system efficacy and dust.
- Some residents also have the expectation that the ventilation system functions as a cooling system. Anecdotally it appears, the handover procedure, particularly in the case of the social housing residents did not sufficiently explain the operation of the ventilation system to the residents.

4 In-use Monitoring results

4.1 Methodology

The parameters being monitored and analysed are temperature, Relative Humidity (RH) and carbon dioxide (CO_2) levels in living room and bedroom, and space heating and electricity consumption. Finally, heat delivered by the district heating network and water use are calculated from information provided by the ESCo.

The following external conditions are also being monitored:

- Temperature (^oC) and Relative Humidity (%)
- Wind speed (m/s) and wind direction (^{o})
- Precipitation (mm)
- Barometric pressure (hPa)
- Solar radiation (W/m^2)

The monitoring system consists of an ELTEK wireless data logger installed in October 2011. The installation of the submeters was undertaken by an electrician and a plumber familiar with the site (they worked on the construction of One Brighton) and was overseen by the UCL team. The setup of the ELTEK system was carried out at UCL but supervised by the ELTEK technicians.

Data was recorded at 5 minute intervals and downloaded remotely via modem by UCL on a weekly basis. The data was checked weekly to identify general failure or maintenance issues. The installed monitoring kit included:

- Electrical sub-meters for electricity being consumed from sockets, lighting, cooker and the mechanical ventilation (MVHR) were installed in the fuse board.
- A heat meter for space heating was installed.
- 2 temperature, relative humidity and carbon dioxide transmitters for living room and bedroom were installed.
- The internal air of the apartment is being monitored using CO_2 as a proxy for air quality.

The location of each device is indicated in Figure 12 below:

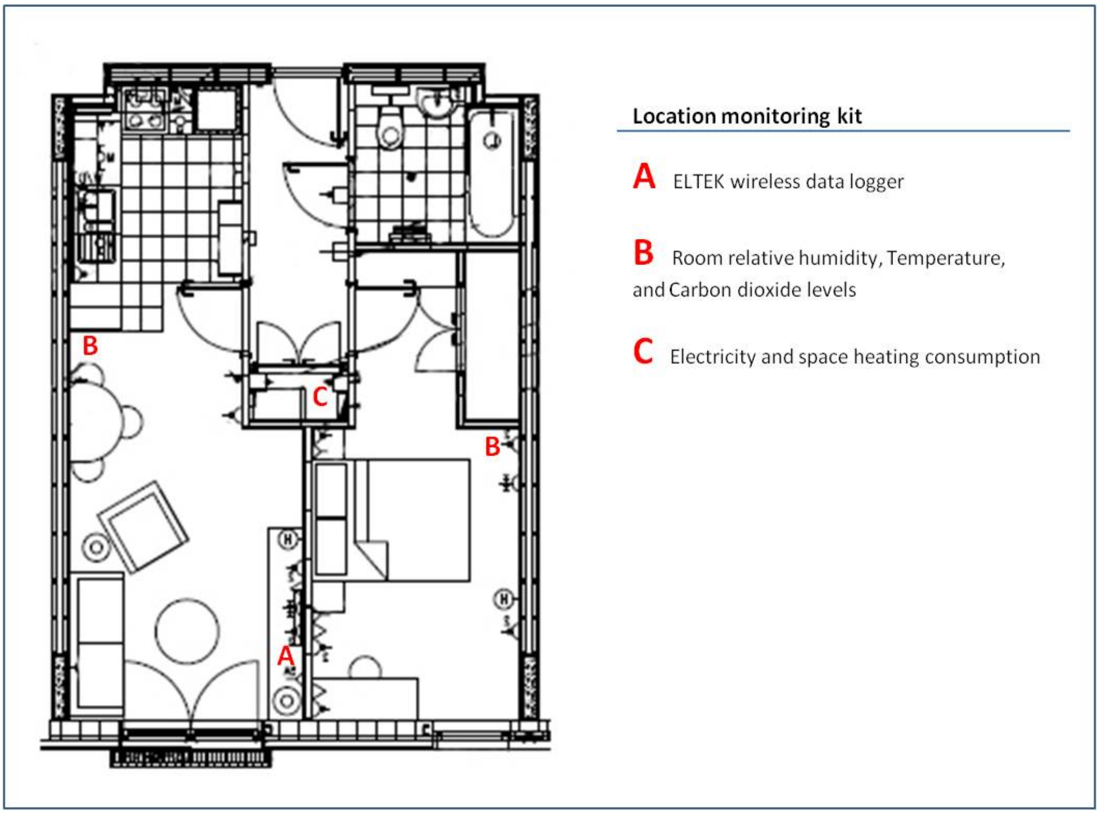


Figure 12. Location of data logger and transmitters of the monitoring kit

4.2 Site wide consumption

Figures below indicate that there is considerable variability of resource consumption across the apartments. The data analysed corresponded to the energy consumed in 2010 (Bainbridge, 2011). The benchmarks used for comparison are: a predicted value for Code for sustainable Homes; Bedzed measured use in 2007/8 (Haltrecht, 2008); Passivhaus (http://www.passivhaus.org.uk/); Design Target (BioRegional Quintain Ltd.,2006); UK stock; and figures derived from the National Energy Efficiency Data Framework (NEED) data: Average of 1& 2 bedroom apartments (DECC 2008).

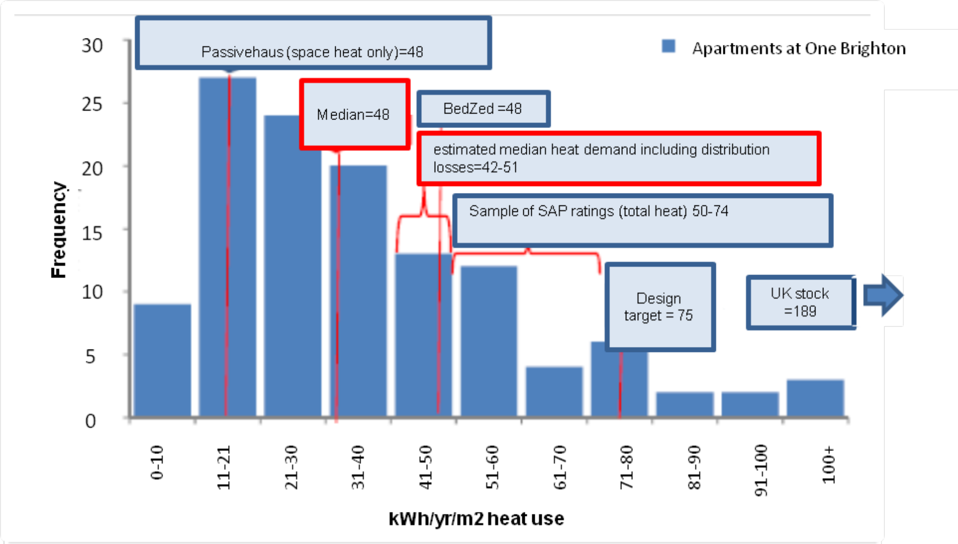


Figure 13. Frequency distribution of annual delivered heat (space and water) use for 122 apartments.

In general OB performs above average in terms of heat energy use and exceeds targets. The metric used for heat energy consumption at OB is for delivered energy to apartments and takes no account of distribution losses or boiler efficiency.

The analysis showed that SAP targets were met for heat consumption and it was much lower than average consumption of the UK Stock (DECC 2010). Overall, the building envelope appears to be performing well; results from the BUS survey show that occupants are broadly happy with the winter condition but also internal temperatures recorded from a few apartments show comfortable conditions during cold months and no evidence of under-heating was found.

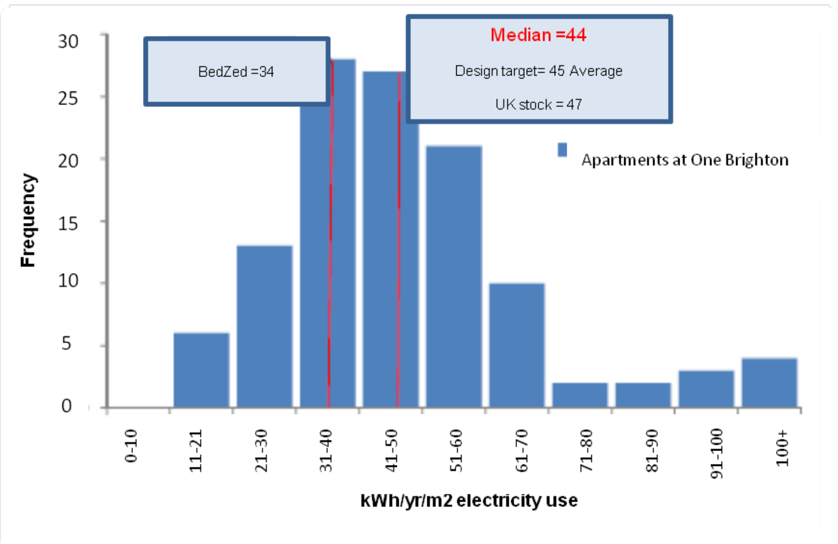


Figure 14. Frequency distribution of annual electricity use kWh/yr/m^2 floor area for 116 apartments at One Brighton

It can be seen that average electricity use at One Brighton is similar to the UK average (DECC 2010) and close to the design targets, but with a wide variation. The apartments contain many energy intensive appliances (e.g. washing machines, tumble dryers, electric cookers, entertainment systems, computers and large TVs) that could be considered “point consumers” of electricity.

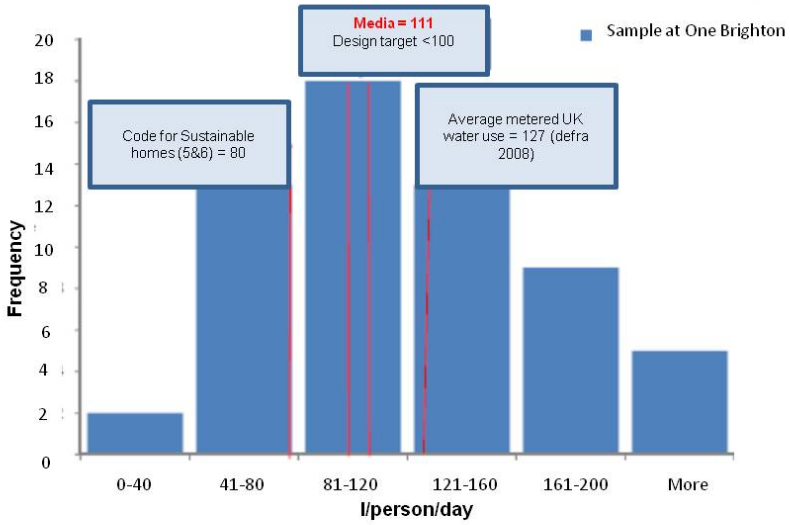


Figure 15. Annual cold water use l/person/day compared to benchmarks (data from 59 apartments)

The median water use is given for those apartments where the occupancy number is known (n=59). If the median is calculated using number of rooms as a surrogate for occupancy number (n=130) the median water use person/day is 125l. It should also be noted that the raw data provided for this analysis was in m^3/month rounded to the nearest cubic meter. This would also introduce an error of up to ±17 litres per day.

The target for water consumption was <100 l/person/day, however the analysis showed that One Brighton exceeded this consumption target despite low flow technologies. Nevertheless, usage seems to be less than the UK metered average (DECC 2010).

4.3 Total energy consumption

Daily total electricity and heat consumption have been provided by Energy Service Company (ESCo) for all apartments. A comparison of energy consumption between the apartment being monitored and all One Brighton apartments (N= 172) is presented in Figures 16 and 17 for the period November 2011 to October 2012. The apartment being studied has higher total electricity consumption than the calculated average for all One Brighton apartments (45 kWh/m^2), whereas for heat consumption it was almost the same as the average of 31.7 kWh/m^2 for all apartments.

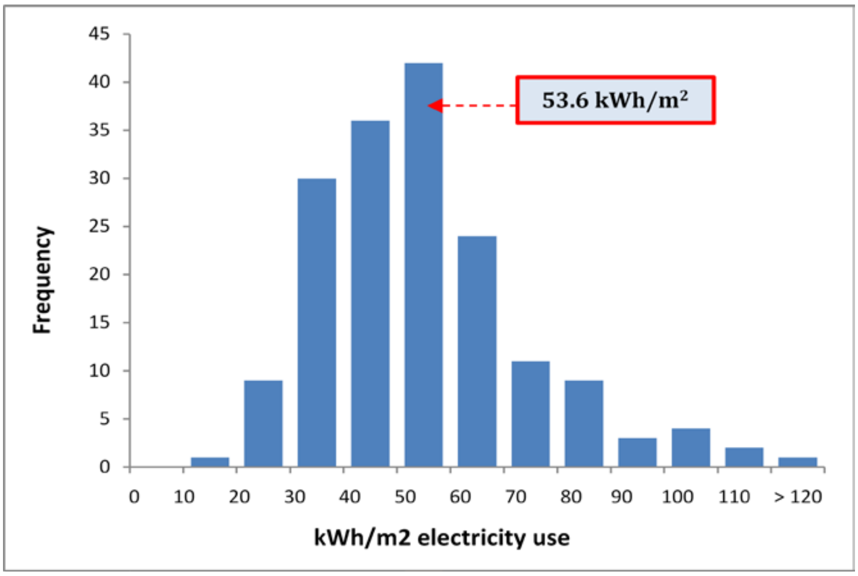


Figure 16. Distribution of electricity consumption for the period November 2011 to October 2012. Data provided by the ESCo

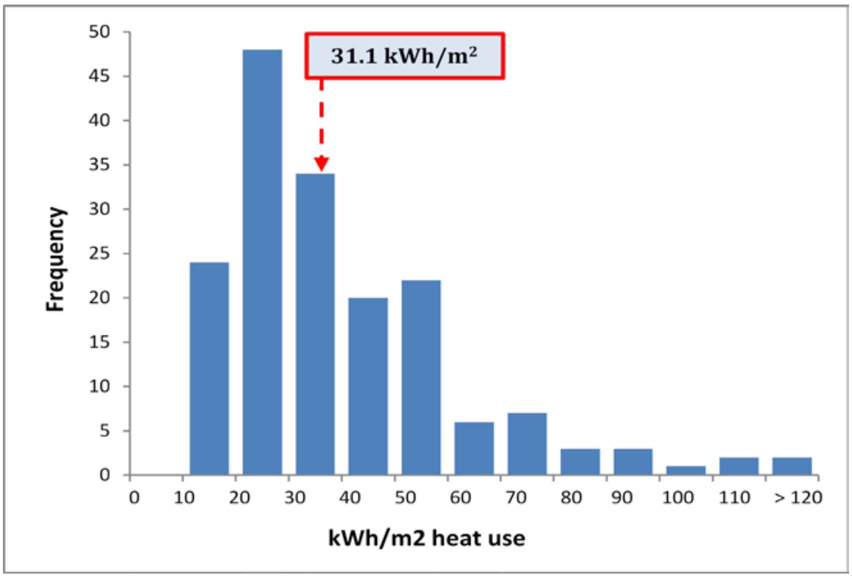
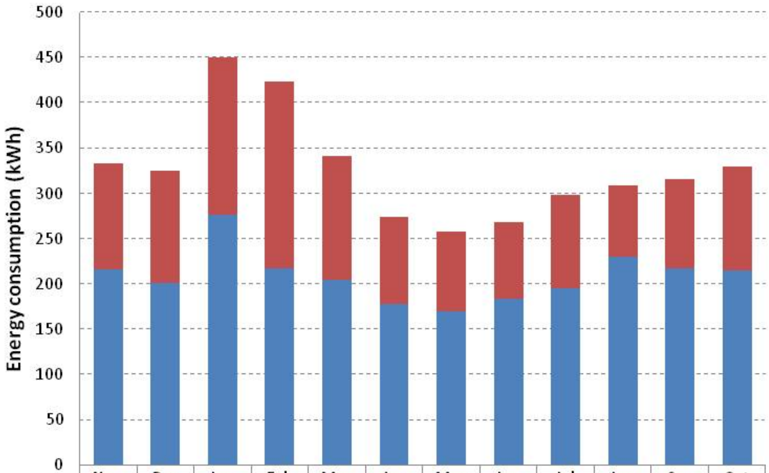


Figure 17. Distribution of heat consumption for the period November 2011 to October 2012. Data provided by the ESCo

The monitored apartment consumed a total of 3927kWh of delivered energy in the reported year (Figure 18). 64% of that energy corresponds to electricity and 36% to heat. As it will be shown later, most of the heat consumed was for domestic hot water production. Similar percentages of electricity and heat were consumed in February, however the electricity used in August was almost three times more than heat consumption.



	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Heat (DHW and space heating)	117	124	174	207	137	96	88	85	104	79	99	115
Electricity	216	201	276	217	204	178	170	184	195	230	217	215

Figure 18. Monthly electricity and heat consumption (kWh) as provided by the ESCo

As indicated before, the energy consumption in the apartment was higher for electricity than the average consumption of all apartments at One Brighton, but practically the same for heat consumption (apartment electricity and heat consumption of 53.6 kWh/m^2 and 31.1 kWh/m^2 respectively compared with 45.0 kWh/m^2 and 31.7 kWh/m^2 of all One Brighton apartments). Nevertheless, the consumption of electricity per square meter in the apartment was not always higher than the average of all One Brighton apartments. During February and July the use of electricity in the apartment was around 6% and 12% lower than the consumption of all One Brighton apartments. On the other hand, heat consumption varied during the year and no clear pattern can be observed.

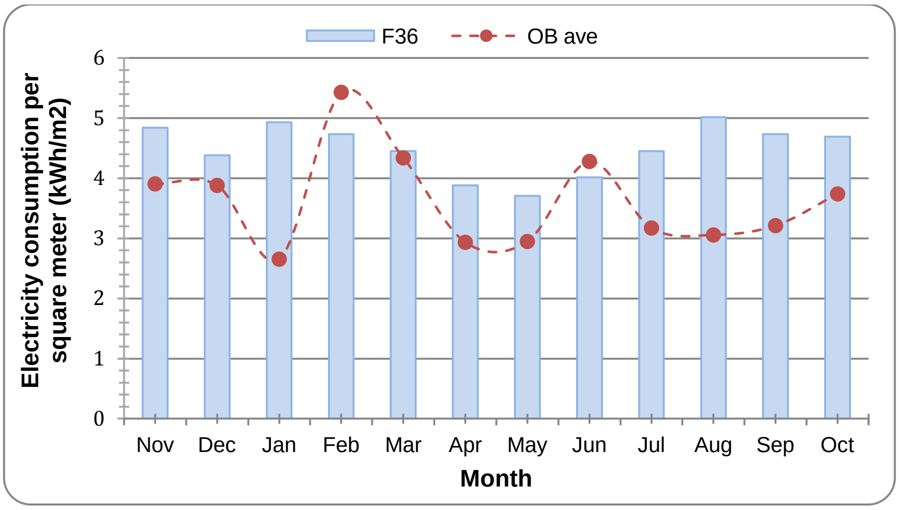


Figure 19. Monthly electricity consumption (kWh/m^2) as provided by the ESCo

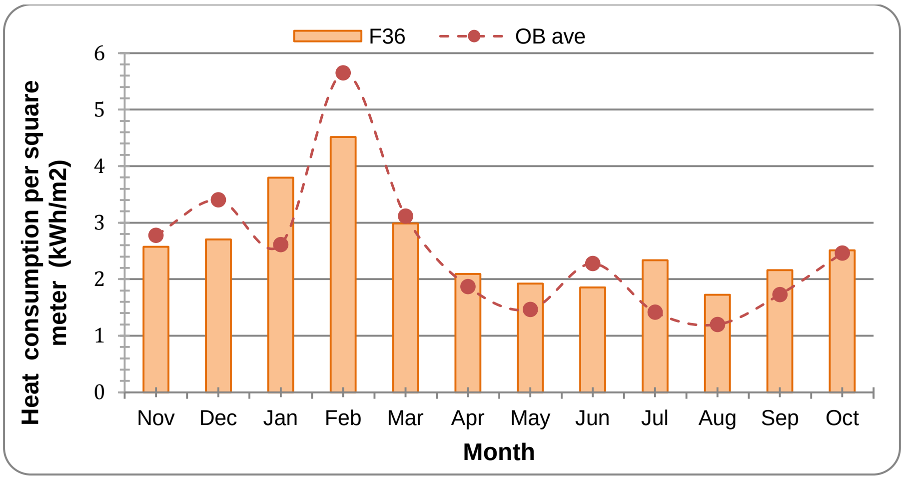


Figure 20. Monthly heat consumption (kWh/m^2) as provided by the ESCo

4.4 Total energy by end use

An initial analysis of the data indicated a problem with the space heating data as when the monitored space heating data was subtracted from the total ESCo heat data, the remainder heat for domestic hot water (DWH) in winter was twice the amount of heat used for DHW outside of the heating season. An investigation of the installation of the heat meter on the space heating circuit showed that the temperature t-piece pocket for the hot-side heat meter temperature sensor was too long for the sensor and not immersed fully in the hot water. As a result the sensor was recording lower temperatures than the actual flow temperatures and will therefore under-record the heat output to the space heating circuit. In order to overcome this situation, the DHW data in the heating season was estimated from the average of the ESCo data when there was no space heating. This is a reasonable approach as the temperature of the incoming water is not likely to vary significantly over the year due to the cold water supply for the apartment being pumped from a large storage tank in the plan room.

As seen in Figure 21, heat consumed in the apartment was mainly for domestic hot water. Space heating was needed during cold months only; December, January and February had the lowest external average and minimum temperatures recorded. Space heating was also required in October; temperatures decreased considerably in October after a month of warmer temperatures. Overall, space heating represented around 25% (345 kWh) of the heat consumed in the apartment.

Practically the same amount of energy was used in summer and autumn (876kWh and 873kWh respectively over a three month period), whereas almost 50% more was consumed in winter (1200kWh). As seen in figures below the heat consumed has been mainly for domestic hot water, however during winter months DHW is almost the same as space heating. Recorded internal temperatures in the apartment during cold months were most of the time above comfort levels (between 19^{o}C and 25^{o}C) and only below 19^{o}C, but above 17^{o}C, during the month with the lowest average external temperature (4^{o}C) and external temperatures as low as -4^{o}C.

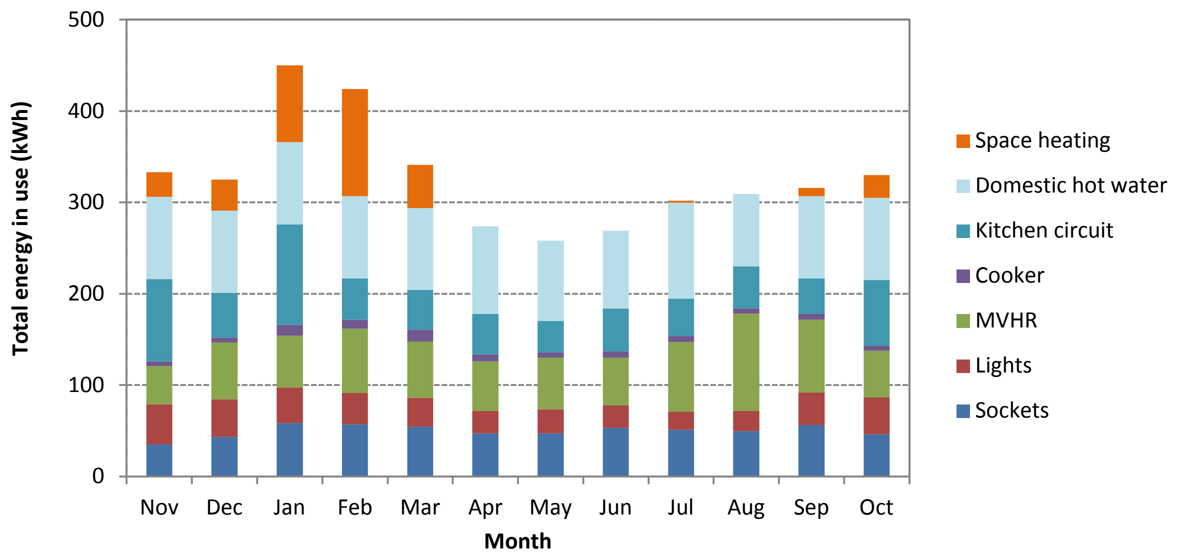


Figure 21. Monthly energy in use (kWh)

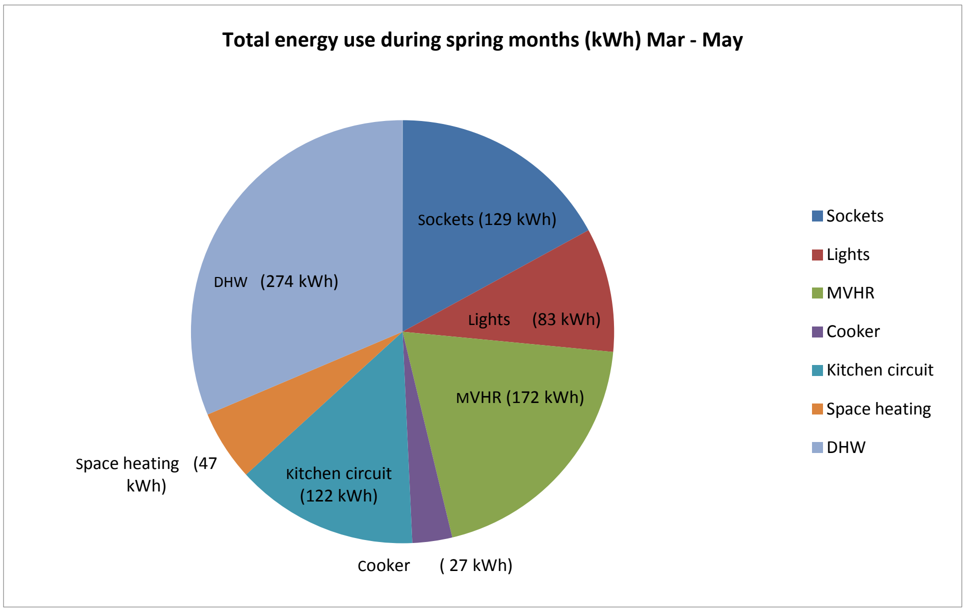


Figure 22. Total energy use (kWh) during spring months (Mar–May)

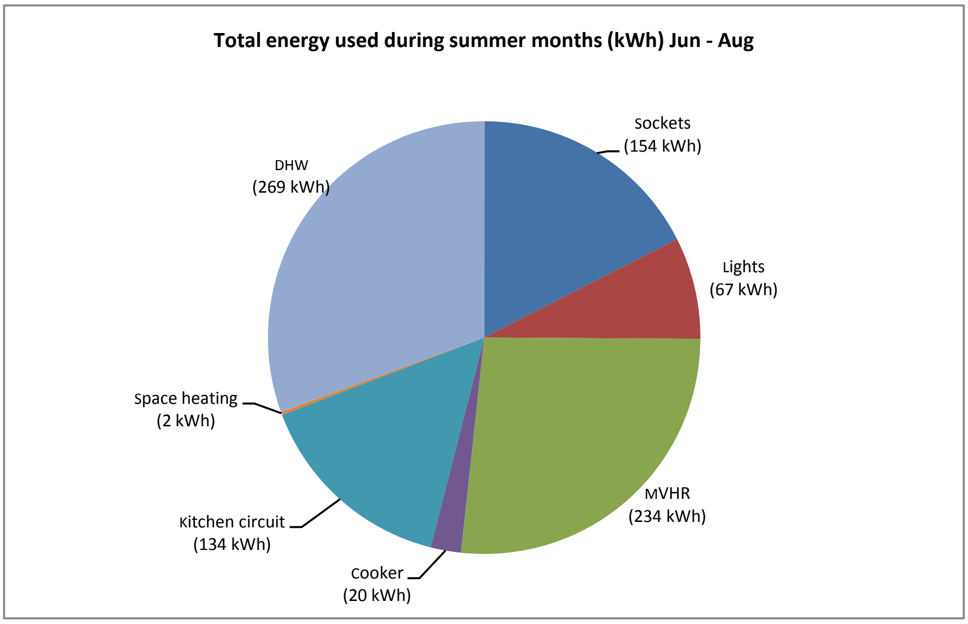


Figure 23. Total energy use (kWh) during summer months (Jun-Aug)

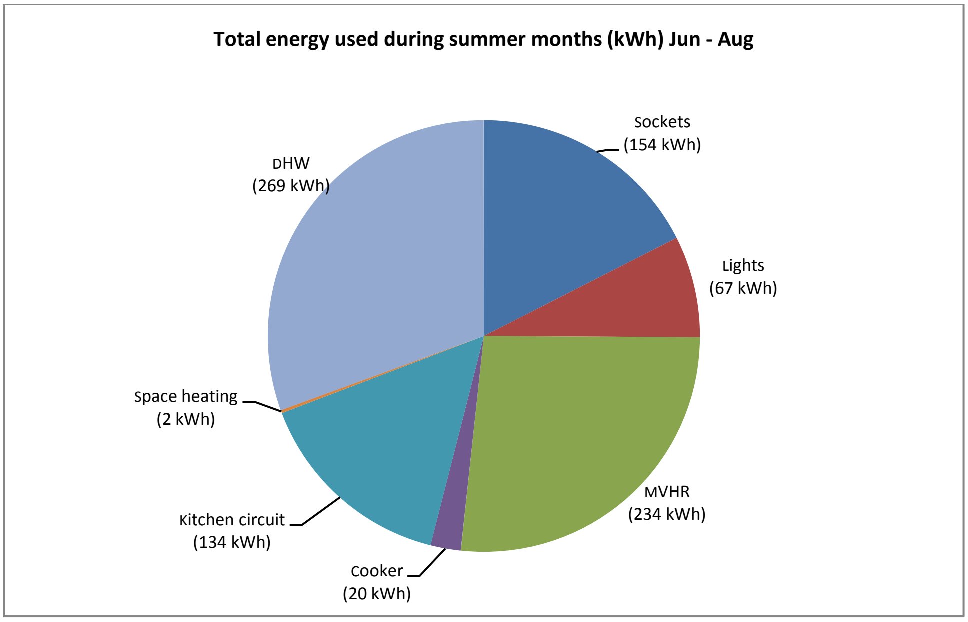


Figure 24. Total energy use (kWh) during autumn months (Sep-Nov)

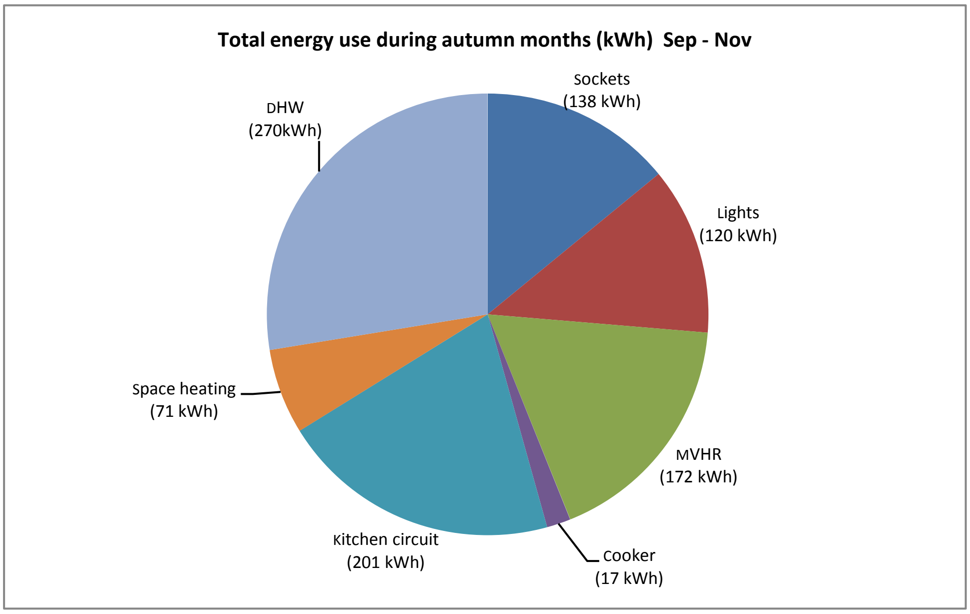


Figure 25. Total energy use (kWh) during winter months (Dec–Feb)

4.5 Total electricity by end use

As previously stated, electricity consumption is being monitored separately for the cooker, ventilation system (MVHR), lighting and sockets. Electricity from the kitchen circuit is not being recorded (refrigerator, microwave, kettle, etc), however has been calculated from the total electricity consumption provided by ESCo.

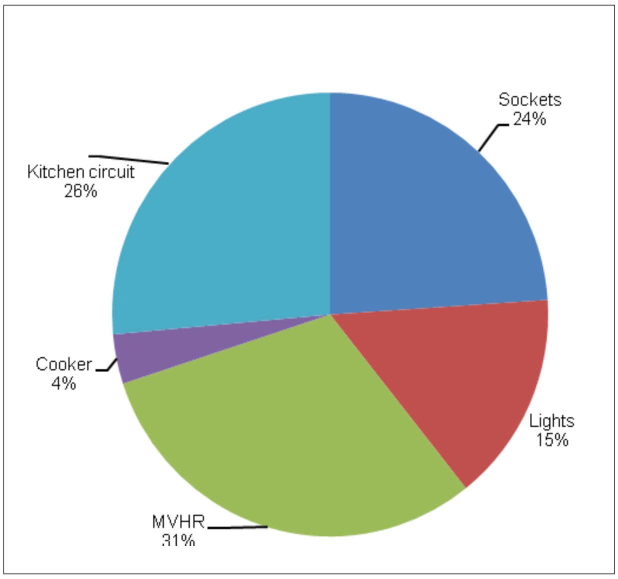


Figure 26. Total electricity use (%)

In general the electricity used by the MVHR equates to approx 30% of the overall electricity consumed in the apartment, reaching almost 40% in summer. It is possible that the MVHR is being used as a cooling system, so the occupant is increasing the fan speed when feeling too warm. It is important to note that residents were instructed to keep windows closed in summer and use the MVHR as cooling system. It is not clear that this is good advice, and it would not be the only way of limiting summertime temperatures in these apartments. An alternative would be to shut off the MVHR (reducing electricity consumption by 40%) and to open windows. The main constraint on this strategy is likely to be external noise and pollution. Occupants would also need to remember to turn their ventilation systems back on in autumn.

The electricity consumed from the kitchen circuit and sockets equates to around 50% regardless of season.

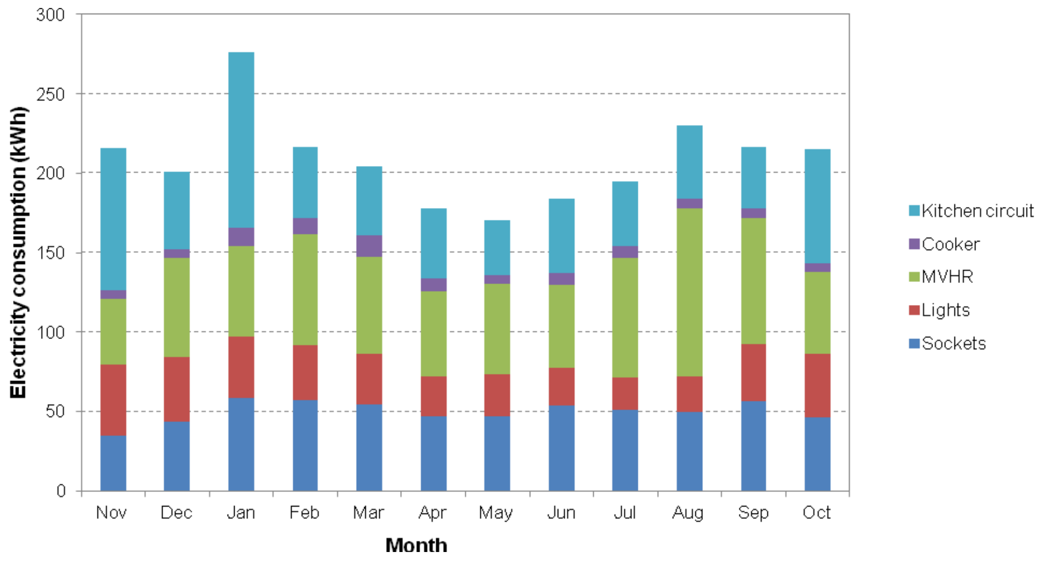


Figure 27. Monthly electricity consumption (kWh)

We can see strong seasonality of lighting use, but also a particularly higher consumption in January from the electrical circuit located in the kitchen.

The ventilation system was constantly operating, with a higher consumption during summer months (Jul – Sep), which could be associated with an increase in the speed of the MVHR fan in order to reduce higher internal temperatures. As seen in Figures 28 and 29, average monthly internal temperatures in bedroom and living room exceeded 25°C during warm months.

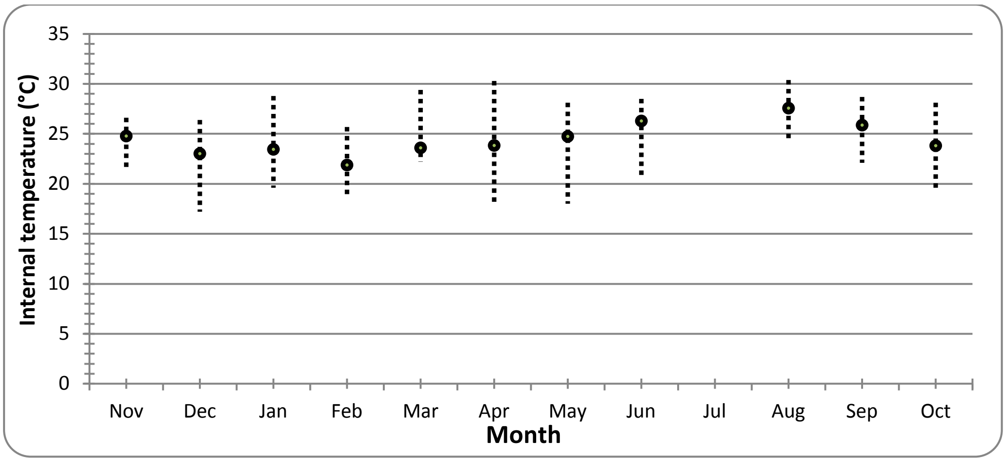


Figure 28. Internal temperature high-low-mean chart living room

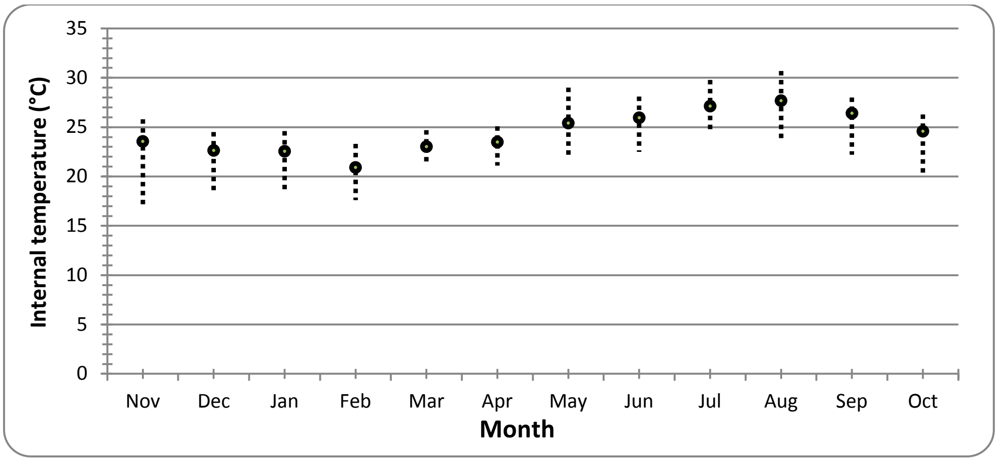


Figure 29. Internal temperature high-low-mean chart bedroom

Even though the percentage of electricity consumed per submeter (MVHR, lights, sockets, cooker and kitchen circuit) each season was in general quite similar, a few differences can be observed. For instance, the electricity consumption of lights during winter was higher than in other seasons and roughly double that of summer consumption. The consumption from sockets was constant and practically the same for each season. The electricity consumed from the kitchen circuit and cooker varied quite widely and further analysis would need to be carried out in order to understand if there is any explanation to the observed pattern. Electricity consumption from the cooker and the kitchen circuit together increases in autumn and winter by approximately 35%.

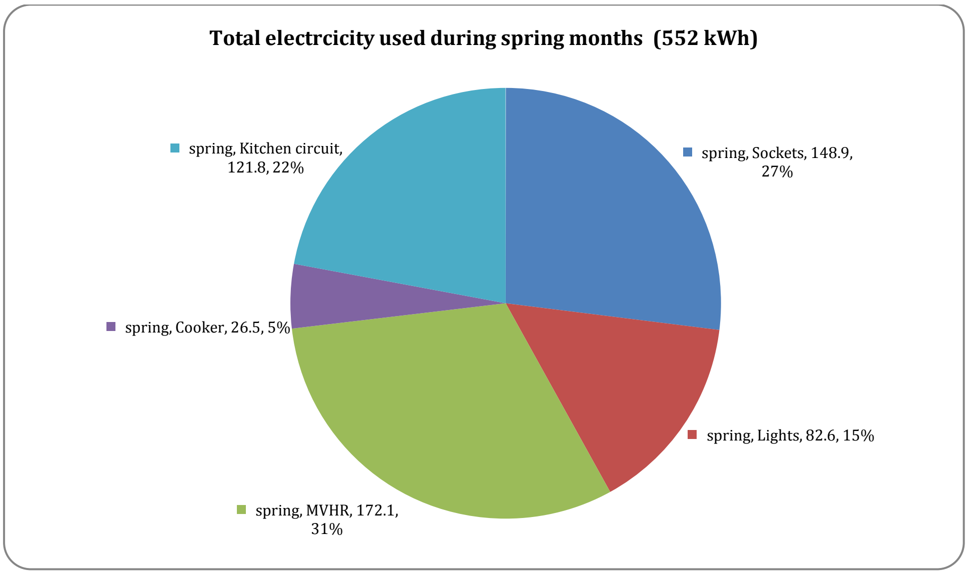


Figure 30. Total electricity use (kWh) during spring months (552 kWh)

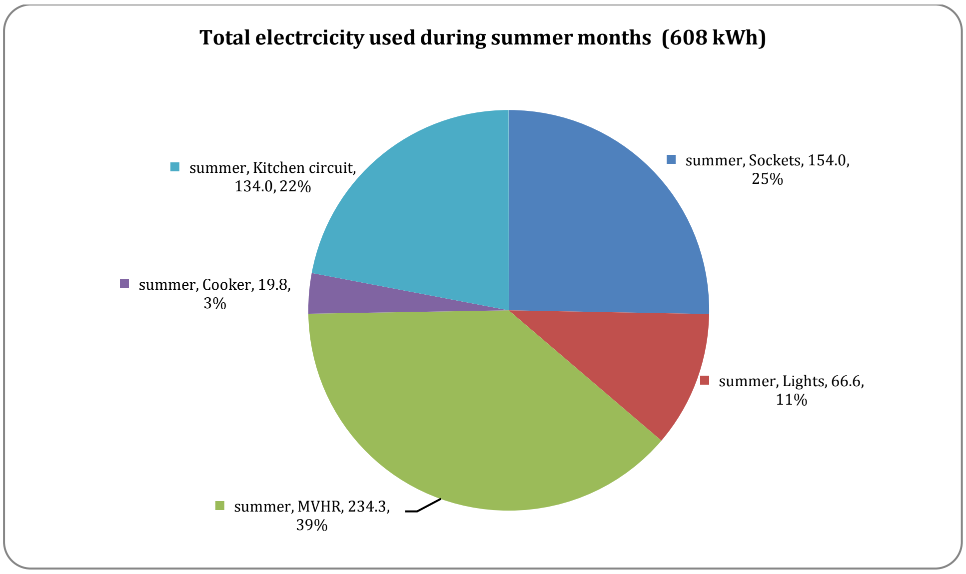


Figure 31. Total electricity use (kWh) during summer months (608 kWh)

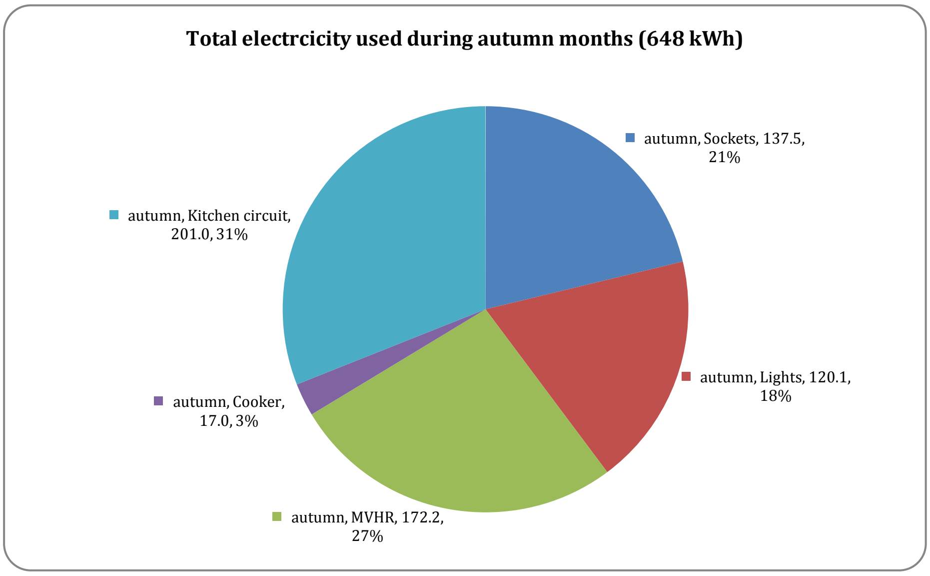


Figure 32. Total electricity use (kWh) during autumn months (648 kWh)

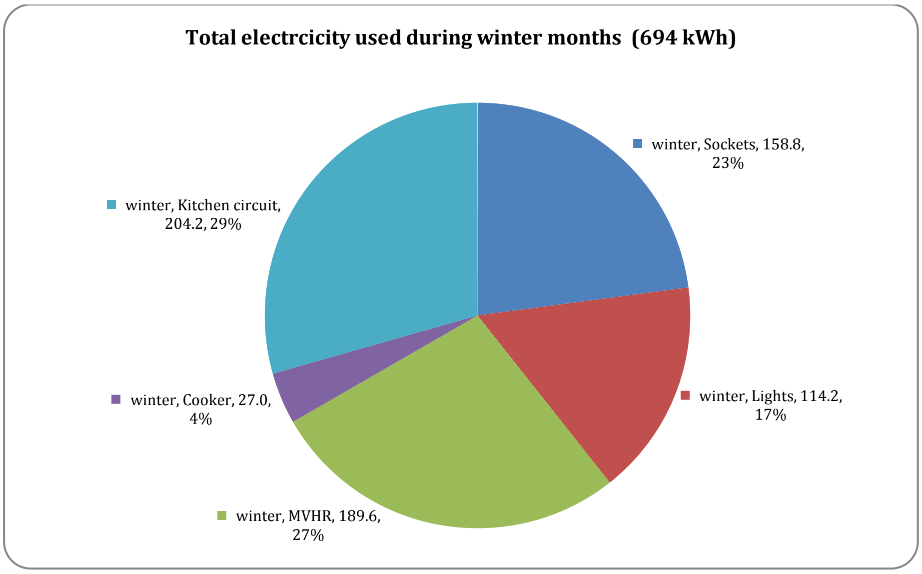


Figure 33. Total electricity use (kWh) during winter months (694 kWh)

4.6 Electricity use: average daily profiles

Average daily profiles were produced for each sub-meter. In general, usage peaks early in the morning and in the evening, following occupancy patterns.

Electricity usage from the MVHR is the least variable, with small peaks in the morning when the resident gets ready for work and in the evening when arriving from work (extraction boost is activated when lights in the bathroom are switched on). Usage from lighting and sockets has a higher increase in the evening when the resident returns from work. The cooker is mainly used in the evening.

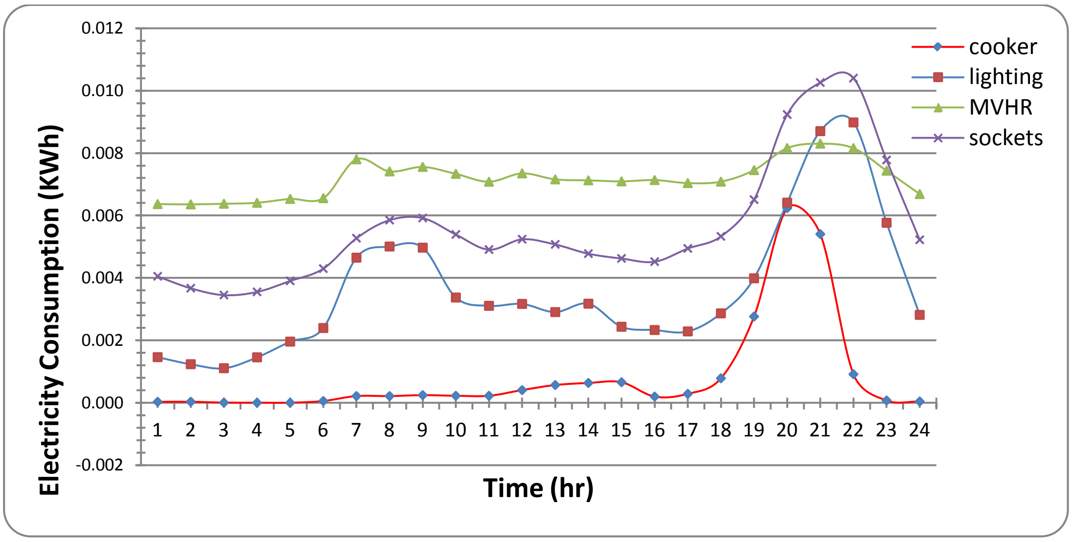


Figure 34. Average daily profiles from cooker, lighting, MVHR and sockets (kWh)

4.6.1 MVHR

Maximum consumption from the MVHR was during summer months (July, August and September, being considerably higher in August). As mentioned before, residents at One Brighton were advised to keep windows closed and operate the MVHR for cooling. In this case, and given the high summer temperatures, it is probable that the resident increased the fan speed to a maximum and maintained it operating thus for the entire month.

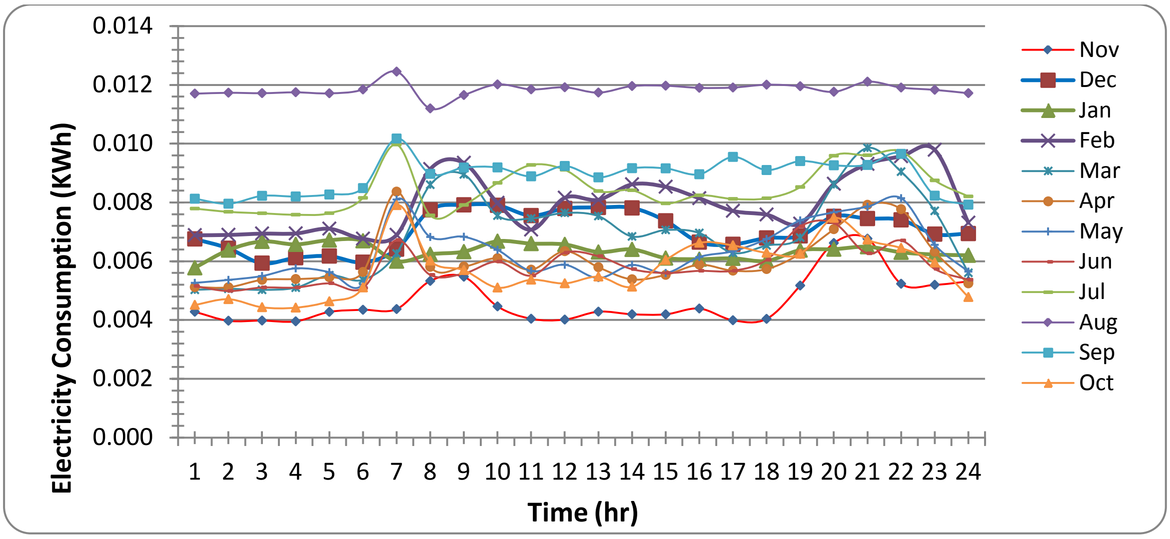


Figure 35. Average daily profiles - electricity use MVHR (kWh)

4.6.2 Lighting

Consumption from lighting varied considerably, but regardless of the month, was highest early in the morning and during the evening. There is a peak, however, around midday in November, which was when lights were used for a short period of time by the resident's partner, who works locally.

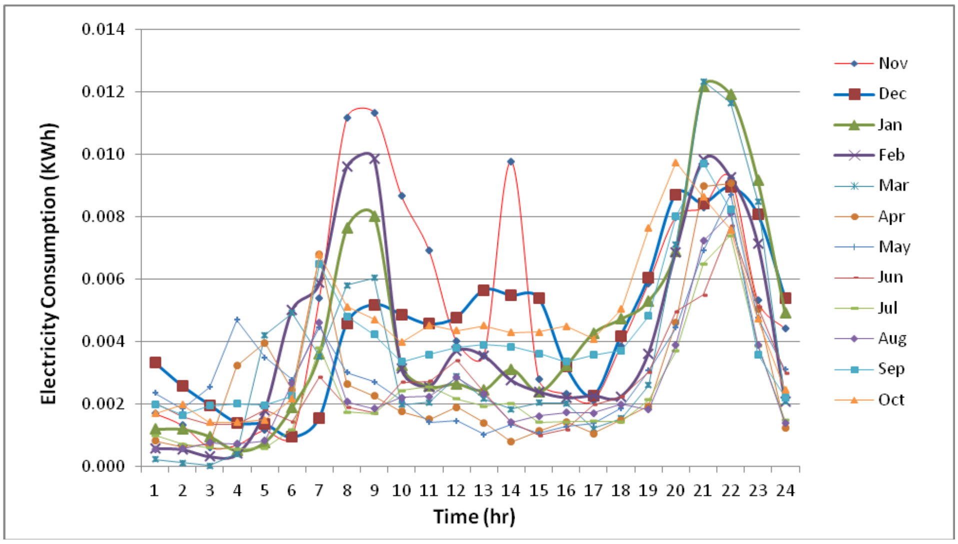


Figure 36. Average daily profiles - electricity use lighting (kWh)

4.6.3 Sockets

As with lighting the consumption from sockets varied and is higher early in the morning and during the evening.

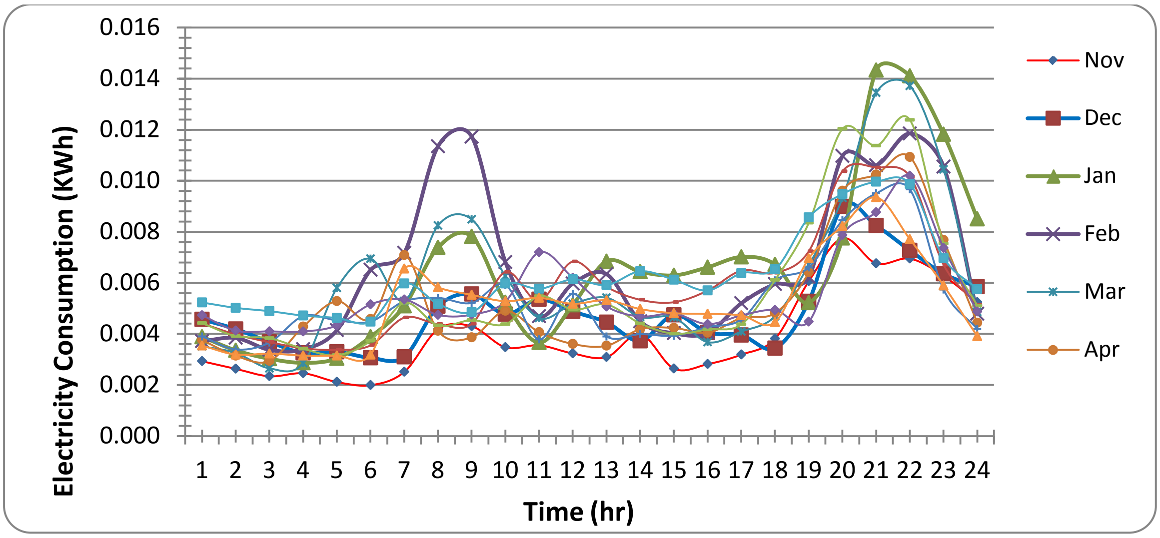


Figure 37. Average daily profiles - electricity use sockets (kWh)

4.6.4 Cooker

Electricity consumed from the cooker (Figure 38), occurred mainly in the evening. As for the average daily profile calculated, there was a higher use in January and March, whereas it was lower in November and April.

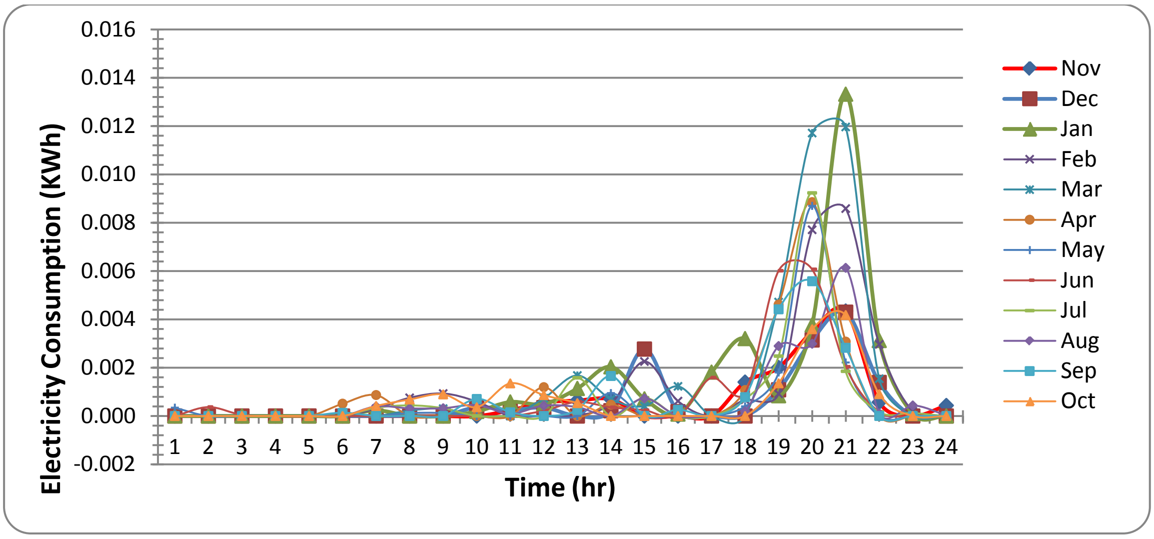


Figure 38. Average daily profiles- electricity use 'cooker' (kWh)

4.7 Electricity use: baseload

Baseload electricity use was calculated using the electricity consumed from sockets and MVHR during the night, and it represents the running load when the apartment is unoccupied or when the resident is asleep. The baseload average power consumption was found to be 128W, which equates to 279kWh per year, 11.3% of the total metered electricity consumption. Note that the baseload calculation takes into account only electricity from sockets and the MVHR but did not include the electricity from the kitchen circuit, and hence the fridge, microwave and other appliances connected to that circuit. Consumption from the kitchen circuit was not included in the base-load calculation because it was not monitored directly (it is calculated from the data provided by ESCo, which is daily total consumption).

Table 8. Baseload electricity use

	Baseload		Total electricity	
	Power (W)	Energy (kWh)	Energy (kWh)	Baseload from total electricity (%)
Nov-11	80	15	222	6.7
Dec-11	133	22	201	11.1
Jan-12	124	22	226	9.8
Feb-12	135	25	217	11.6
Mar-12	118	21	204	10.4
Apr-12	114	21	178	11.9
May-12	120	22	170	12.7
Jun-12	108	20	184	10.9
Jul-12	145	26	204	12.8
Aug-12	197	37	230	15.9
Sep-12	164	30	217	13.6
Oct-12	96	18	215	8.3
Average	**128**	**23**	206	
Total		279	2468	**11.3**

4.8 Indoor environmental conditions

4.8.1 Temperature and RH

Mean internal temperatures and humidity recorded over the period reported are given in Tables 9 and 10. Mean internal temperature ranges from a high of 27.7°C to a low of 20.9°C in the bedroom and from a high of 27.6°C to a low of 21.9°C in the living room. On average the difference between internal and external temperatures was 14.5°C. The lowest mean internal temperature was recorded in February (when the lowest external temperature was recorded). Similarly the highest mean internal temperature was registered in the warmest month (August). It is important to note that the datalogger installed in living room failed during July, hence no information is reported for that month.

Table 9. Mean internal and external temperatures (°C)

		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Average

Bedroom	Ave	23.6	22.6	22.6	20.9	23	23.5	25.4	26	27.1	27.7	26.4	24.6	24.5
	Min	16.8	18.2	18.7	17.6	21.2	21.1	22	22.5	24.5	23.5	22.2	20.4	
	Max	25.8	24.5	24.6	23.3	24.7	25.1	29	28.1	29.8	30.7	28	26.3	
	stdev	1.4	0.9	1.1	1.6	0.7	0.7	1.6	0.8	0.9	0.7	1.1	0.9	
Living room	Ave	24.8	23	23.5	21.9	23.6	23.8	24.7	26.3	-	27.6	25.9	23.8	24.6
	Min	21.5	17.2	19.6	18.9	22.2	18.1	18	20.8	-	24.2	22.1	19.4	
	Max	26.6	26.4	28.8	25.7	29.4	30.3	28.1	28.5	-	30.4	28.7	28.1	
	stdev	0.8	1	0.9	1.4	0.7	1	1.2	1.1	-	1.2	1.7	1.2	
External	Ave	11.4	7.5	7.1	4.0	8.9	8.2	12.1	13.7	15.7	17.1	14.2	12.5	11.0
	Min	1.9	0.2	0.4	-4.9	2	0.5	4.2	7.5	9.8	6.8	5.4	3.8	
	Max	16.4	12.8	12.5	11.6	20.2	17.3	25.5	22.3	26.5	25.6	22.9	16.7	
	stdev	2.3	2.7	2.6	4	3.3	2.4	4.5	1.9	2.6	2.2	2.8	2.3	

Although average RH was generally within acceptable levels (40% to 70%) and never exceeding a RH that may cause problems such as mould growth, the lowest humidity recorded suggest that the air in both bedroom and living room was quite dry, which may have been uncomfortable for residents (e.g. dry eyes).

Table 10. Mean internal and external RH (%RH)

		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Average

Bedroom	Ave	50.6	42.1	43.1	38.6	41.2	38.9	44.4	48.5	48.9	49.9	45.4	50.0	45.1
	Min	40.8	32.5	31.5	24.6	32.4	26.3	32.2	39.6	35.2	31.9	32.7	38.9	
	Max	64.4	55.6	56.7	50	51.4	49.6	58.5	57.6	61.2	68.8	58.9	63.8	
	stdev	3.8	3.9	4.3	6.1	3.9	4.3	4.9	3.3	5.0	4.7	5.5	5.1	
Living room	Ave	48	40.8	40.8	38.1	40.1	37	44.3	47.9	-	49.3	45.5	50.6	44.3
	Min	38.5	30	26.2	23	24.9	18.2	34	35.8	-	31.5	32.7	37.1	
	Max	65.5	59.8	61.4	58.1	52.7	63.7	63.6	63.4	-	63.7	63.3	68.9	
	stdev	4.3	4.5	5.7	6.6	5	5.8	6.7	4.5	-	4.5	5.5	5.6	
External	Ave	83.2	79.3	78.2	78.7	73.1	74.4	75	78.9	77	77.1	72.1	80.2	77.3
	Min	51	49	46	43	24	29	26	44	37	39	38	47	
	Max	96	95	96	96	95	94	95	95	95	93	93	94	
	stdev	8.4	8.9	10.5	11.8	15.3	11.6	14.5	9.6	12.1	10.3	12.3	10.3	

Plots of the daily mean internal temperature and daily mean internal relative humidity are given below. Daily mean temperatures in both rooms were never below under-heating levels, even during the coldest days of the year (early in February). In contrast, mean daily temperatures during warm months were found to be above 25^{o}C from May to October and on a few days in August, close to 30^{o}C.

Figure 39. Daily mean internal temperatures in bedroom and living room and daily mean external temperatures

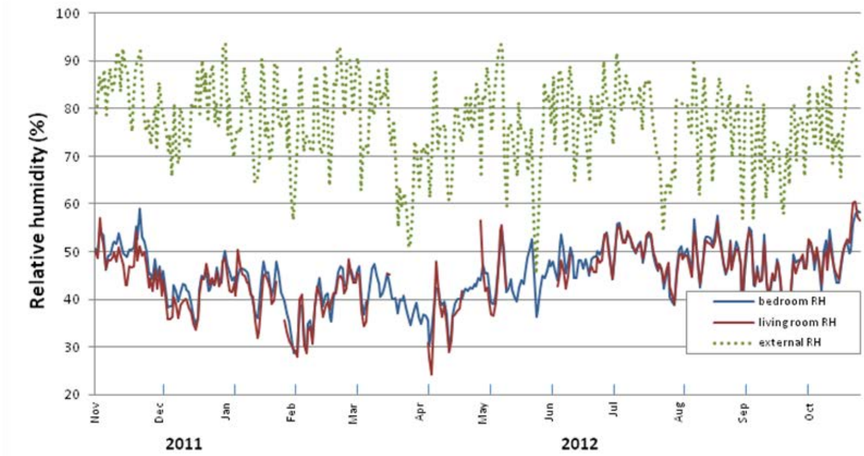


Figure 40. Daily mean internal RH in bedroom and living room and daily mean external RH

Indoor temperature and relative humidity conditions were analysed in terms of the proportion of time they were outside desirable ranges for internal temperatures (23-25°C for the bedroom and 25-28°C for the living room) and the 40-70% RH range as specified in CIBSE guide A.

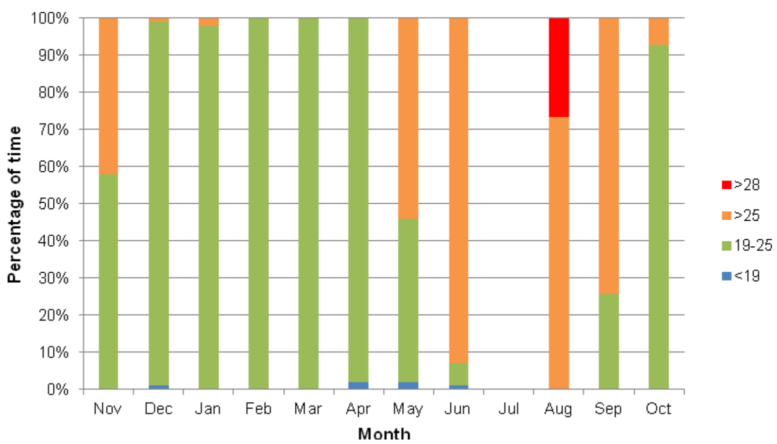
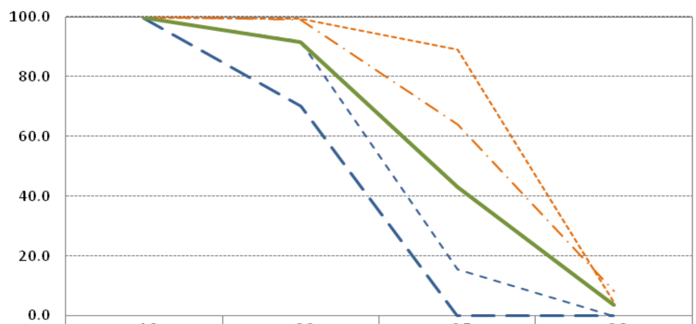


Figure 41. Living room internal temperatures

Temperatures in the living room were for most of the time during cold months within comfort levels (19 to 25°C), however they were predominantly above 25°C during warm months. It is important to note that temperatures in August were for almost 25% of the time above 28°C, a borderline value for overheating in living rooms. Temperatures are not reported for July due to a problem with the datalogger; nevertheless it is thought that similar temperatures to those recorded in August may have occurred in the living room during July.

Overall, temperatures were above comfort levels for 42% of the time, and above overheating levels for almost 4% of the time. Comfort temperatures were exceeded more than 50% of the time in the period between May to October.



	>19	>22	>25	>28
Nov-jan	99.7	91.8	15.5	0.0
Feb-Apr	99.5	70.2	0.2	0.2
May-Jul	99.6	99.3	89.2	4.6
Aug-Oct	100.0	99.0	63.9	8.4
Entire period	99.7	91.6	42.9	3.6

Figure 42. Living room overheating - % hours over temperatures (°C)

Temperatures in the bedroom were found to be above comfort levels for most of the time. Temperatures above 23°C were recorded in all months, with greater number of hours above overheating temperatures - 95% of the time in July and August and 70% in September. February presented temperatures below comfort levels for 15% of the time, but were never below 17.5°C (minimum recorded in bedroom), which is more than acceptable considering the lowest external temperature of -4.9°C recorded that month.

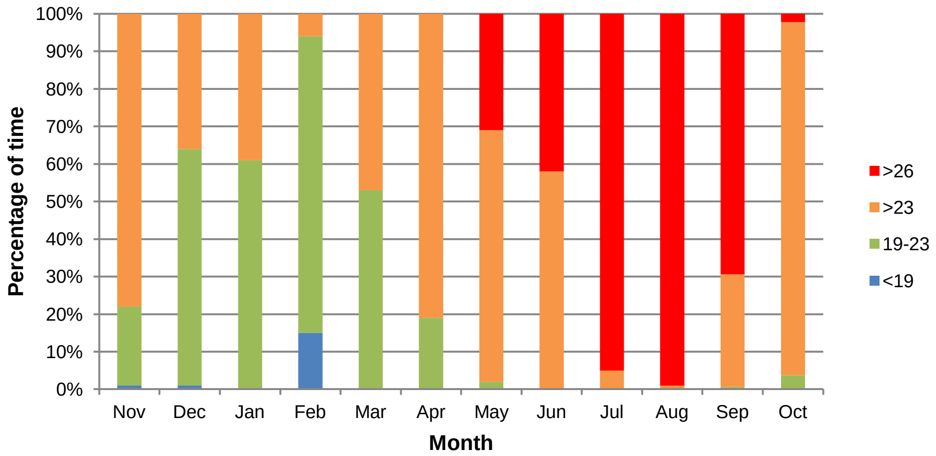
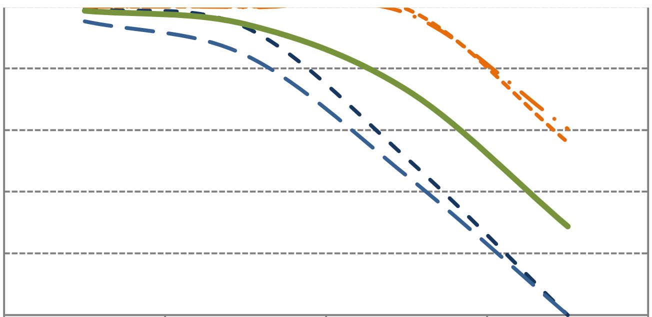


Figure 43. Bedroom internal temperatures

During the entire period temperatures were above minimum comfort levels for more than 70% of the time (Figure 44). Overheating was mainly a problem from May to October.



	>19	>21	>23	>26
Nov-jan	99.5	93.3	50.9	0.0
Feb-Apr	95.2	84.2	45.1	0.0
May-Jul	100.0	100.0	99.2	56.0
Aug-Oct	100.0	99.8	97.8	60.4
Entire period	98.7	94.3	73.0	28.7

Figure 44. Bedroom overheating - % hours over temperatures (degC)

Overheating seems to be a problem in the apartment during summer months. Monitoring carried out in the apartment during August 2011 showed that for practically the entirely month internal temperatures exceeded overheating temperature levels of 28°C and 26°C in the living room.

As indicated before, RH was found to be within recommended levels most of the time, and was never above levels of humidity that may facilitate the development of mould growth. However for significant periods of time, RH was recorded below the bottom of the recommended range (40% to 70%).

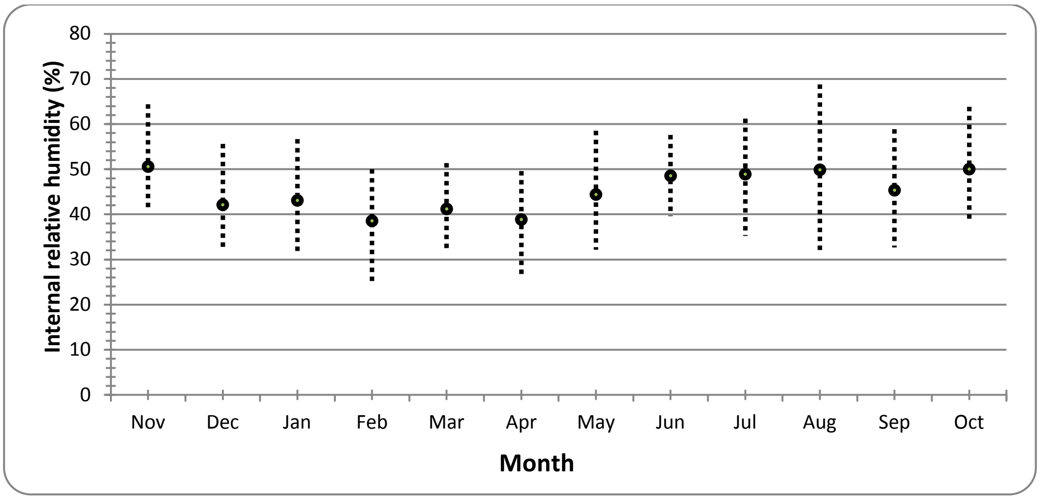


Figure 45. Internal relative humidity high-low-mean chart bedroom

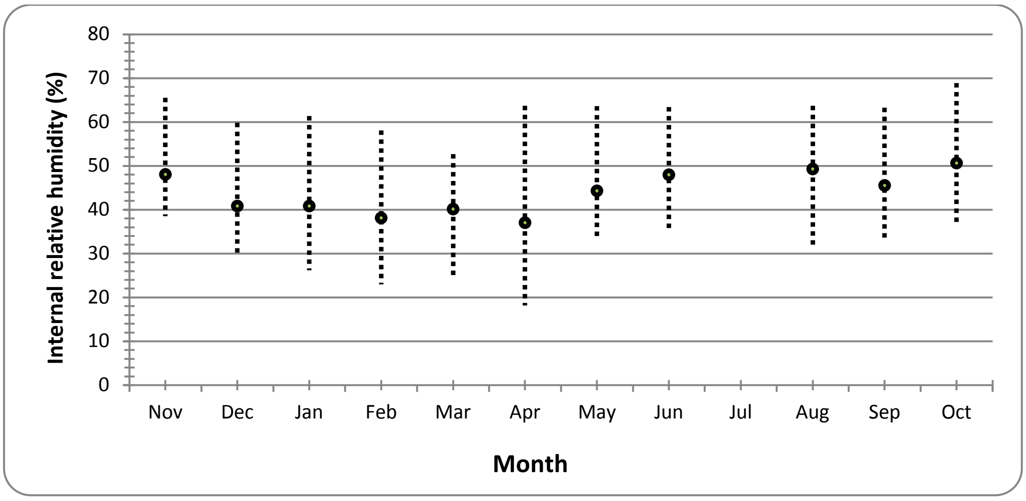


Figure 46. Internal relative humidity high-low-mean chart living room

4.8.2 CO_2

Mean carbon dioxide concentrations were below 900 ppm in both rooms, but with maxima close to 3000 ppm in November and February. The latter is significantly higher than the 1500 ppm recommendation of **DIN**-Norm 1946-2. Monthly maxima in other months are in the range 1500-1900 ppm.

Table 11. Mean carbon dioxide concentrations (ppm)

		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Average
Bedroom	Ave	831	771	848	871	828	784	780	791	774	647	779	827	794
	Min	438	431	428	401	429	413	435	437	440	429	411	417	

	Max	2798	1599	1602	2734	1670	1515	1533	1432	1596	1721	1781	1626	
	stdev	359	299	279	428	314	317	293	281	293	197	296	318	
Living room	Ave	746	703	794	797	741	682	690	723	-	685	791	840	742
	Min	441	435	451	436	452	429	441	452	-	480	484	486	
	Max	2431	1376	1509	2193	1242	1316	1891	1306	-	1353	1661	1672	
	stdev	224	197	200	295	177	170	163	170	-	136	209	224	

Concentrations of carbon dioxide were analysed using a range of 800-1000 ppm often used as an indicator that ventilation rate in a building is adequate (CIBSE guide B, 2008) and a maximum level of 1500 ppm above which air quality is considered to be poor.

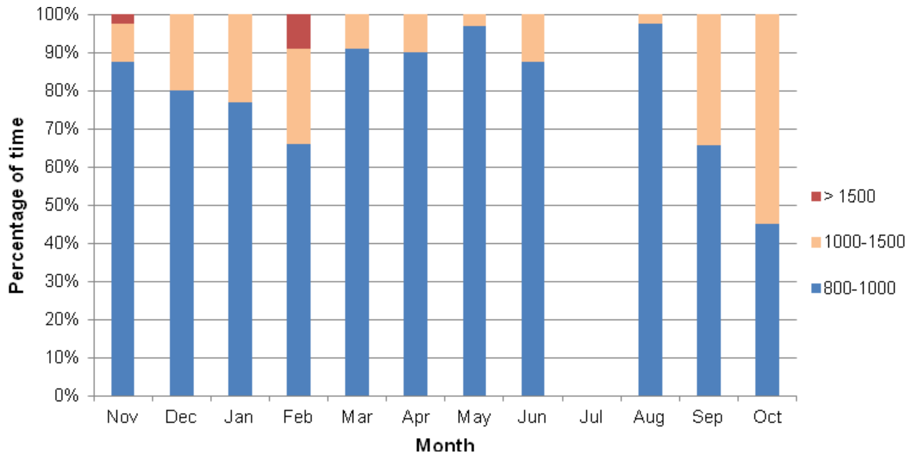


Figure 47. Living room internal carbon dioxide levels during occupied hours

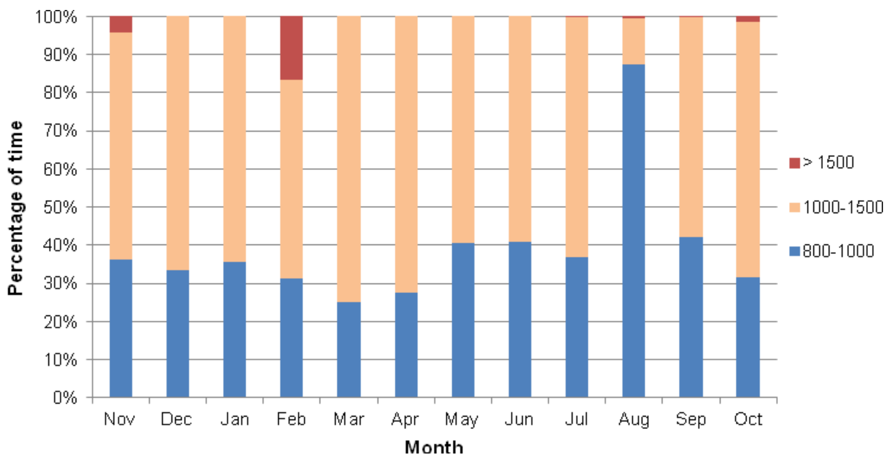


Figure 48. Bedroom internal carbon dioxide levels during occupied hours

As can be seen in Figures 47 and 48 the levels of carbon dioxide in the apartment during occupied hours were in general below 1500 ppm; most of the time below 1000 ppm in the living room and between 1000 and 1500 ppm in the bedroom. The 1500 ppm levels were only exceeded in February (for ~15% of the time). As to be expected, levels of carbon dioxide in the apartment were as low as external levels during unoccupied hours. Higher levels of carbon dioxide in the bedroom were due unmistakably to its uninterrupted use at nights

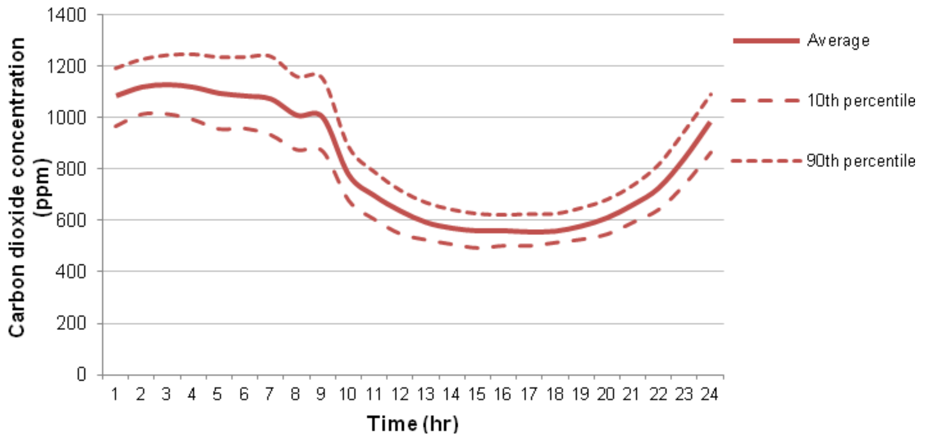


Figure 50. Daily (24 hrs) profile of carbon dioxide in bedroom

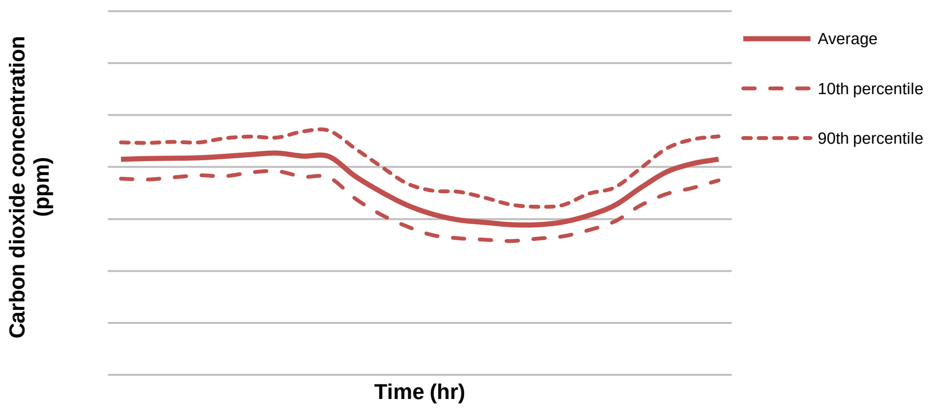


Figure 51. Daily (24 hrs) profile of carbon dioxide in living room

Plots of the daily mean carbon dioxide concentration in the bedroom and living rooms are given below. As seen, only twice did the daily mean concentration of CO_2 exceed 1500ppm. Both events occurred during cold months. A possible explanation for such events is that windows were not open at all during those days, which actually fell on weekends, but also maybe there were meetings taking place those days (people visiting the apartment).

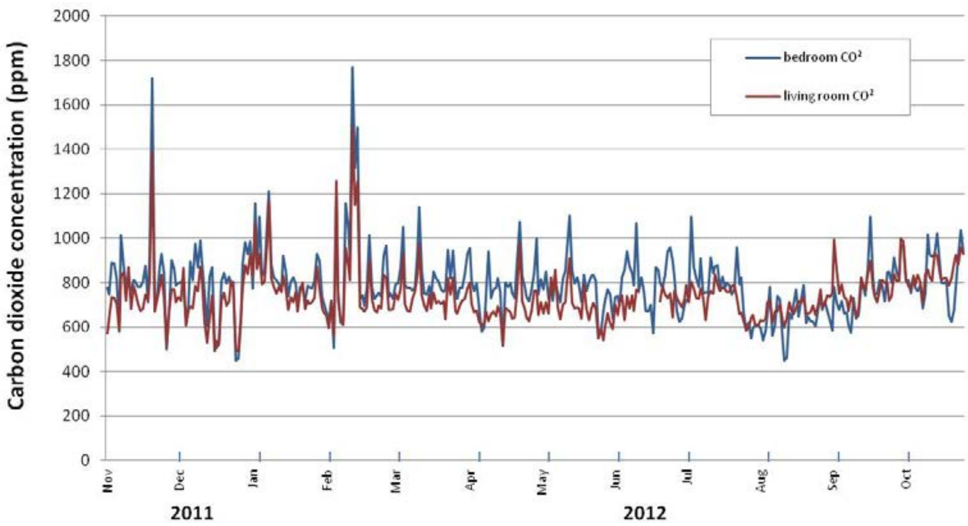


Figure 52. Daily (24 hrs) profile of Carbon dioxide in living room

4.9 Key findings

- Heat use is dominated by the use of domestic hot water.
- Compared against both commercial and domestic buildings as well as heat energy benchmarks, OB appears to perform well. The main note of caution here is around the effect of heat losses from the communal heating system, which appear to be significant.
- The data provided by the ESCO has shown that in all 172 apartments the SAP targets were met for heat consumption and that measured heat consumption was much lower than the average consumption of the UK stock. But we voice the same note of caution as in the previous point.
- Actual electricity consumption of the apartment was slightly lower than the target of One Brighton average and close to the UK stock average.
- Even though One Brighton contains low flow technologies to minimise water consumption, water use in the monitored apartment exceeded the target (100l/person/day) by ~25%. The difference is not statistically significant.
- The electricity consumption of the apartment being monitored exceeded the overall average of 45 kWh/m^2 for all 172 apartments at One Brighton, by 8.6 kWh/m^2. The difference is within one standard deviation and is not significant.
- As expected, electricity consumed for lights is higher during winter months. However, electricity used in the MVHR seems to increase in summer months (40% of the overall electricity used in summer compared with 27% during winter). An initial explanation for

this is that the system may have been used at a higher fan speed to reduce the internal temperatures during warm days.

- The wall construction at One Brighton is designed to be intrinsically airtight and free from thermal bridges and convective bypasses. It is therefore expected to perform well. Infra-red images taken both from the outside and the inside the building and measurements made during the Coheating test are all consistent with this. The '*High thermal performance standards'* considered for insulation (40% above 2002 building regulation), windows (u-value of 1.3 W/m^2K), and air tightness targets ($5m^3h^{-1}m^{-2}$ @ 50 Pa) were lower than required under the Building Regulations (ADL1A 2006), plays a key role on providing comfortable conditions during cold months.
- Internal temperatures in the living area were found to be comfortable in the colder half of the year, but exceeded comfort levels from May to September. The target range of temperatures for bedrooms is narrower than that for living rooms (19-23°C compared with 19-25°C). Bedroom temperatures were for most of the time above the target range and with a greater number of hours above the overheating threshold, particularly during warmer months.
- Summer overheating and the operation of the communal heating system and heating/ventilation system are issues which require attention.

5 Conclusions and recommendations

5.1 Key findings

- Walls are the dominant heat loss element at One Brighton. The wall construction is designed to be intrinsically airtight and free thermal bridges and convective bypasses. It is therefore expected to perform well. Infra-red images taken both from the outside and the inside of the building show little evidence of thermal bridging, and the Coheating test that was undertaken in one apartment shows a measured heat loss that is, within margins of error, consistent with design expectations. Consistent with the high levels of insulation achieved at One Brighton, the BUS survey showed high levels of satisfaction with the apartments in winter.
- In general the building meets the occupants' needs, as a high percentage of residents thus indicated.
- There is clear evidence of a tendency to overheat at One Brighton. Primary determinants of overheating are solar heat gains through fabric and fenestration, fabric heat loss and thermal mass, ventilation and control of internal heat gains. The work and measurements described in this report took place during a year in which maximum external temperatures in summer were around 2°C lower than in the heat wave of August 2003. In the event of a similar, or of an even more severe heat wave in the future, conditions at One Brighton could become severely testing.
- External noise from busy streets appears to be a factor that limits window opening in hot weather. A tendency not to open windows in hot weather may have been reinforced at One Brighton by the residents' manual provided by the developer that states:

  "keeping windows closed in summer will allow your (MVHR) unit to provide free cooling by letting in cooler air from outside and extracting warmer air from inside your home".

5.2 New technologies

- The application of new technologies in the buildings significantly increases both the requirement for effective communication up and down the supply chain, and the difficulty of achieving it. At One Brighton, this is exemplified by the biomass boiler, which was supplied by an Austrian company. The design of the biomass boiler system was complicated due to the lack of understanding of the system but also the lack of locally available information. These issues not only affected the design and delivery stage of the biomass boiler but also the later operation of it.

- The use of new construction technologies such as the masonry (clay 'ziegel' blocks) used at One Brighton and exported from Germany was initially an issue not just for design and construction teams but also for external companies such as insurers. There was a lack of experience using this new technology that trouble engineers and design team but also delayed the construction process since obligated contractors to learn to use this new technology. A European insurer was hired to support the project since UK insurers had no knowledge of continental European construction techniques and were not willing to support the project. This is a classic example of a procedural barrier to innovation (Lowe & Bell 1997:29)[1].
- The mechanical ventilation with heat recovery (MVHR) system presented challenges in their design stage and later installation. Designers responded to the lack of space in the apartments by placing the MVHR above the ceiling in the bathroom. This severely limits access for maintenance and replacement of filters, and may in the longer term affect indoor air quality and operational life of the system.
- Training of people prepared to operate systems such as those used at One Brighton is not simple. Although there are in the industry some highly trained individuals who are capable of managing such projects, it is unusual to find those with high levels of interpersonal skills as well.
- The introduction of new technologies has been a continuous challenge to the Green Caretaker. He has been forced to deal with issues and ultimately experiences, which unfortunately cannot easily be transferred. This became critically important when the original building manager moved on.

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[1] Lowe & Bell (1997). *Towards Sustainable Housing: building regulation for the 21st century*, Prepared by Centre for the Built Environment, Leeds Metropolitan University, for Joseph Rowntree Foundation. ISBN 1 898883 12 2. http://www.leedsmet.ac.uk/as/cebe/projects/towards_sustainable_housing.pdf

5.3 What worked well

- The Green Caretaker has been a key player in the success of One Brighton. He has helped to continuously communicate to residents the ethos and purpose and functions of the green systems of the development.
- Facilities such as the *Allotment and bike store are areas* are a great success in the project and seem to be loved by residents.
- Heat use is dominated by the use of hot water. Despite relatively low space heating usage, recorded internal temperatures in the apartment during cold months were most of the time above comfort levels (between 19^{o}C and 25^{o}C). This demonstrates that the building fabric is providing good thermal insulation.
- In general OB performs above average in terms of heat energy use and exceeds targets. In many ways, One Brighton performs better than expected, and appears as an adequate alternative for future sustainable developments. Nevertheless, as per comments from representatives of developers, investors are not completely aware of the benefits of developments such as One Brighton.
- The project has been of high value for BPE teams. Maintaining relationships with developers, operators and occupants is very important, but more importantly with residents participating in the studies, hence technical people need to have/develop interpersonal as well as technical skills. The project has been an opportunity to test methodologies as well as generate expertise within technical teams. Monitoring techniques have been improved thanks to new technologies but more importantly to the BPE holistic approach.

5.4 What did not work well

- Some residents had the expectation that the ventilation system also functions as a cooling system. This points to a failure in the handover procedure. Confusion on the part of occupants about the function of the MVHR system in summer is likely to lead to disappointment.

- Significant internal heat gains come from heat distribution systems. These cause raised temperatures in circulation spaces. Additional heat gains come from uninsulated components of the HIU within apartments.
- Commissioning of systems such as the MVHR units is essential in a project like One Brighton. In this case the MVHR was not commissioned as indicated by the manufacturer. Commissioning was limited to a simple physical record of its installation in each apartment.
- Electricity used by the MVHR is proportionally high. It equates to approx 30% of the overall electricity consumed in the apartment, reaching almost 40% in summer.
- Parts of the One Brighton development are shaded (lower apartments in Pullman Hall), but parts are exposed to significant levels of solar radiation, especially apartments facing South-East overlooking Fleet Street. In the latter, external shading, or window systems (such as 2+1 glazing) that incorporate effective protection against solar gain, would have been beneficial in reducing heat gain and overheating.

5.5 Areas for future work

- Heat production and distribution systems in highly insulated compact and low heat loss dwellings need to be insulated as carefully as the external envelope, to minimise overheating in summer and the waste of energy in winter.
- Control of summer overheating in highly insulated dwellings, particularly in apartment blocks, requires as careful attention to insulation of heating systems as to the building envelope. A survey of the integrity and continuity of insulation on the communal heat distribution system could be undertaken.
- All those who attended the walkthrough enjoyed the experience and the presentations and focus group discussion that followed. Most communicated that they had not been involved in this type of feedback session for previous projects that they had worked on and felt that it was a valuable experience. This suggests that more wash-up meetings or project feedback sessions, where BPE findings are presented to the design and construction team, could be of high value and help transmit in-use performance knowledge. This could potentially go some way towards closing the performance gap.