Levitt Bernstein People.Design

Loudoun Road

Post-occupancy evaluation report

Job name
Loudoun Road

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Executive summary

Loudoun Road in Camden was completed in 2013 for Origin Housing Group and provides 42 new homes, of which 36 are affordable. The project incorporated Passivhaus principles including high levels of insulation; utilisation of internal and solar gains; excellent airtightness; and good indoor air quality by means of a whole-house ventilation system with heat recovery. This strategy achieved an estimated 54% reduction in carbon emissions (Part L 2010) through building fabric improvements and the installation of solar thermal panels.

Monitoring of five dwellings at Loudoun Road was carried out between March and August 2015. The monitoring included: collecting heat consumption data; logging temperature and relative humidity in two apartments in winter and three in summer; and analysing the results of a questionnaire.

The winter temperature monitoring highlighted the benefits of high levels of insulation and the installation of mechanical ventilation with heat recovery. These features are thought to have significantly contributed to the stability of internal temperatures and warmth of the living spaces, with a constant and flat 20-23°C measured despite external temperatures dropping as low as 5°C.

Whilst in summer, despite the external temperature peaking at 32°C, all living spaces measured remained at a constant 25-27°C internally without the need for cooling. This highlights the ability of the insulated fabric to keep out the heat in summer as much as it keeps in the heat in winter.

These design decisions have resulted in a low heating demand in winter and high reported levels of comfort, with more than two thirds of residents using less than the Passivhaus target of 15 $kWh/m^2.yr$ in-use. Consequently, residents' average heating and domestic hot water consumption combined was four times smaller than the UK average for a similar size home.

When compared to the Building Regulations Standard Assessment Procedure (SAP) calculation, the dwellings performed close to expected in terms of their heating consumption. However, their domestic hot water consumption was over estimated on average by a factor of four.

This has consequences on the predicted reductions in carbon emissions - with a predicted 54% reduction at planning and a 71% reduction based on measured heat consumption. This leads to questions surrounding the accuracy, benefits and drawbacks of enforcing carbon offset payments at planning for high performance buildings.

Overall, the results demonstrate that pursuing a high fabric performance has had a positive effect on occupant satisfaction, internal comfort, energy consumption, energy bills and quality of construction - while reversing the performance gap.

Introduction

Introduction

This report is a post-occupancy evaluation and design review of the housing scheme in Loudoun Road, London Borough of Camden, for Origin Housing.

About this report

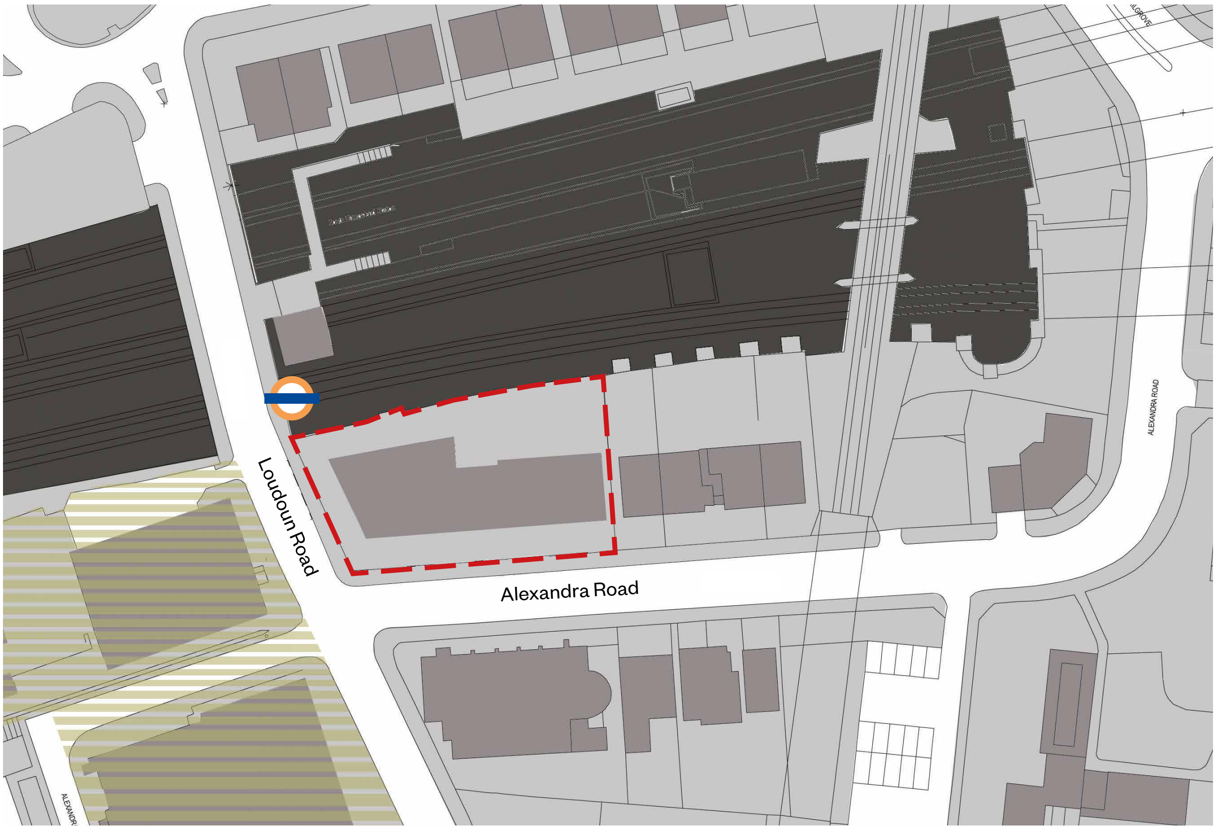
It presents the findings of initial lessons learned, thermal comfort monitoring, occupant questionnaires and informal discussions with users. It is designed to provide an insight into the performance of the building and how residents feel living there, in order to inform the design of future projects.

Project overview

The Loudoun Road scheme, completed in 2013, provides 42 dwellings, 86% of which are affordable, on a total site area of approximately 0.16ha. The development contains a mix of smaller one-bedroom homes to larger four-bedroom family homes. The mix supported London Borough of Camden's policy to secure a range of housing sizes to help meet local need, as identified by the Camden Housing Needs Survey. The proposals capitalised on the site's excellent location, within close proximity to an array of community facilities, namely the newly refurbished Swiss Cottage Leisure Centre and Library, and connections to rail, tube and bus infrastructure. The site has the maximum PTAL rating of 6(A). There is no vehicular access into the site, except for two dedicated wheelchair parking spaces.

The existing context is characterised by a variety of contrasting building typologies and a dramatic change in topography and levels. Directly to the south of the site is the Grade II listed All Souls Church. The site is also located adjacent to the Alexandra Road Conservation Area, which is characterised by the setting of the listed Alexandra Road Estate further west. It sits to the south of a deep railway cutting on steeply sloping Alexandra Road. The building responds positively to these dramatic building-scapes, engages with the street and provides a focal point that builds on the area's unique character.

The scheme consists of accommodation distributed around two building cores, with principal access from Alexandra Road and Loudoun Road respectively. The building form creates a protected shared rear garden and the ground floor dwellings have direct street level access via landscaped front gardens, providing active frontages along both streets.



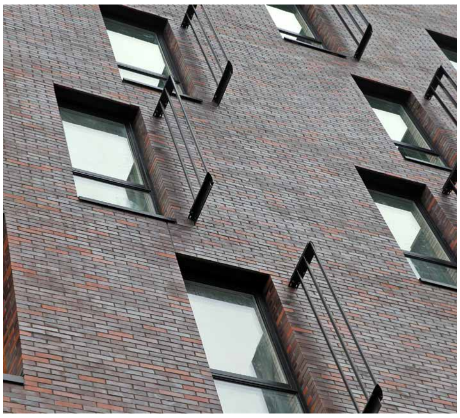
Site Boundary Conservation Area South Hampstead Station

Map showing site boundary and building footprint

Loudoun Road

The development is arranged over three principal brick volumes, stepping up in height towards Loudoun Road, which respond to the contextual conditions. A four-storey building adjacent reinterprets the volume of the Victorian terrace. An intermediate building in contrasting brick acts as a plinth for the principal corner element. A bold architectural treatment, in the form of an elevated, faceted eight-storey geometric volume with recessed balconies, is provided on the western aspect, facing Loudoun Road. A landscaped area directly off Loudoun Road works with a two-storey cut in the built form, to provide an attractive entrance to the building and a high quality public realm.

The proposals sought to retain and reinforce the residential character along Alexandra Road by following the building line of the existing Victorian residential dwellings. Larger family dwellings are located at ground level, benefiting from a generous set back. The scheme responds sensitively to the existing streetscapes and when viewed in silhouette from a distance along the northern railway edge, its form follows the volume of the neighbouring terraces before rising to address the busy crossroad at Loudoun Road.

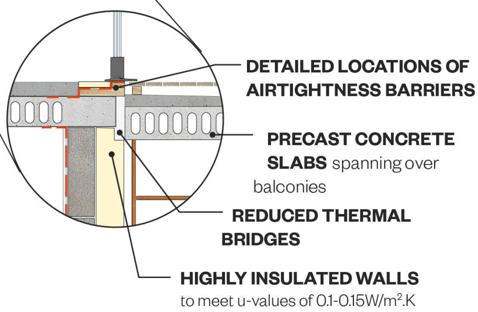


External shading on the west façade

Front entrance

View from the southeast showing the stepped façade

West-facing elevation



1. **HIGH FABRIC EFFICIENCY**
   U-values as-built :
   walls - 0.1-0.15 W/m².K
   floor - 0.15 W/m².K
   roof - 0.15 W/m².K
   windows - 0.87 W/m².K
   doors - 0.9 W/m².K

2. **HIGH AIR TIGHTNESS**
   As built:
   air permeability - 0.65-1.87 $m^3/h.m^2$ @50Pa
   air change rate - 0.57-0.59 h^{-1} @50Pa

3. **NATURAL VENTILATION**
   through openable windows for purge ventilation in summer.

4. **SOLAR SHADING**
   horizontal brise soleil over exposed south facing windows, vertical shading on the west.

5. **DAYLIGHT MAXIMISED**
   with average daylight factors of ≥2% in kitchens and ≥1.5% living, dining and home office areas.

6. **CENTRALISED GAS FIRED BOILERS**
   supplying heating and hot water to dwellings.

7. **MECHANICAL VENTILATION WITH HEAT RECOVERY (MVHR)**
   containing a heater battery with heat supplied by centralised system.

8. **SOLAR THERMAL ARRAY**
   providing centralised system with hot water from a renewable source.

9. **BIODIVERSE ROOF**
   increasing local ecology

10. **ACOUSTIC INSULATION**
    insulating dwellings 5dB beyond Building Regulation requirements.

11. **LOW HEATING DEMAND**
    69% of dwellings measured in use have a heating demand of ≤15 kWh/m^2.yr

CODE FOR SUSTAINABLE HOMES LEVEL 4 ★★★★

Sustainability strategy

The project brief was driven by a strong sustainability agenda by the client, Origin Housing, and local planning policy at the time. In accordance with the Mayor of London's Energy Hierarchy, the development sought to significantly reduce the energy demands and carbon emissions through a highly efficient building envelope, designed to Passivhaus levels of super-insulation and air-tightness. This has resulted in an average CO_2 reduction across the site of 54% over Part L 2010. In addition, all homes achieved Code for Sustainable Homes Level 4.

The boundaries of sustainability were challenged by following Passivhaus principles very closely, but stopped just short of achieving overall certification. This hybrid approach attempted to provide the best of both worlds with regards to high levels of energy efficiency and cost-effective design. The diagram opposite highlights the sustainable features at Loudoun Road.

Building fabric and orientation

A high performance building fabric was specified with low u-values within the typical Passivhaus range. These were achieved using traditional brick and block construction with triple glazed windows.

In addition, high levels of airtightness meeting the Passivhaus requirement of <0.6 ACH^{-1} @50Pa in testing were achieved. This was detailed with residents in mind, making adjustments to the wall build-ups to future proof and protect the airtightness barrier from the hanging of pictures on walls.

The building is orientated along an east-west axis, allowing the majority of units to be dual-aspect or face south.

These design decisions have resulted in a low heating demand, with more than two-thirds of residents using less than the Passivhaus requirement of 15 $kWh/m^2.yr$ in-use.

The Passivhaus Planning Package (PHPP) software was used at pre-planning stages, but it is not clear from our records whether this was continued at construction stage. But it is known that genuine effort was made to match the standard as closely as possible on-site, with a dedicated Passivhaus specialist appointed to oversee the construction of the building.

Heating strategy

The mechanical ventilation with heat recovery (MVHR) system retains the majority of heat in the homes. On colder days, supplementary heat is provided from the communal gas boilers and is supplied through the MVHR to boost the heat. The communal gas boilers, together with roof mounted solar thermal panels, heat a communal hot water tank that also provides domestic hot water to the homes.

Ventilation

The dwellings have mixed mode ventilation, with the MVHR system providing continuous background ventilation with a boost function and openable windows for natural ventilation.

Shading

Deep balcony reveals, together with horizontal brise soleil on the south façade and vertical shading on the exposed west façade, assist in reducing excess solar gain during summer months.

Lighting

All dwellings were designed to achieve average daylight factors of 2% in kitchens and 1.5% in living areas to reduce the requirement for artificial lighting during daytime. LED lighting has been provided throughout to reduce electricity consumption.

Acoustics

As part of the Code assessment, the apartments exceeded Building Regulations Part E by 5dB, reducing the sound transmitted from dwelling to dwelling.

Methodology

Methodology

The aim of the study is to understand the performance of the homes in respect to the building's design, environmental impact and resident satisfaction, especially in terms of energy consumption, enjoyment and comfort.

Outline of study

It is important for the client and design team to know how a building is operating and if it can perform better, in order for future homes we design to become as comfortable and energy efficient as possible. The participation of residents in this study was an opportunity to gather their feedback.

Levitt Bernstein together with Origin Housing approached a mixture of rental and shared ownership residents within the scheme (at 154 Loudoun Road and 22 Alexandra Road) about their experience of their new home. This included the monitoring of internal temperatures, air quality and energy consumption. We were particularly interested to discover if any homes may have had high or low heat energy consumption or if they experienced particularly warm temperatures during summer. The monitoring was used to assist us to understand how, when and why residents use heat in an energy efficient new home.

Methodology

The study took place over the course of the 2015 calendar year to capture the performance of the homes across seasons.

During this time, we visited five properties to discuss thermal comfort and energy use in the first instance. As part of this, we set up temperature and air quality monitoring equipment to log hourly internal environment data for around a month at a time over summer and winter. In parallel, we collected hourly external temperatures and heat consumption data connected to the communal heating system.

Residents were invited to participate on a voluntary basis after we generated an initial shortlist selection. The shortlist was based on a combination of each residents' response to Origin Housing's New Build Resident Satisfaction Questionnaire, their heat consumption data and the location and orientation of their apartment in the building.

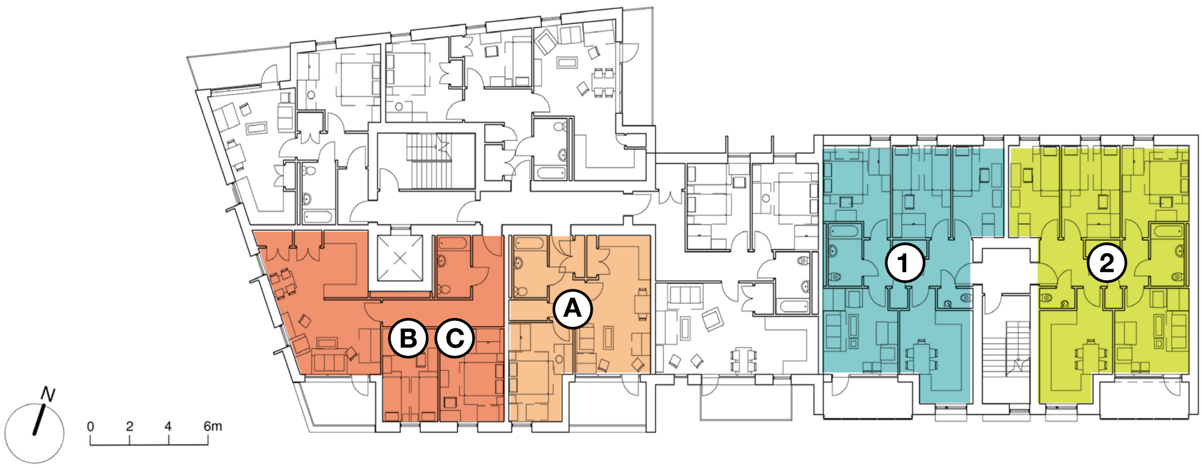
For the winter monitoring, we sought similar sized apartments with the same orientation and those housing residents with particularly high or low heat consumption (see p.17 for approximate location of units 1 and 2, although these are spread across different floors). Whereas, for summer monitoring, we sought south facing apartments that had previously fed back on their perception of summer internal temperatures (see p.17, units A, B and C which are also spread across differing floors). The specific location of the units monitored in terms of their floor has not been disclosed to preserve anonymity.

The chapters that follow cover the results of the Resident Satisfaction Questionnaire, followed by the winter and summer monitoring results and energy consumption.

The findings presented are to be fed back to Origin Housing through this report. We intend to use the results to improve and verify our future designs.

Logging equipment used in homes


External temperature logger



Approximate location of dwellings participating in the study

Resident feedback

Resident feedback

Origin Housing resident satisfaction questionnaire

Origin Housing provided residents with the New Build Resident Satisfaction Questionnaire upon moving in to collect information on how they felt about their new homes.

In total, residents in 14 out of the 36 homes responded in early to mid-2014 with varying degrees of question completion. Residents were invited to answer questions on the following topics:

- The neighbourhood
- Layout of the development
- Management of the development
- The external appearance and spaces
- Internal features of the home, including specific questions on the kitchen and bathroom and decoration
- Communal areas
- Moving in experience
- Any other items the residents wished to raise.

Due to the quality and comprehensiveness of the Origin questionnaire, we were able to analyse the responses for the purpose of this study without the need to create a new questionnaire. The aim was to learn whether residents are comfortable in the building and whether the design met their needs and expectations.

This also informed our decisions on which apartments to carry out further monitoring on. The response rate was around 38%, with the responses cross-checked against our observations and informal discussions with residents to provide greater confidence and understanding.

Results of the Origin Housing questionnaire

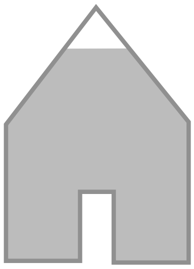
The results of the questionnaires generally showed that most liked the appearance of their homes, with the apartment, room and storage sizes meeting their needs. They felt secure but some were bothered by external noise levels when windows were open. Residents noted that daylight levels were mostly adequate and that their homes were warm enough without heating.

The results of the residents' feedback have been presented over the following pages.

Response rate (14/36 homes)

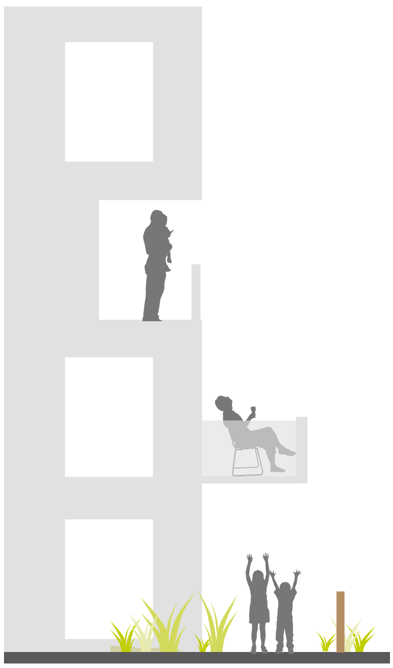
38%

The outside of your home



13/14

like the outside appearance of their home and felt the size of their home was about right



Balconies

Residents comments

Residents were given the opportunity to comment on their balcony, with most commenting on the size or exposure.

"Good size - though having the door opening out in the middle of balcony wastes space"

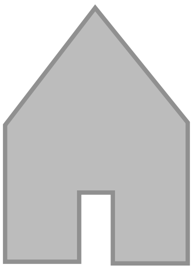
"It's well covered and not overlooked which is good"

"Perfect in size"

"Our balcony does not have cover unlike the others, this means it is open to the elements such as dirt and rain etc."

"Very good size, wood is untreated though"

The inside of your home

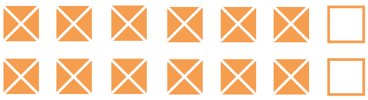


100%

of residents surveyed were happy with the layout of their home, with one comment:

> prefer the bedrooms not to back on to other bedrooms as you can hear [the neighbours] very loudly

Storage space



12/13

have enough storage space

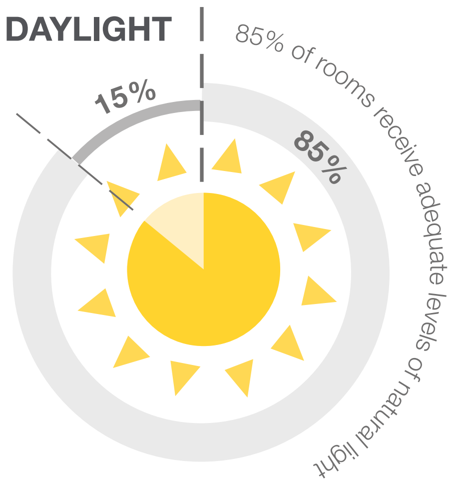
Would smaller bedrooms be acceptable if there was more storage space?

Daylight

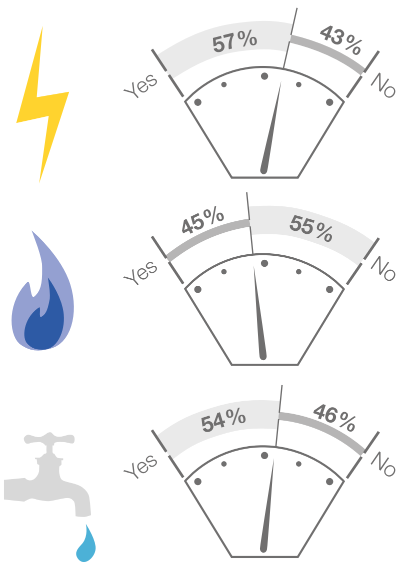
The respondents found the levels of daylight were adequate in all rooms. However, two respondents noted that there was no window in the bathroom, but enough windows otherwise.

Do you have enough windows?

> "It becomes so hot in summer that all night every night we had all windows open and fans on so maybe more for those times would be good"
>
> **"As flat is single-aspect it's hard to ventilate"**



Do you know how to turn off the water / gas / electricity in an emergency?

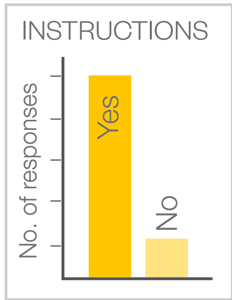


Building services

Curiously, just under half of the respondents noted they knew where to turn off their gas supply, however, gas has not been piped to homes; dwellings are supplied with heat from the communal system. This could be highlighting a misunderstanding in the building services provided.

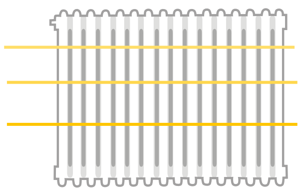
Instructions

Residents were asked if they were left an instruction leaflet for their home, in the knowledge that one should have been left. Most noted that they had but it would appear that not all had the information they required.



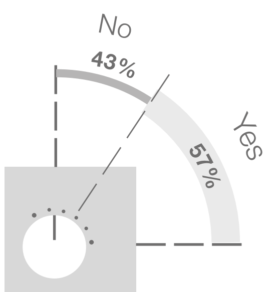
What sort of heating do you have?

15% electric
46% communal heating
38% other
0% full gas central heating



Heating

Although some residents suggested they knew where their gas supply tap was, none noted that they had gas heating. But it is apparent from the response that, in general, they are not clear how their heating systems work or how heat is supplied.



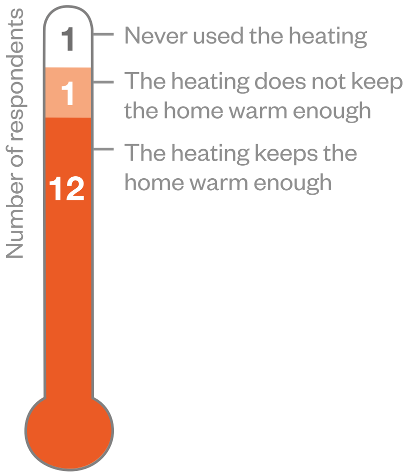
Do you find the heating and hot water easy to adjust?

Controls

Just over half of respondents felt their heating and hot water was easy to adjust. Notably, those who reported they had not received an instruction leaflet have also said that the heating and hot water were not easy to adjust.

13/14

Heating



"Our building is very warm, too warm for many, but I love it."

"The room heating system is slow and noisy, only areas immediately underneath the vent are heated for a short period."

"The building has a very high insulation rate."

"We haven't had to use it yet as our flat is so hot! Even in winter we have half the windows open at all times."

"Too many admin charges that outweigh the cost of the utility itself"

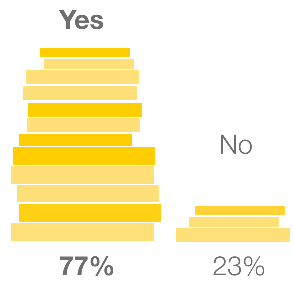
"Flat gets very hot and hard to cool down"

"Too expensive"

"Heating is difficult to control and would prefer a timer."

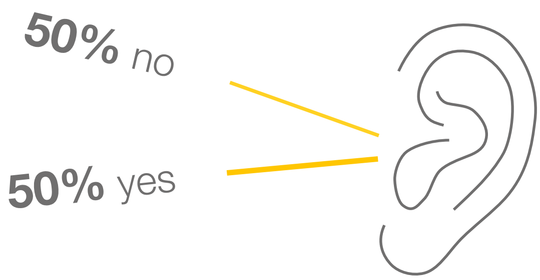
"There are two bills for energy supply. Heating and hot water. I find that the bill is relatively complex and high."

Heating costs



Do you find the cost of running the heating and hot water reasonable?

Acoustics
When asked, half the respondents suggested they were regularly bothered by noise from traffic or their neighbours, while half were not. Those who were affected by external noise noted that it was due to traffic noise, noise from railway engineering works, or one resident said they heard noise from the apartment above. It was not clear from the questionnaire whether the windows were open or closed at the time.



64% of respondents are very satisfied with their accommodation overall

21% fairly satisfied


M/CS
SOLO

Winter monitoring

Winter monitoring

Summary

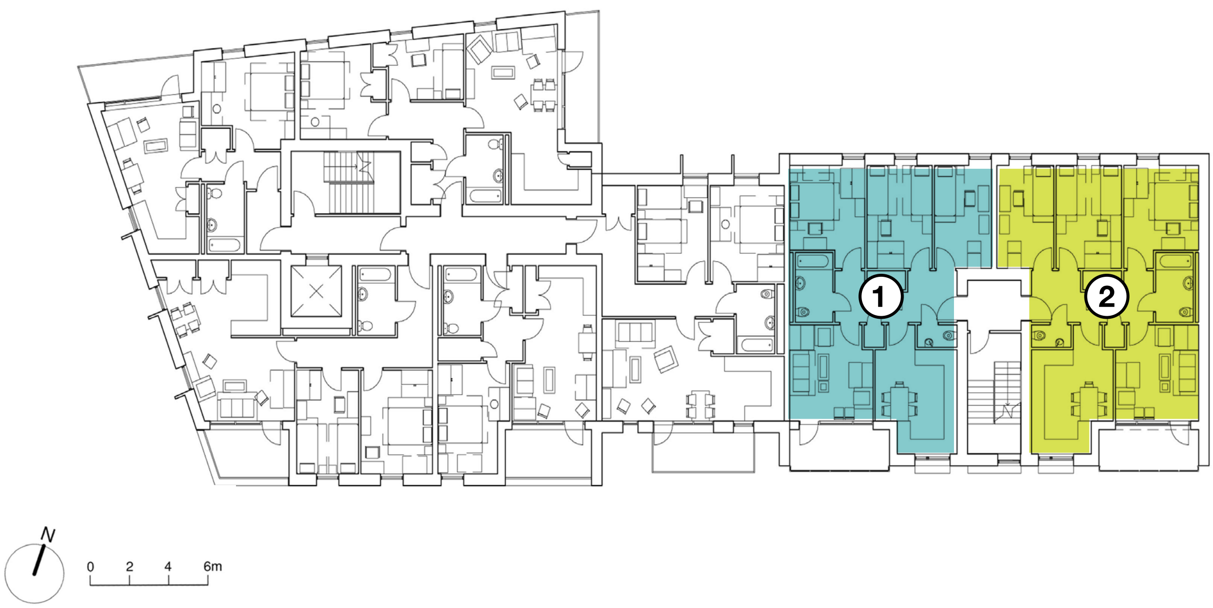
The primary aim of monitoring homes in winter was to determine whether the high levels of airtightness and insulation associated with Passivhaus principles kept the homes and residents warm.

From 27th March until 14th May 2015, combined temperature, humidity and light monitors were placed into two homes to study the internal conditions. At the same time, we monitored external temperatures whilst being provided with the monthly heat consumption of each home.

For the duration, a logger was placed in the living room area of each home, where residents typically spent most of their time.

While the typical winter months had passed by March, the external temperatures still dropped to lows of 5°C and it is clear from the heat consumption data that these homes were still using their space heating.

The results of winter monitoring have been presented in this chapter.



Approximate location of dwellings participating in the winter study

Results of monitoring

In order to analyse and present representative temperature and humidity data from the winter monitoring period, two of each of the coolest, warmest and average days have been extrapolated (see graphs on the following page).

The most striking overall observation is that both of the homes monitored stayed at a constant 20-23°C despite the fluctuations in external temperatures. This is true of the apartments whether the external temperatures are 5°C, 10°C or 20°C and whether it is day or night.

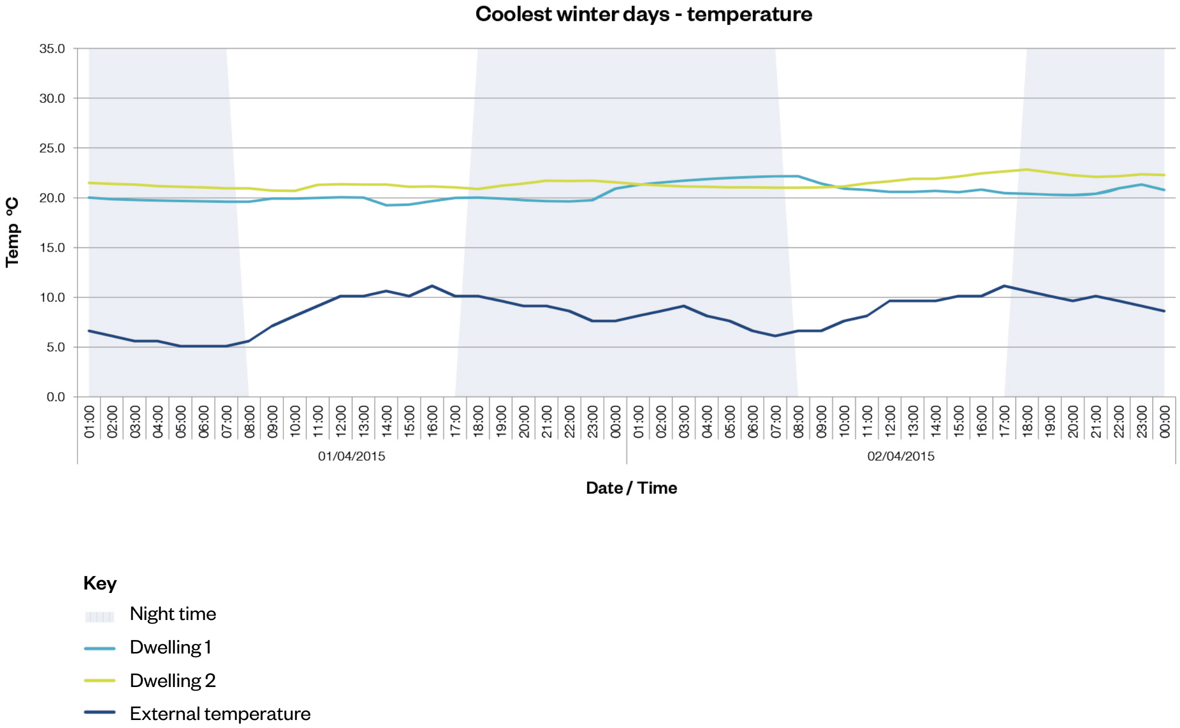
It is not specifically known when the heating was used during this period, but it can be assumed that the insulation and mechanical ventilation with heat recovery (MVHR) are significantly assisting. This is because there appears to be little or no heat loss during the night when heating is typically turned off.

Mechanical ventilation with heat recovery unit (MVHR) used at Loudoun Road

Heating control panel used at Loudoun Road

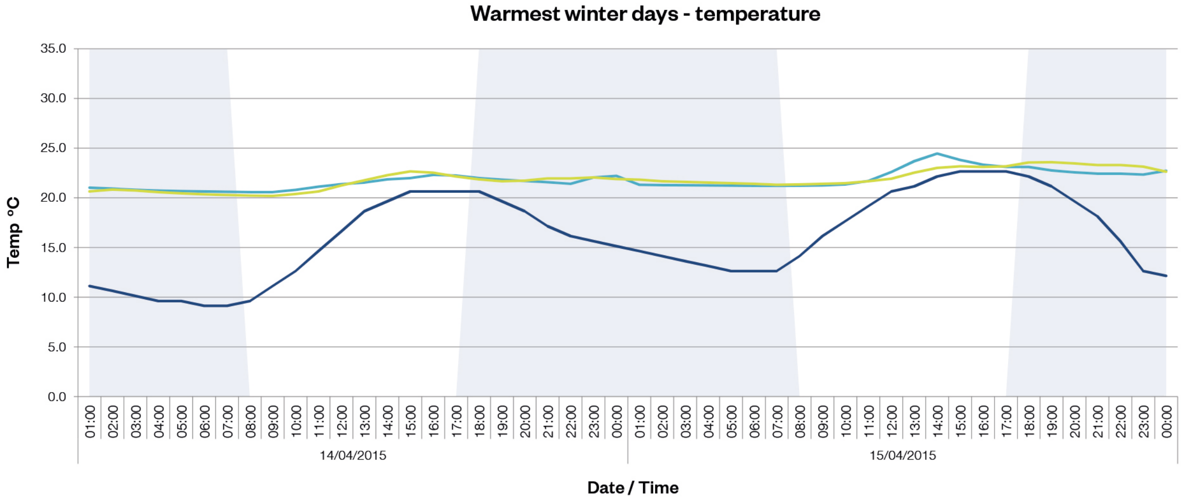
Coolest winter days

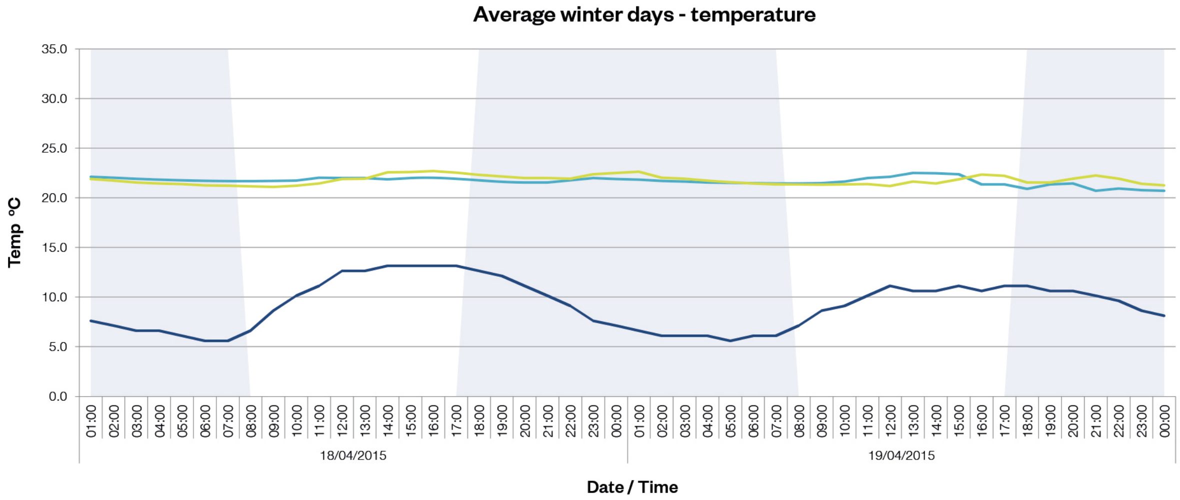
By combining the results of temperature monitoring with the heat consumption data, we were able to determine that the homes needed very little heat to keep them warm, despite external temperatures of 5°C. This assists in the validation of the importance and effectiveness of well-insulated buildings combined with high levels of air tightness.



Warmest and average winter days

When the external temperatures rose by more than 10°C from night to day, it can be seen on the graph that this had very little effect on the internal temperatures of the homes. It would appear from the results that the external temperatures have very little bearing on the internal temperature.





Humidity

The humidity graphs opposite show that one of the homes is holding a lower humidity than the other. As stated by CIBSE Guide A, “humidity in the range 40–70% RH is generally acceptable”.

This would indicate that both homes are within the acceptable range, although on occasion, Dwelling 1 has humidity levels slightly lower than 40% and Dwelling 2 slightly higher than 70%. It is noted that Dwelling 2 has consistently higher levels of humidity than Dwelling 1. In general, the three homes monitored during summer appear to be holding similar humidity levels to Dwelling 1, indicating that Dwelling 2 is potentially an anomaly and should be investigated further to determine whether the MVHR is working correctly.

Due to levels of humidity below 45% in Dwelling 1, it can be said that it is at lower risk of mould growth and house dust mites are less likely to prosper. CIBSE Guide A states that “To limit the growth of house dust mites, indoor RH in dwellings should be kept below 60%”.

It is highly likely that the MVHR units are the main contributor in keeping humidity levels low whilst retaining warmer air temperatures.

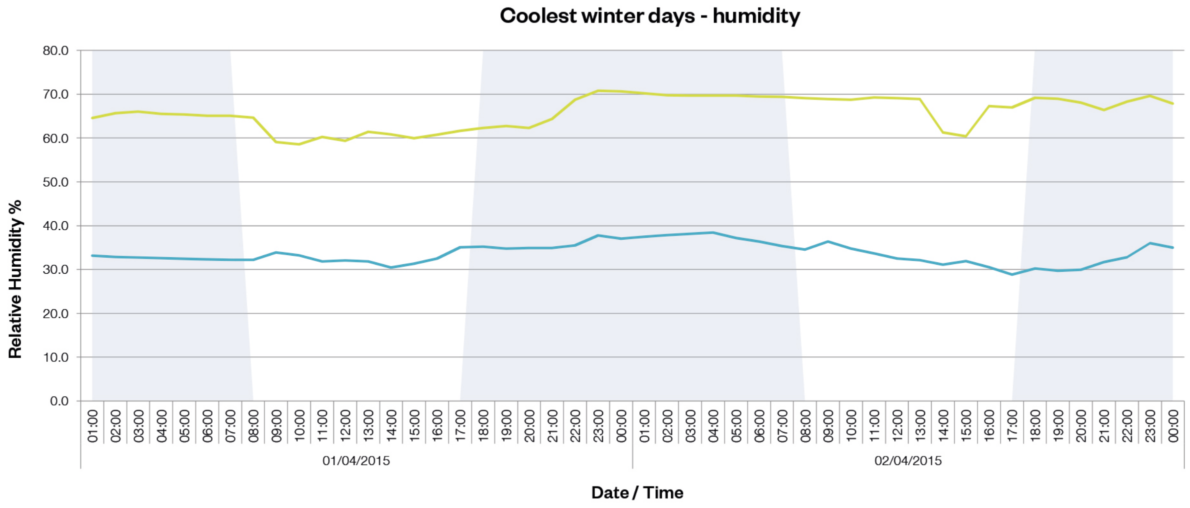
This indicates that the homes are well-ventilated without losing heat.

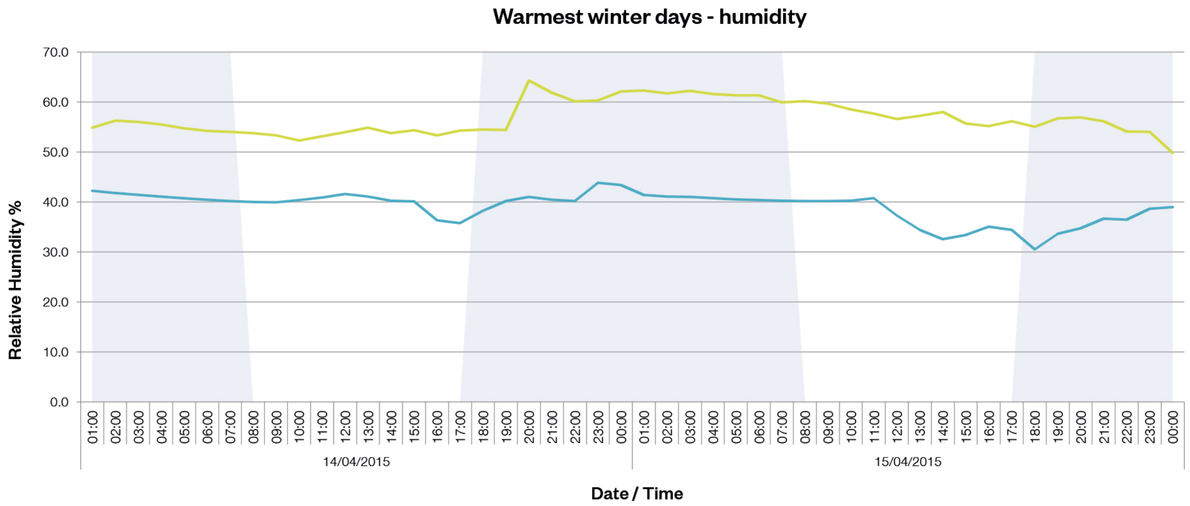
Key

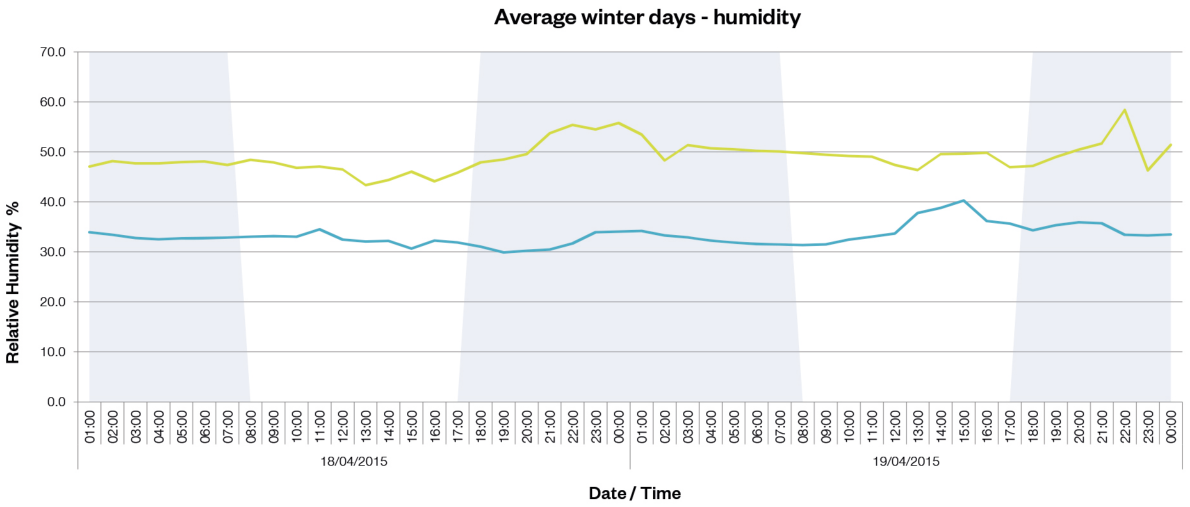
Night time

Dwelling 1

Dwelling 2


Coolest winter days - humidity
Relative Humidity %
Date / Time
01/04/2015
02/04/2015


Warmest winter days - humidity
Relative Humidity %
Date / Time
14/04/2015
15/04/2015


Average winter days - humidity
Relative Humidity %
Date / Time
18/04/2015
19/04/2015

Summer monitoring

Summer monitoring

Summary

The primary aim of monitoring specific homes during summer was to determine whether they were uncomfortably warm, particularly because the apartments are south-facing and have high levels of insulation and airtightness.

From 30th June until 21st September 2015, combined temperature, humidity and light monitors were placed into three homes to study the internal conditions. At the same time, we monitored external temperatures whilst being provided with the monthly heat consumption of each home.

For the duration of the summer monitoring, a logger was placed in the living room area of each home where residents typically spent most of their time.

During the monitoring period, we were able to observe how the homes responded to peak external temperatures of 32°C.

The results of summer monitoring have been presented in this chapter.

Approximate location of dwellings participating in the summer study

Results of monitoring

For the summer monitoring period, two of each of the coolest, warmest and average days have been extrapolated (see graphs overleaf) in the same way as the winter monitoring.

As was noted with the winter monitoring, the homes have maintained very stable internal temperatures despite the fluctuations in external temperatures. However, the higher summer external temperatures have meant that these homes maintain a slightly higher average internal temperature of 23-26°C.

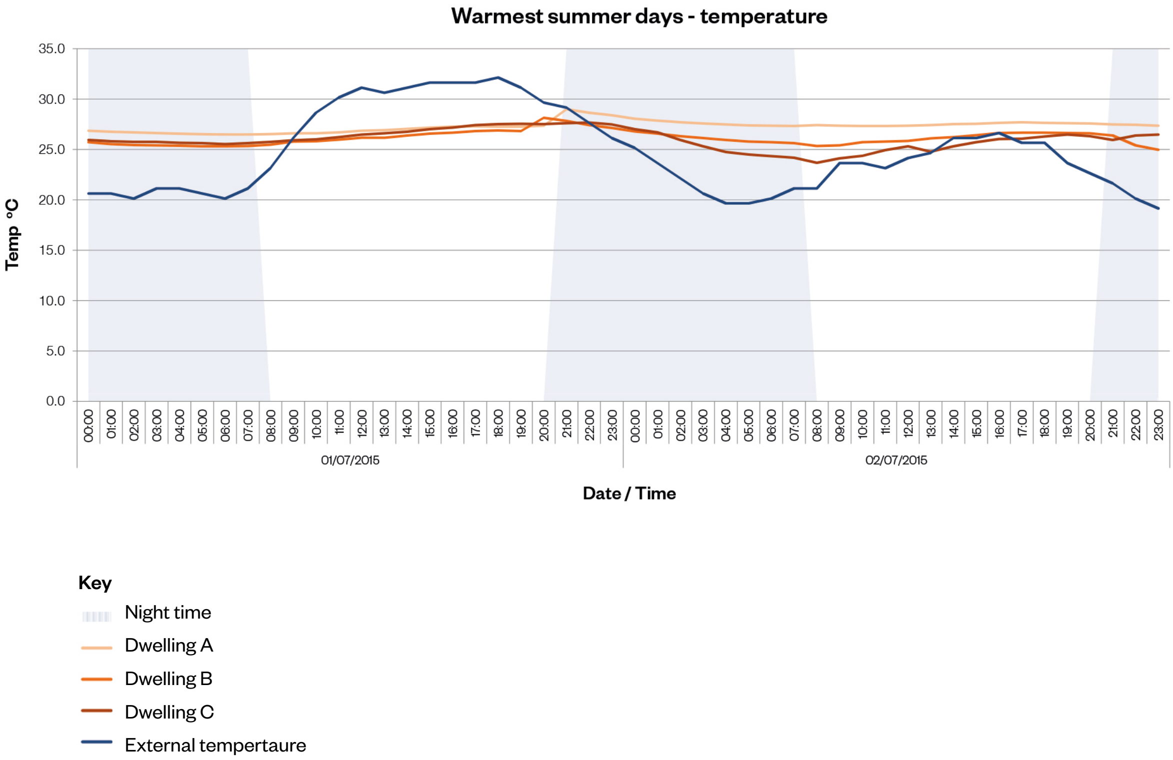
This is also true of the apartments whether the external temperature is 10°C, 20°C or 30°C and whether it is day or night.

It is not specifically known if and when the residents opened their windows during these periods but it would appear from the results that the MHVR summer bypass was likely to be in operation and that the insulation was working to keep heat out in summer, as much as it kept heat in, in winter.

Warmest summer days

One of the most interesting findings in summer is that on the hottest day (below) where external temperatures exceeded 32°C, the internal temperatures of all three south-facing apartments did not exceed 27°C, creating at least a 5°C difference between internal and external temperatures.

This highlights that the insulation is not only keeping heat in in winter but also heat out in summer. This could also be due to good external shading reducing or preventing sunlight and heat from entering the rooms. As defined by the recently superseded method (CIBSE Guide A) of calculating overheating in homes, the dwellings would not have exceeded the 28°C limit.

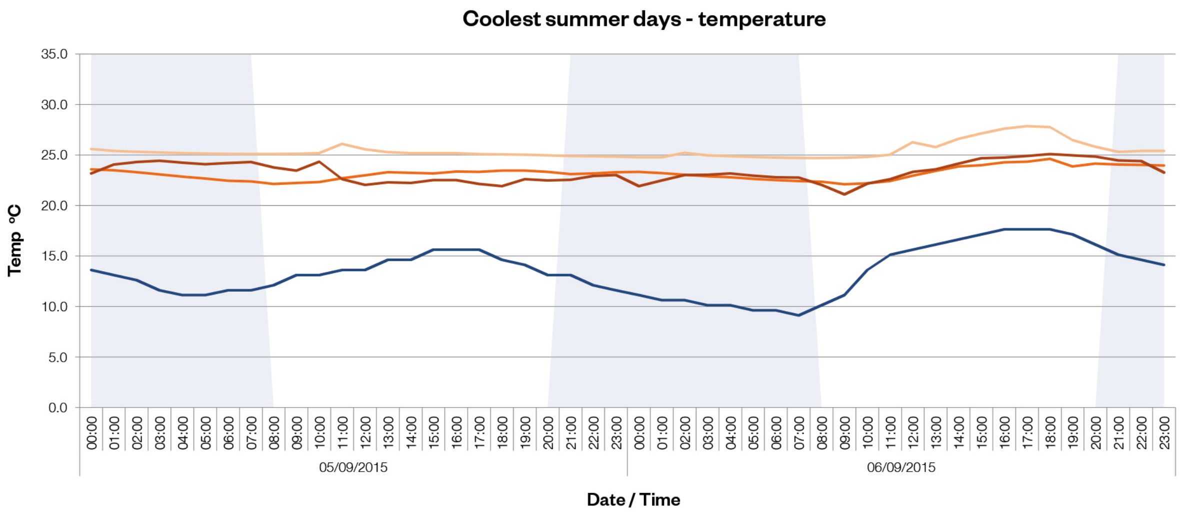


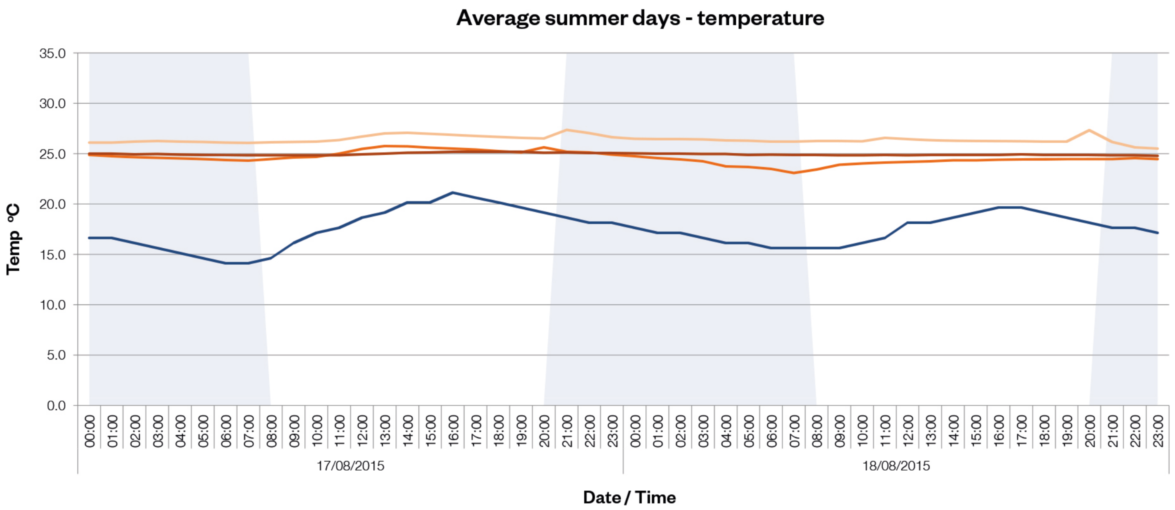
Coolest and average winter days

It is noted that on the hottest, coolest and average summer days, the homes remained between approximately 23-26°C almost constantly - with the internal temperature lines staying reasonably flat regardless of the external temperature. Although this is positive on one hand because homes are not reacting to external temperatures and therefore not overheating, it is also curious that the internal temperatures are not dropping on cooler evenings after a hot afternoon, leading to perhaps uncomfortably warm nights. This may explain why residents note that their homes are sometimes too warm.

It would appear from the data that residents are either not opening their windows to cool their homes when external temperatures are lower or the ventilation provided by the windows is inadequate. Residents have anecdotally reported that external noise from passers-by sometimes prevents them from opening their windows at night. Nevertheless, there is evidence that the use of triple glazing can make homes quieter internally. Therefore, when open, the background external noise levels can be perceived as too loud due to reduced exposure to external noise generally.

CIBSE Guide A notes that where internal temperatures exceed 24-26°C sleep and comfort can be impaired. As the bedrooms were not monitored as part of the study, their temperatures are unknown. Therefore, it is difficult to determine whether temperature would have affected residents' sleep.





Humidity

The graphs opposite show that humidity in the homes is on the lower side of average, at between 35-50%. This indicates that the MVHR system is working well to reduce moisture in the air.

As with Dwelling 1 monitored during the winter, it can be said that these three homes will also have a lower risk of mould growth and house dust mites are less likely to prosper.

This is a particularly impressive result for the homes, demonstrating that an efficient and effective MVHR controls internal moisture levels.

Key

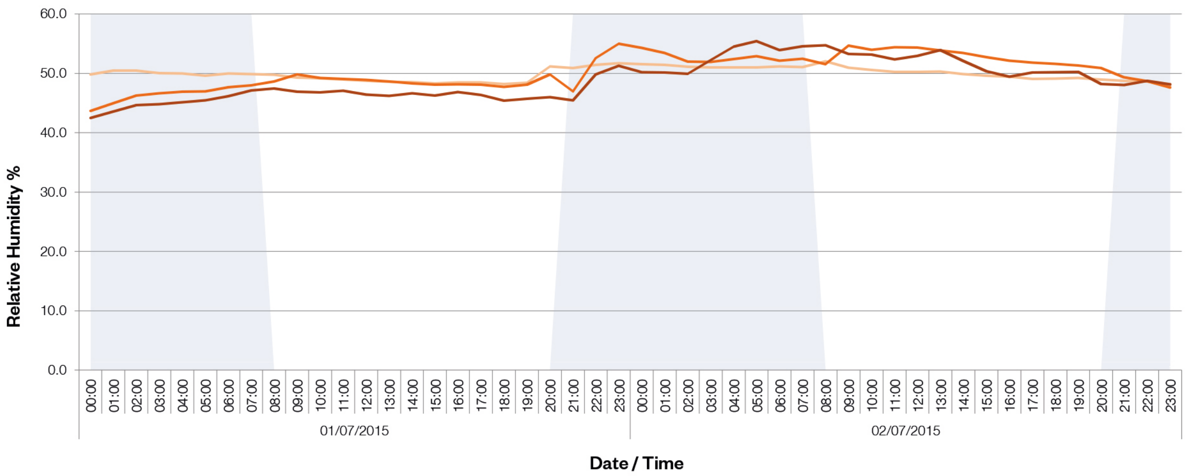
Night time

Dwelling A

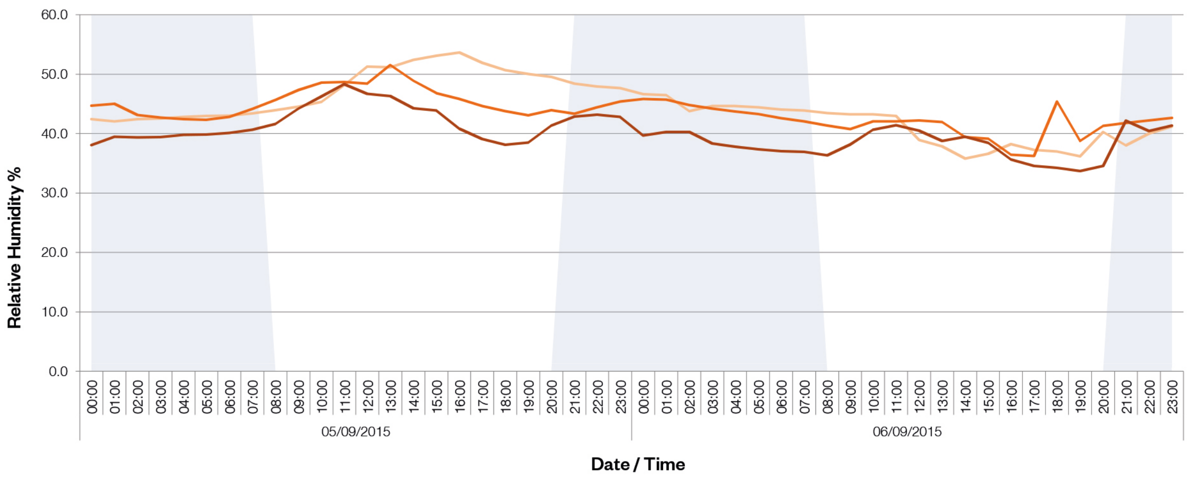
Dwelling B

Dwelling C

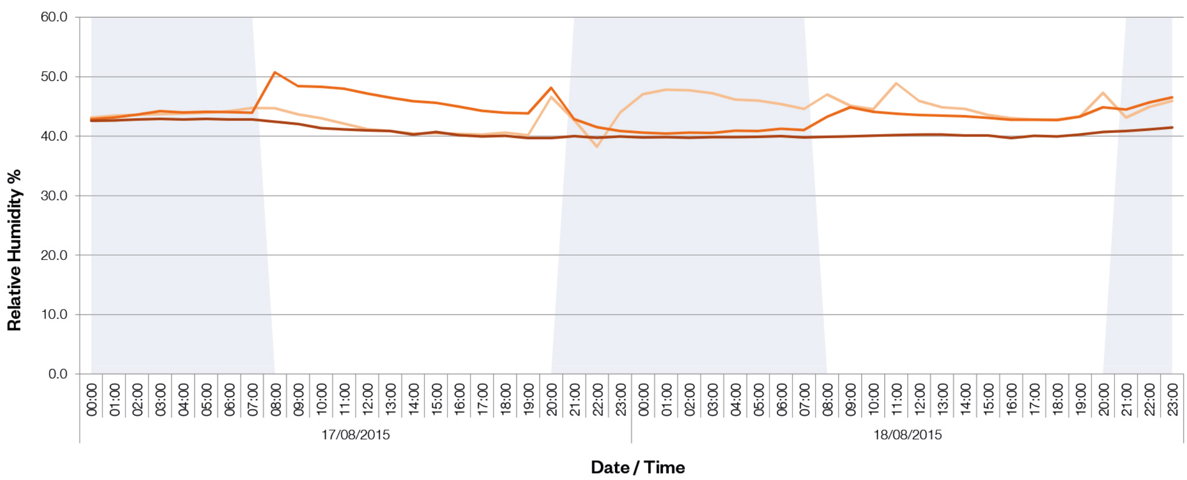
Warmest summer days - humidity



Coolest summer days - humidity



Average summer days - humidity



Energy

Energy

Heat consumption

Heat consumption for monitored units

Analysis of heat consumption was carried out to determine whether the energy efficiency of the building has resulted in lower consumption in-use. Monthly heat consumption has been compared to Thames Valley degree-day data which accounts for weather variations.

'Heating degree-days are a measure of the severity and duration of cold weather. The colder the weather in a given month the larger the degree-day value for that month' (Carbon Trust, 2012).

In this case degree-days with a baseline temperature of 15.5°C were used. Where the external temperature is below the base degree-day temperature it is assumed that the heating system will be turned on.

The graphs opposite show a similarity between the data profiles of heat consumption (heating and domestic hot water) and degree-days, indicating a higher demand for heat in winter and lower demand in summer. This demonstrates that the residents have been using the heating to keep warm in winter.

Further regression analysis using predicted heat consumption has revealed that some months the residents have been able to make a saving in heat consumption when compared to the weather data, but other months they are using more heat than would be expected. It is unknown why this is but given the low amount of heat energy consumed by the residents, it may be that their patterns of heat consumption are more difficult to relate to weather patterns.

Overall development heat consumption

The portion of heat used for heating versus that used for hot water has been estimated for each home. Based on the heat consumption for heating only from January-December 2014, 27 out of the 39 units with sufficient data were comparable with the Passivhaus criteria for heating demand (less than 15 kWh/m^2.yr). This is a significant achievement for the building in-use because following handover the residents have had sole control over their heating use. On average, the heating demand is slightly lower than 15 kWh/m^2.yr and closer to 12 kWh/m^2.yr.

Cost of heat

Reviewing the total heat consumption (heating and hot water) of each unit together with cost has revealed that on average residents are paying £178/yr (2100 kWh), with a maximum of £811/yr (9600 kWh) and minimum of £42/yr (500 kWh). But, it is worth remembering that the apartments are different sizes with different numbers of residents and behavioural patterns. These figures also do not include service charges.

At Loudoun Road the cost of heat from the communal gas boilers per kWh (£0.084/kWh) is twice that of the UK average price for gas (£0.0429/kWh - Energy Savings Trust). So, despite the low consumption of heat, the residents' heating bills can be high. This is compounded by a relatively high set of standing charges at Loudoun Road (approximately £210/yr for heat and water), likely due to the additional maintenance and management of the communal system.

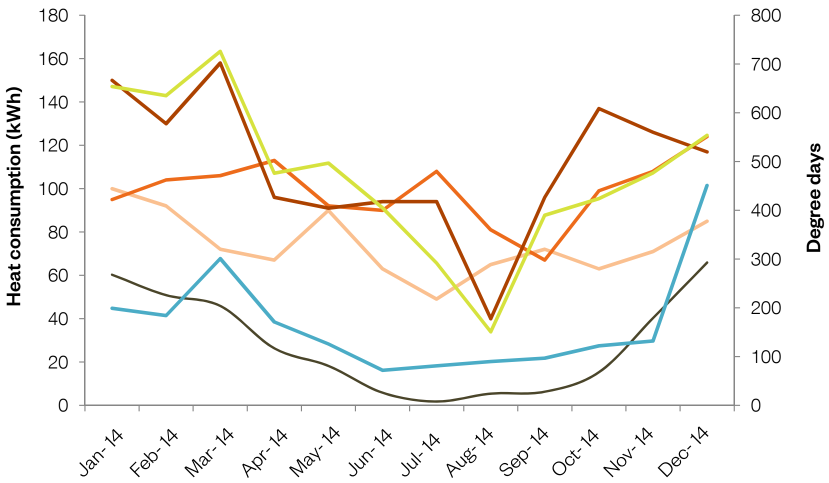
If residents were paying the average price for gas in the UK then the average bill at Loudoun Road would be £90/yr, with the lowest bill £21/yr and highest bill £410/yr.

To put this into context, the average gas bill for a small home or apartment in the UK in 2014 was £385 (9,000 kWh) with an average standing charge of £85 (Energy Savings Trust). Despite the higher than average cost of heat in Loudoun Road, most residents are paying and consuming less than the UK average overall.

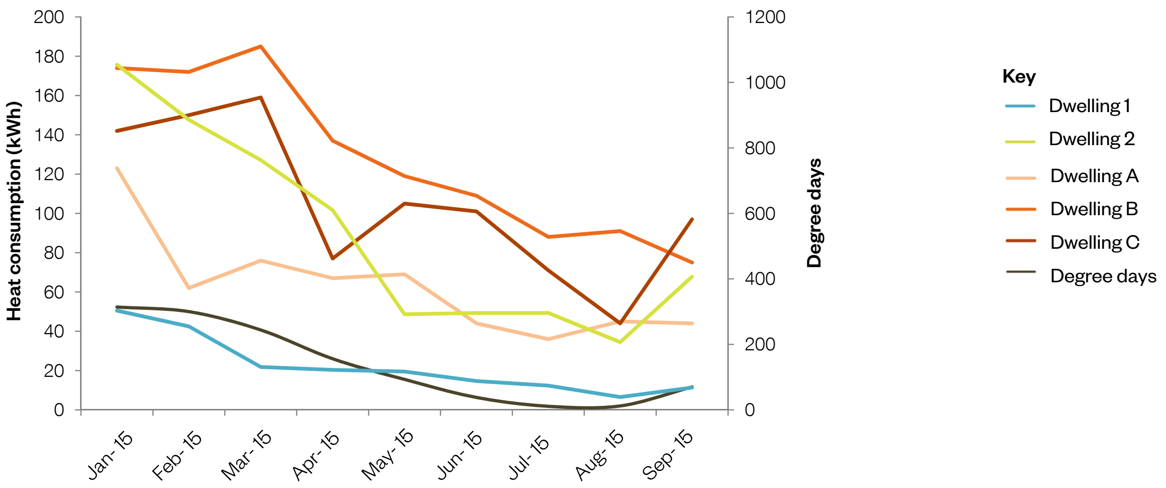
It is fair to say that Loudoun Road is not alone in charging a higher cost for heat than average gas prices. This is an emerging trend among developments with communal heating, where it is unavoidable to charge more than the price of gas due to the maintenance and management of systems and billing.

It should be noted that all figures above exclude electricity consumption, which is an additional cost to the households.

Heat consumption with monthly degree day data - 2014



Heat consumption with monthly degree day data - 2015



Building Regulations

Prediction versus measured

The measured heat consumption of the apartments has been compared to the predictions made by the Building Regulations calculations to determine how closely they correlate.

To separate the space heating from the domestic hot water the total, monthly and yearly heat consumption for each apartment was analysed. Over the summer months, the average base heat load for each apartment was taken to represent the hot water demand, with the assumption that the space heating would not have be in use during this time.

Heating

It was initially expected that there would be a disparity between the measured performance of the homes and the predicted performance - known as the performance gap.

However, when the extrapolated space heating data was compared to the Building Regulations calculation results (standard assessment procedure (SAP)), in the majority of cases there was a surprisingly similar predicted heating demand to the actual demand. Suggesting that the differences in heating consumption between actual and predicted is likely to be down to occupant preference.

It can also be seen that 69% of apartments met the Passivhaus heating demand target of ≤15kWh/m^2/yr in-use - highlighting the success of the strategy even during occupancy.

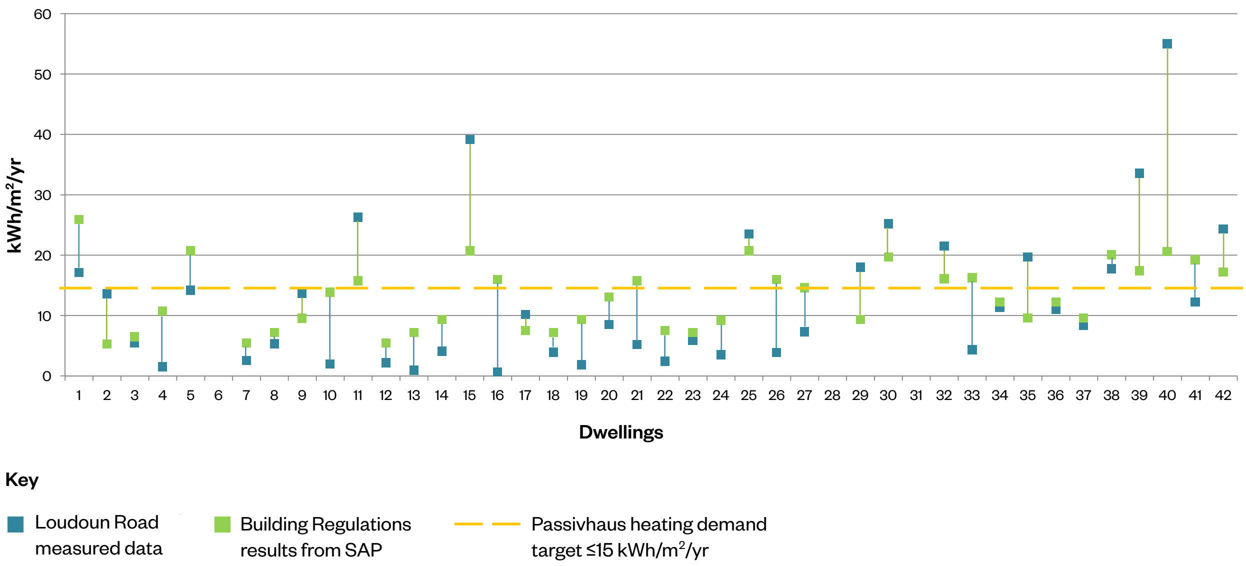
The heating demand results opposite show the close correlation between the SAP data and measured data.

Hot water

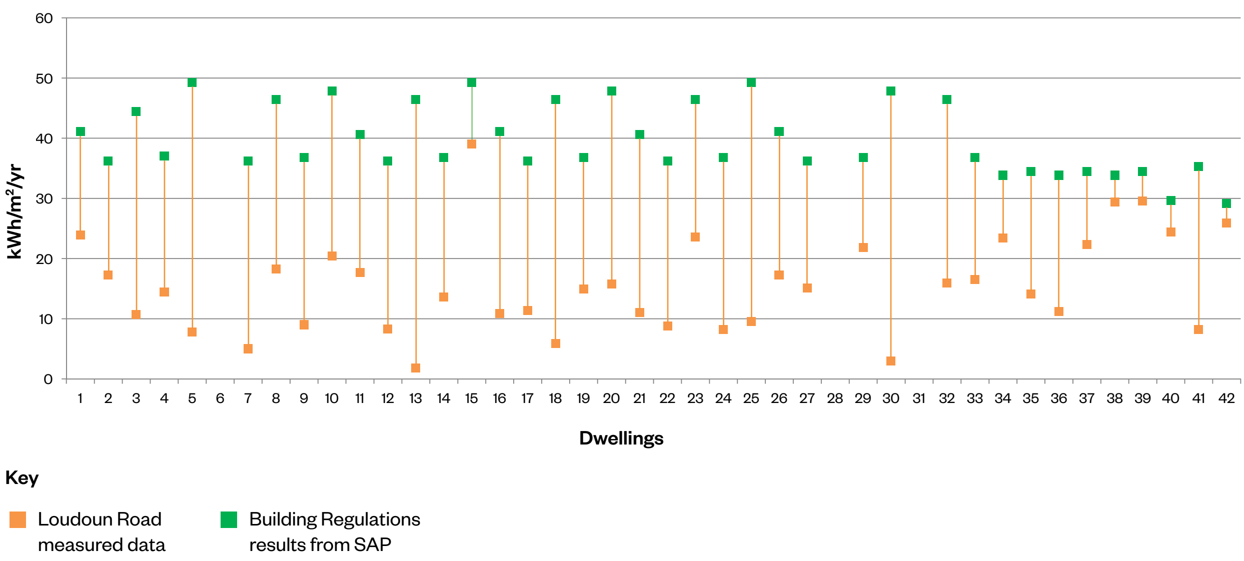
While the measured and predicted space heating demand figures correlated, the Building Regulations prediction for domestic hot water consumption was significantly higher than the extrapolated measured data. Leading us to believe that SAP could be regularly overestimating the residents hot water consumption but around a factor of four (see hot water demand results opposite).

If the hot water consumption is being overestimated, then this potentially has repercussions on the predicted carbon emissions value. Therefore, in reality there could have been greater energy and CO_2 emission reductions than the Building Regulations output suggested.

Heating demand



Hot water demand



Carbon reductions

Comparison to policy requirements

Loudoun Road was calculated to achieve a 54% reduction in CO_2 emissions over Building Regulations Part L 2010 as part of the planning submission. This would approximately translate to a 48-50% reduction in CO_2 emissions under the current Part L 2013.

The difference in calculation methodology between Part L 2010 and 2013 means that it is difficult to predict how the building would have performed, without re-calculating using the current version of SAP. It may be that Loudoun Road would have performed well under SAP 2013 due to changes to the thermal bridging inputs. For the purpose of this report, the difference in CO_2 reductions between SAP 2010 and 2013 uses a standard conversion of approximately 4-6% difference.

The 54% reduction in carbon emissions exceeded the London Plan policy target of 25% reduction at the time of planning submission. This also exceeds the 35% minimum reduction as per current planning policy. Although, as can be expected, if built now it would not meet the latest zero carbon target and would therefore be required to make carbon offset payments.

Having reviewed the measured heat consumption of all apartments at Loudoun Road, it is estimated the development would achieved approximately 71% reduction in CO_2 emissions over Part L 2010. This demonstrates a huge difference in the performance of the building when comparing the predicted and the actual energy consumption.

Carbon offset
Under current planning policy (London Plan 2016) where a development does not meet zero carbon, an offset payment is requested for the remaining carbon emissions beyond 35%. Therefore, the difference in measured and predicted performance at Loudoun Road under current planning policy would have a significant impact on the carbon offset payments at planning submission.

If Loudoun Road had been subject to the carbon offset payment under London Plan 2016, the payments would have been calculated for the predicted consumption. This is a higher figure than has been proved to be the case for the building in operation.

The table opposite demonstrates:

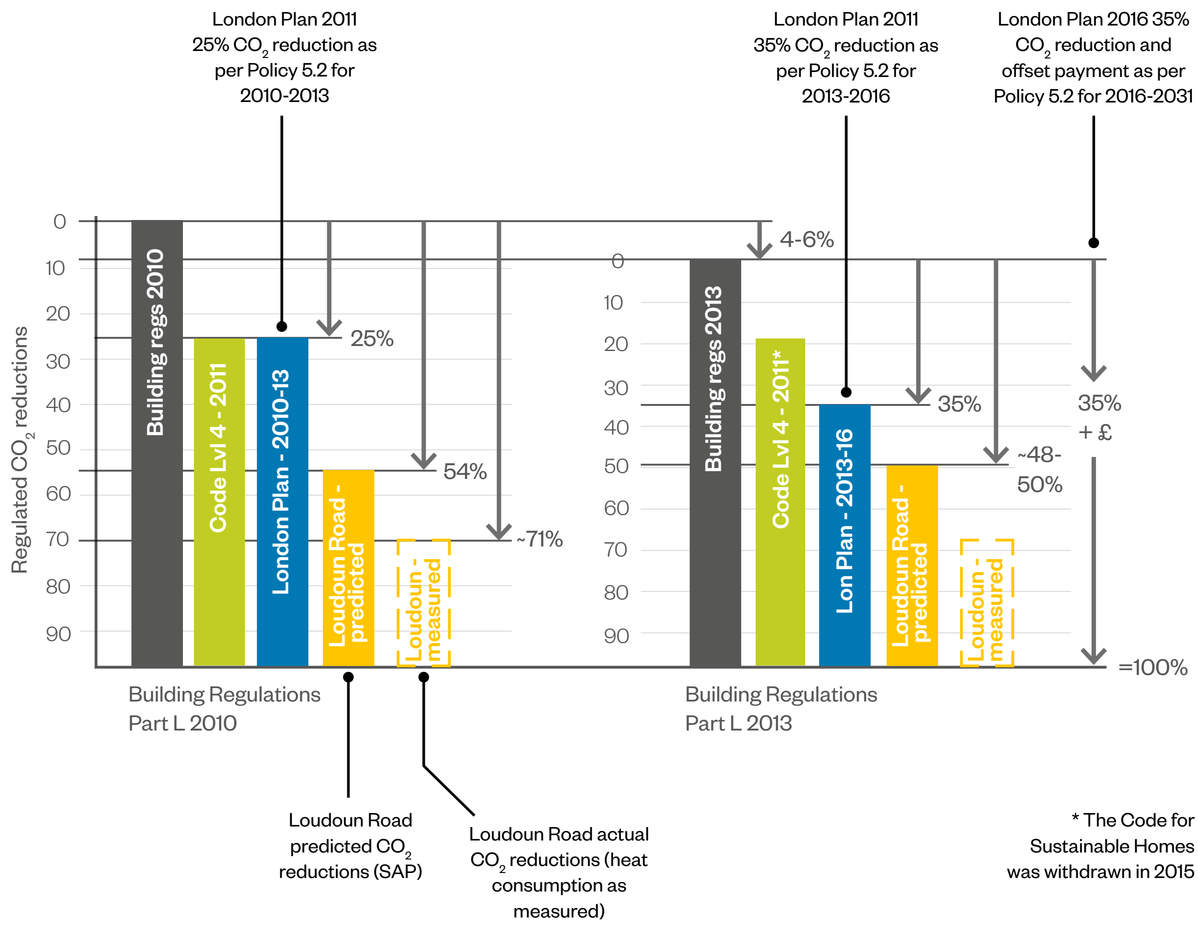
- The potential cost difference in offset payments between the predicted calculations and the actual performance
- That homes can perform better than the prediction
- The scale of increase in payments between a standard development achieving 35% reduction and Loudoun Road as predicted and as-built
- The increase in payment required if the new proposed carbon offset comes in, under the draft London Plan 2019.

While there is a potential saving of up to £72K in offset costs for a development like Loudoun Road in the future, this is dependent on changes to SAP so that it better reflects the true performance of a home and updates to the London Plan. Alternatively, if the carbon savings could be demonstrated post-completion, as part of the draft proposals in the London Plan 2019 for POE, this might provide a more balanced 'carrot' and 'stick' approach to meeting carbon reductions.

It is unknown whether the additional cost in building to a high level of thermal performance would have outweighed the potential offset payment savings.

Carbon factors
There has been an ongoing consultation regarding updates to the carbon emission factors used in SAP. This effect of changing carbon factors has not been explored in this report, although it would make an interesting future study.

2010 versus 2013 Building Regulations Part L



Offset payments

	Loudoun Road Predicted CO_2 emissions (SAP)	Loudoun Road CO_2 emissions based on meter readings	A standard 35% reduction development of the same size
CO_2 reduction Part L 2010	54%	~71%	40%
Estimated CO_2 reduction Part L 2013	~48-50%	~65-67%	35%
Tonnes of carbon/yr	~32.6	~21.8	~47.2
Carbon offset at £60/tonne of carbon (London Plan 2016)	~£59k	~£39K	~£85K
Carbon offset at £95/tonne of carbon (draft London Plan 2019)	~£93K	~£62K	~£134K

Potential £72K saving in offset payments in the future

Conclusion

Conclusion

This report has reviewed the outcomes of a post-occupancy evaluation of Loudoun Road from several perspectives:

- The overall sustainability and energy strategy as designed
- Residents' feedback on entering the homes
- The temperature and humidity of the homes in-use
- The associated consumption and cost of heat for the homes
- The difference between predicted and measured performance
- A comparison with carbon reduction targets for planning.

Overall, the design was successful in achieving the project goal of delivering low energy homes. By following the principles of Passivhaus, there have been some notable benefits to the energy efficiency of the building.

Residents' feedback
The results of the questionnaires generally showed that the respondents like the appearance of their homes. The spaces were noted to be of a good size and daylight levels adequate. The residents felt secure but some were bothered by external noise levels. A theme emerged from the questionnaire results regarding the warmth of the homes, with some reporting that they were warm enough without the heating. The results of the survey assisted in informing the monitoring during summer and winter.

Winter monitoring
The winter temperature monitoring of the two homes highlighted the benefits of high levels of insulation and the installation of mechanical ventilation with heat recovery (MVHR). These features are thought to have significantly contributed to the stability and warmth of internal temperatures, with 20-23°C measured despite external temperatures of as low as 5°C. The results of the humidity monitoring is thought to support this by indicating that the MVHR is assisting homes to retain warmth whist providing good levels of ventilation.

Summer monitoring
As was found in winter, the internal temperatures of all three homes monitored in summer were unaffected by external fluctuations in temperature. The most significant finding was that despite the external temperature peaking at 32°C, all three monitored homes remained below 27°C internally. This highlights the ability of the insulated fabric to keep out the heat in summer as much as it keeps in the heat in winter.

It is noted that where external temperatures drop of an evening the internal temperatures still remain reasonably high. It is unknown whether the residents have chosen not to open their windows to ventilate or whether the ventilation from windows is not effective at cooling internal temperatures.

The results of the humidity monitoring during summer show that the homes have relatively low humidity levels. This is again thought to be a benefit of having MVHR.

Energy consumption and cost
Analysis of the residents' energy consumption for space heating has revealed that during January-December 2014, 27 out of the 39 units with sufficient data met the Passivhaus criteria for heating demand (less than 15 kWh/m^2.yr). This is a significant achievement and demonstrates there is a low heating demand in the homes.

Due to the installation of a communal heating system at Loudoun Road, the cost of heat per kWh together with the service charges associated with the maintenance and management is higher than the national average pricing for gas. However, due to the reduction in heat consumption, the residents' energy bills are still below the national average overall.

Predicted and measured energy and carbon
The comparison of predicted and measured heat data and the resultant carbon emissions demonstrated that there was a gap between the predicted and actual performance. Unlike as is typically seen in the industry, the performance gap

in this case relates to the building performing better than predicted. This highlights that a fabric first approach demonstrates proven energy and carbon savings in reality - not only meeting but exceeding predictions.

The downside to this is that the predicted carbon emission reduction (54%) is not as high as the building in-use (71%). In the future, this has the potential to lead to higher carbon offset payments than necessary. This is mostly down to the disparity in predicted versus measured domestic hot water consumption.

Overall

The results of the study have demonstrated the benefits of using Passivhaus principles when designing homes. Despite this building not being certified by Passivhaus, the use of these principles has furthered the sustainability and comfort levels.

It is through careful orientation, high levels of insulation, appropriate shading, air tightness levels, system design and good build quality that the energy consumption of the homes has been reduced. The most striking discovery is the validation that the building fabric and MVHR systems have the ability to stabilise internal temperatures and humidity levels despite external temperature fluctuations.

The passive design measures are a credit to the ambitions of the client and ability of the design team and contractor in making a sustainable building - demonstrating it is possible to reverse the performance gap.

levittbernstein.co.uk

London
Thane Studios
2-4 Thane Villas
London N7 7PA

+44 (0)20 7275 7676

Manchester
Bonded Warehouse
18 Lower Byrom Street
Manchester M3 4AP

+44 (0)161 669 8740