TSB Design for Future Climate
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Good Homes Alliance
One Brighton

Good Homes Alliance

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Executive Summary

Building Profile

One Brighton is a high-density mixed-use development with 172 residential units - mostly single-sided one or two-bedroom apartments - above 2000 m^2 of community and commercial office space. The scheme is part of a highly sustainable Masterplan for the regeneration of the New England Quarter adjacent to Brighton Rail Station. Completed in 2009 to BREEAM Excellent standard, One Brighton is an outstanding example of a contemporary urban, green apartment building. Sustainability was integrated throughout the design by following the 'One Planet Living®' model developed by BioRegional, together with WWF-International.

This project is unique in the TSB Design for Future Climate Portfolio in that it considers a retrofit adaptation strategy for a modern building which is already built and completed. Furthermore, detailed Post Occupancy Evaluation of the Building has already been funded by the Technology Strategy Board Building Performance Evaluation Programme. Real performance data was gathered during 2011-2013 for five different apartments in the development. Residents were also surveyed using the Building Use Survey methodology. Although many sustainability principles, such as water stress and flooding, are well addressed in the design, results from the BPE programme indicate that overheating is a serious concern within the development.

The results of the project have been used to inform a future management and maintenance plan for One Brighton, which is responsive to climate change and can be funded by means of the service charge and accrued sinking fund.

Climate Change and Other Risks

Brighton benefits from its coastal location. The climate is therefore relatively mild compared to other cities within the South-East of England.

A risk assessment of projected changes in climate was carried out. Water availability and flooding risks were already addressed within the original design and further adaptation is not necessary. The building was specified for the marine environment, therefore the material structures are expected to be reasonably robust. Winter performance of the building is not a concern; indeed heating requirements are expected to decrease in future. However, temperatures are also projected to rise in summer. The current baseline summer mean daily maximum temperature for Brighton is just below 20 °C, but it could be 24 °C by the 2050s (central estimate) and as high as 31 °C by the end of the 21st century (under the most extreme scenario, 2080s high emissions, 90%ile). As overheating within the development is already a concern, summer thermal comfort could be seriously compromised unless adaptation measures are undertaken.

Adaptation Strategy

This project used dynamic thermal simulation to investigate overheating risk at One Brighton and its sensitivity to different factors, such orientation, solar gain and ventilation. Several adaptation options were designed, modelled and costed and a cost-benefit analysis carried out in order to develop a retrofit adaptation strategy to ensure the thermal comfort of occupants well into the future.

A key finding of the project is that the current overheating is actually due to inadequacies in the installation, commissioning and control of the MVHR system within the apartments, rather than flaws in the design. Due to inadequate ventilation, heat is building up in the thermal mass of the building. Once these defects have been rectified, opening the windows wide for natural ventilation is sufficient to keep the building cool for the early part of this century. The MVHR system is essential to this strategy as it pulls fresh air deep into the single-sided apartments. However, occupants are also concerned about security, safety and noise when opening windows. We recommend that, when the windows are due for replacement in around 2040, the management company consider a range of possible measures to make it possible for windows to be opened more securely. We also recommend that ceiling fans are installed at the same time to provide additional air movement and cooling effect.

In the latter part of the 21st century, shading will also be required to reduce the overheating risk to acceptable levels. An innovative solution, electrochromic glass, is proposed, which is simple to retrofit when the glazing units have reached the end of their service life. Window replacement is anticipated around 2070.

Adaptation Strategy
Strategy A - Up to 2040
Educate residents about opening their windows to provide optimal natural ventilation.
Educate residents to close internal blinds or curtains during hot, sunny weather.
Provide daily weather forecast information, together with recommended action, via the green caretaker. This information could be displayed in the foyer or even disseminated via a smartphone app.
Strategy B - 2040 **Planned Window Replacement**
Implement measures to allow more secure window opening for natural ventilation.
Install ceiling fans to provide perceived cooling benefit.
Strategy C - 2070 **Planned Window Replacement**
Install ElectroChromic glass to provide shading from solar gain (except in lower pane of bedroom window).
Install opaque panel in lower pane of bedroom window to provide shading from solar gain.

Other options such as centralized active cooling were also examined. They are not recommended as part of the adaptation strategy as they are more complex and expensive than the proposed solutions. However, they may become necessary further into the future or for other sites.

Lessons Learnt

The monitored data from the BPE programme provided valuable information, both qualitative and quantitative, about the performance of the occupied One Brighton development and the occurrence of overheating. Unfortunately the monitored BPE data was not suitable for use in the TAS dynamic thermal simulation model, even though this was part of the original project concept. However, it did lead to the identification of a major performance gap issue, namely that the MVHR system within the apartments is currently functioning inadequately.

A further key lesson is that architects, building physicists and cost consultants need to collaborate closely throughout the building modelling and design process. Otherwise, unnecessary time can be spent pursuing and developing adaptation options, which turn out to be impractical to implement.

Extending Adaptation

A project conference held on 25 June 2013 targeted supply chain providers in order to stimulate interest, investment and innovation in the development of adaptation solutions.

A large number of apartment blocks have recently been or are being constructed in urban areas within the UK. The Good Homes Alliance has published a guidance document, aimed at key industry sectors, which highlights the risk of overheating and applies the lessons learnt from this project to their design and adaptation. One of the key recommendations is that such developments should benefit from the same specialized input to the design team - from services engineers and building physicists – as any large commercial building.

1 One Brighton

1.1 Introduction

This report considers a retrofit adaptation strategy to reduce the risk of overheating in a contemporary apartment block, One Brighton. The project is unique in the TSB Design for Future Climate Portfolio in two respects. Firstly, it is the only study, which is considering pure retrofit as opposed to new-build or more large-scale refurbishment of a building. Secondly, it builds upon the work of the TSB Building Performance Evaluation (BPE) Programme already undertaken for the development.

This project was proposed by Pete Halsall, Chief Executive of the Good Homes Alliance, former Managing Director of BioRegional Quintain, (the scheme developer), and a current director of the One Brighton Management Company. Initial results from the TSB BPE programme showed that some of the apartments in the development are already overheating. The key motivation for this project was the desire to derive optimum learning from the BPE monitoring undertaken and to future-proof the development by incorporating the recommended adaptation strategy in the future maintenance plan, as well as disseminating the lessons learnt more widely within the industry.

1.2 The Development

One Brighton is an excellent example of a recently constructed contemporary urban, green apartment building. It is a high-density mixed-use development with 172 residential units above 2000 m^2 of community and commercial office space. The scheme comprises two blocks located on two sites adjacent to Brighton Rail Station, which are part of a highly sustainable Masterplan for the regeneration of the New England Quarter. The development was commissioned in August 2003. Construction commenced on site in Autumn 2007. The first resident moved in during September 2009.

The development comprises 2% 3-bed, 47% 2-bed, 40% 1-bed and 11% studios, with unit sizes ranging from 30 m2 to 70 m2. The 19 low-cost “eco-studios” address the needs of the intermediate housing market in Brighton, particularly first time buyers. Affordable housing also forms a considerable proportion of the development, (30% with 54 units) and is concentrated in the northern block, Pullman Haul. Figure 7 show a typical level floor plan. Figure 8 shows a typical layout of a one-bedroom apartment.

The intended life-span of the building is at least 60 years, but could be 100 years or longer, assuming it is well maintained.

1.2.1 Site and Orientation

Figure 3 shows the location of One Brighton relative to both the mainline railway station and the sea. The site slopes downhill away from the station, i.e. from west to east. The two blocks are situated along the east side of the site (Figure 4), with single sided apartments double-backed along a central communal corridor, which runs along the north-south axis. Hence the majority of the apartments face either east or west, with the exception of those in the tower at the southern, seaward end of the development.

A busy main road runs along the east of the site. At the southern end of the site another road branches off the main road and provides vehicular access to Brighton railway station and its car park.

1.2.2 New England Quarter Masterplan

The New England Quarter occupies an 8 ha site in Brighton City Centre, to the east of the Station. The Masterplan for regeneration of this area was approved by Brighton & Hove City Council in September 2003 and gave consent for a mixed-use scheme including:

- 355 residential units in 6 blocks
- Station car park

- Sainsbury's food store
- Community facilities
- Training centre
- Offices and workspace
- A new language school
- Two hotels
- Site of Nature Conservation Interest (Greenway)

Work commenced on the regeneration site in June 2004. The station car park was completed in 2005, Sainsbury's and Bellerby's Language College in 2007 and the Jury's Inn Hotel in April 2008.

As part of the planning permission a S106 Legal Obligation was signed with the developer. Schedule 4 of the S106 dealt specifically with the issue of sustainability and laid out a detailed series of criteria committing the developer to a methodological approach to achieving energy efficiency in the development. These included:

- 40% savings in Carbon (CO2) emissions be achieved for each Block
- a Framework Sustainability Document be submitted laying out how these savings will be achieved
- all residential development to achieve BRE Ecohomes 'Very Good Standard'
- all other development to achieve Bespoke BREEAM 'Very Good Standard'
- Green Procurement Procedure should be submitted and adopted for each Block.

Achieving this level of carbon savings required sustainable design and construction of highly energy efficient buildings with reduced demand for mains gas and electricity, as well as the use of on site renewables. (Initially, a Combined Heat and Power Plant (CHP plant) was planned to serve the entire development, which would have reduced demand for mains gas and electricity. However, this did not go ahead).

The masterplan also addressed urban biodiversity by requiring the creation of a 'greenway' through the centre of the site.

Additional references to the masterplan can be found in Appendix 1.

1.3 One Planet Living

One Brighton was designed according to the 'One Planet Living®' model developed by BioRegional, together with WWF-International, http://www.oneplanetliving.net/, following ten guiding principles of sustainability, which are outlined in Figure 1, right. It was also constructed to achieve an 'Excellent' rating for both EcoHomes and BREEAM standards. These aspirations are particularly reflected in the following aspects of the original design strategy.

1	Zero carbon
2	Zero waste
3	Sustainable transport
4	Sustainable materials
5	Local and sustainable food
6	Sustainable water
7	Land use and wildlife
8	Culture and community
9	Equity and local economy
10	Health and happiness

Figure 1 One Planet Living® Principles

1.3.1 Zero Carbon - Building thermal design, materials and structure

The building fabric is designed to achieve high levels of thermal efficiency.

The design is based upon a lean concrete frame using post-tensioned slabs. This technique reduces the thickness of the slab by up to 15%.

An innovative external wall construction incorporates NBT Thermoplan fired clay blocks and wood fibre insulation to achieve un-bridged U-values of 0.21 W/ m^2K and bridged U-values of 0.25 W/ m^2K. A 12mm layer of mineral plaster was applied to the internal face. The external façade was finished in lime render or rain screen timber and glazed tile cladding (Figure 10).

The internal parging coat of mineral plaster provides the primary air-tightness barrier. A high standard of air-tightness was achieved. On-site pressure test results gave a value of ca. 2/85$m^3/h/m^2$ at 50 Pa, which is better than the target of 5$m^3/h/m^2$ at 50 Pa.

Windows are triple glazed and low-E coated, with a g-value of 0.46 and a U-value of 0.80 W/m^2K.

The brown roof system is laid on rigid insulation, on a hot melt rubberised monolithic membrane, over the in-situ reinforced and post-tensioned concrete slab. It has a U-value of 0.19 W/m^2K.

Internal separating stud walls have a double layer of 15mm plasterboard on each face and 100mm of Isover acoustic insulation.

As well as the thermal mass in the external wall, the ceiling concrete soffit is exposed within the main living areas of the apartment. Thus there is substantial exposed thermal mass in the interior of each apartment.

A Mechanical Ventilation and Heat Recovery (MVHR) system is installed in each apartment, to provide ventilation, space heating and hot water. Heat is supplied to the apartments via a network of heat distribution pipe work in the buildings and a heat exchanger in each flat.

The communal circulation spaces are naturally ventilated by means of architectural slots in the façade with opening windows (Figure 9).

Unusually for developer housing, some thermal modelling was carried out at the design stage to evaluate the risk of overheating. This focussed on the corridors through which the main communal heating pipes run. Following this work, changes were made to the design to allow cross-ventilation of the corridors. However, when built, the planned safety railings were omitted from the opening doors at the end of some corridors (Figure 11). Hence, cross-ventilation of the corridors is not possible on these levels.

1.3.2 Zero Carbon – On Site Renewables and Energy Efficiency in Use

A site ESCo (Energy Services Company) manages the sustainable energy supply for the building. The wood fired biomass boiler system is designed to provide 100% of the hot water and space heating requirements though the MVHR system located in each apartment. There is also a central back up gas boiler.

Roof mounted Photo Voltaic panels power the communal power circuits and communal lighting. Energy demands of the building are further reduced through the use of low energy light fittings the specification of low energy triple ‘A’ rated appliances throughout the building, lobbying of main entrances and excellent standards of air tightness.

1.3.3 Local & Sustainable Materials

The main structural concrete frame used 100% recycled or secondary aggregate (an industrial by-product from Cornwall), 100% recycled reinforcement and 50% ground granulated blast furnace slag (GGBS) cement replacement. The contractual requirement for 25% recycled materials across the whole scheme was exceeded.

All timber products were FSC certified and UK sourced. Most materials were subject to environmental review for low toxicity and low embodied energy. Examples include ultra low VOC paints and crushed recycled glass as paver bedding.

1.3.4 Other One-Planet Living Sustainability Initiatives

In line with the One-Planet Living principles, the scheme has implemented a wide range of other initiatives to reduce its eco-footprint and support sustainable community living, including recycling and composting, rainwater harvesting, green walls, brown roofs, bicycle parking facilities and a car club. There is access to outdoor space at all levels of the building and residents are able to grow their own food on the rooftop mini-allotments.

1.4 Original Design Team

The One Brighton development was commissioned in August 2003 and completed in 2009. The original design team responsible for the development comprised:

Client - Crest Nicholson BioRegional Quintain LLP

Main Contractor - Denne Construction

Architect - Feilden Clegg Bradley Studios

Structural Engineer - Cameron Taylor

M&E Engineer - Fulcrum / MLM

Landscape Architect – Nicholas Pearson Associates

Cost Consultant - Jones Lang LaSalle

Planning Consultant - Planning Perspectives

1.5 Design for Future Climate Adaptation Strategy

1.5.1 TSB Building Performance Evaluation

Detailed post occupancy evaluation has been carried out at One Brighton under the Technology Strategy Board Building Performance Evaluation Programme. Residents were surveyed using the Building Use Survey (BUS) methodology (Bainbridge 2011). 82% of residents indicate that the building meets their needs. However, comfort conditions in winter are better than in summer. In summer the main issue appears to be overheating; 75% of occupants responding to the BUS survey reported that it is hot or too hot.

Also as part of the BPE programme, real performance data - external weather conditions, internal environmental conditions, energy consumption, appliance and consumer goods and occupant perceptions and habits - has been gathered for 5 different one-bedroom apartments in the development. Despite its green credentials, the monitored data indicates that the building is already subject to overheating in the current climate.

1.5.2 Adaptation Strategy

The concerns around current summer overheating in One Brighton, demonstrate the need for a robust adaptation strategy to ensure the comfort of building throughout the rest of the 21st century. This project is unique in the TSB Design for Future Climate Portfolio in two respects. Firstly, it is the only study, which is considering pure retrofit as opposed to new-build or more large-scale refurbishment of a building. Secondly, it builds upon the work of the TSB Building Performance Evaluation Programme already undertaken for the development.

Figure 2: One Brighton development east-facing façade (left) and west-facing façade (right). Brighton Railway Station is just visible in the bottom left hand corner of the photograph on the left.

Figure 3: Aerial view of Brighton showing location of One Brighton development, with site outlined in right hand view.

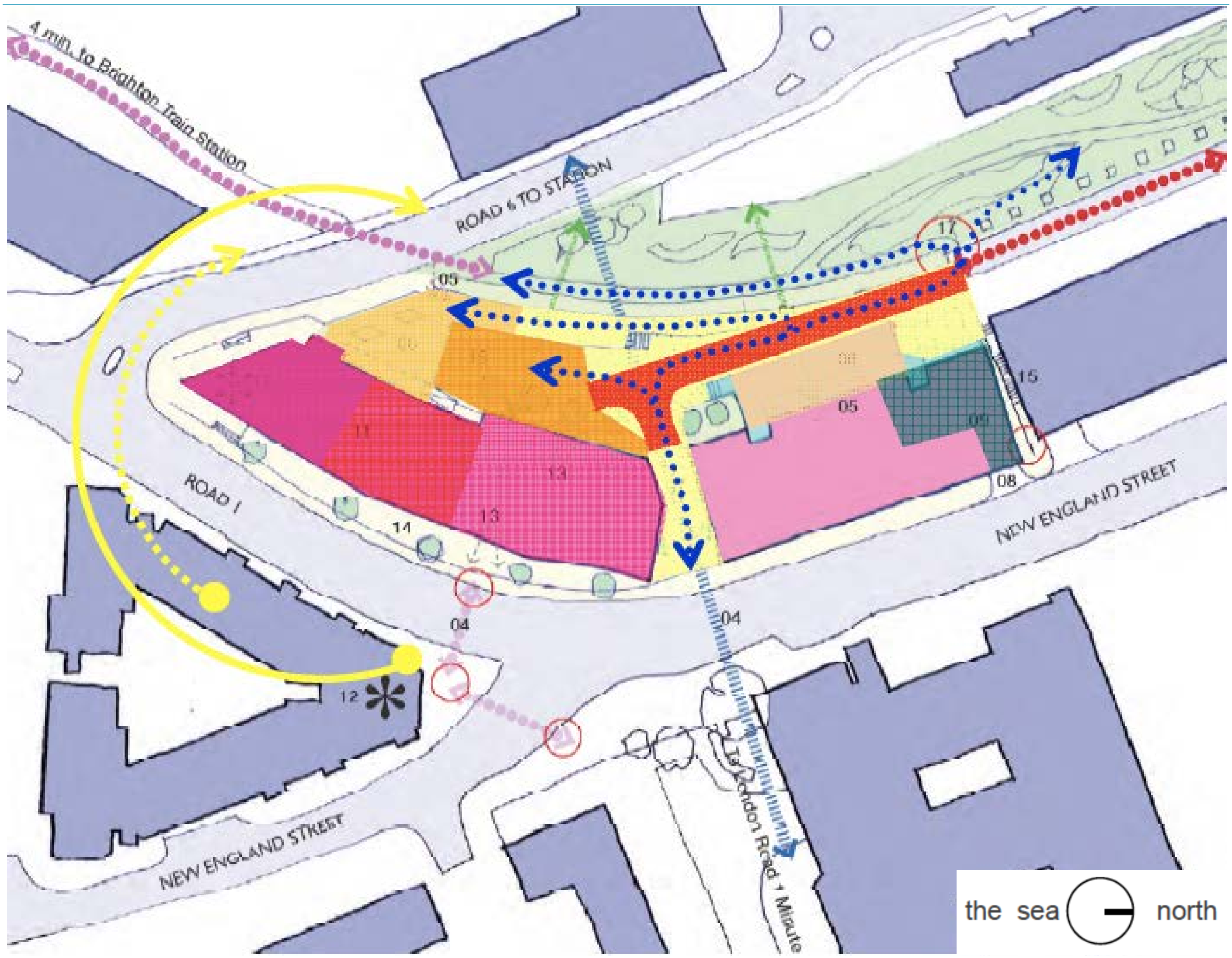


Figure 4 One Brighton site plan and orientation (FCB Studios).

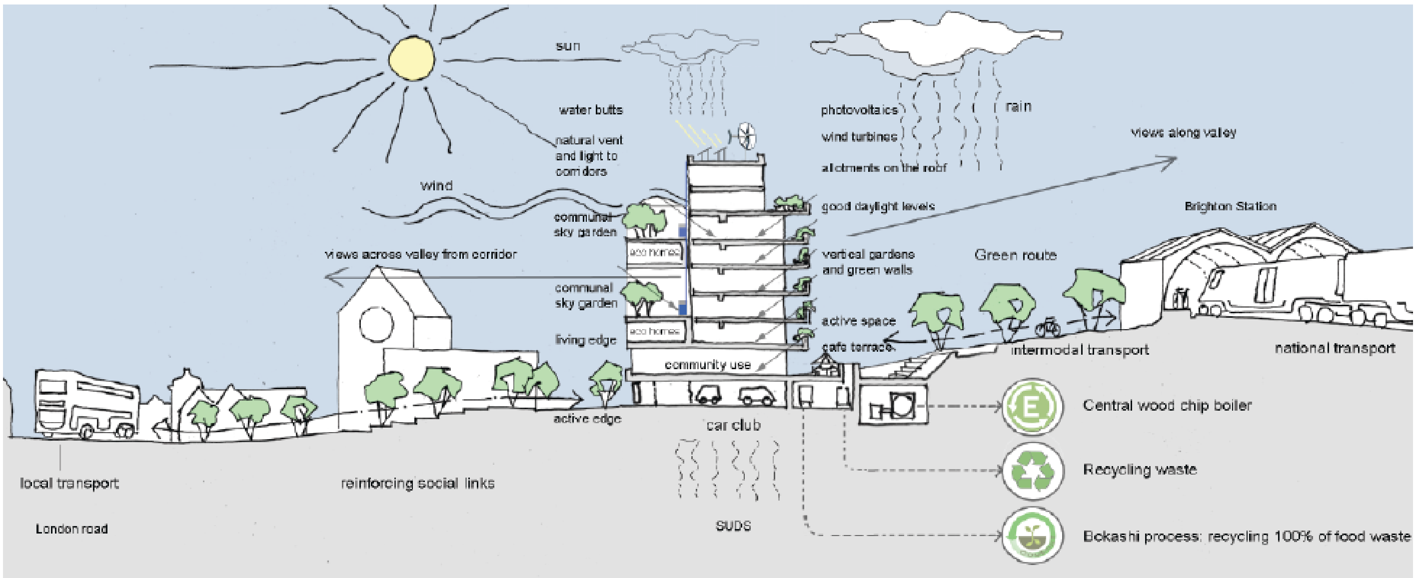


Figure 5: Section of One Brighton Development facing south towards the sea (FCB Studios).

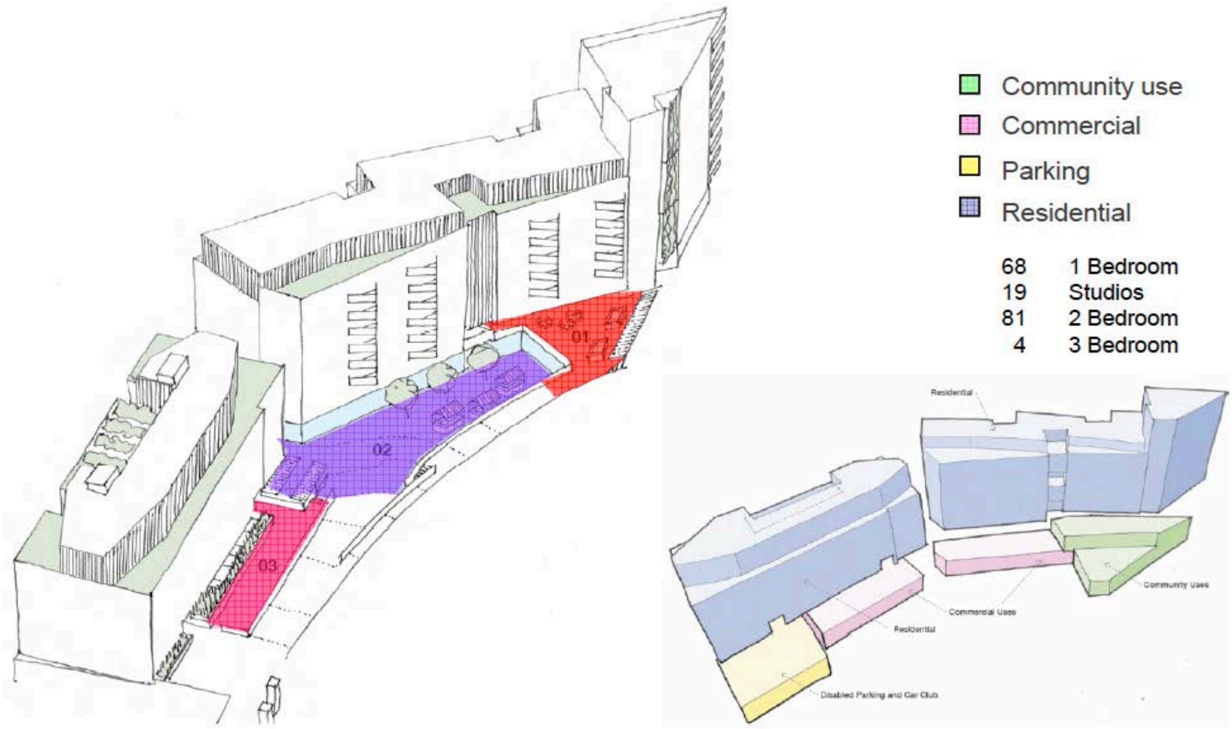


Figure 6: One Brighton, showing Blocks and Usage (FCB Studios).

Figure 7 One Brighton Floor Plan – Level 3. Most of the social housing units are contained within the rectangular shaped block to the north of the site, Pullman Haul. The block to the south of the site, Brighton Belle, consists predominantly of privately owned units. A larger version of this plan is available in Appendix 1.

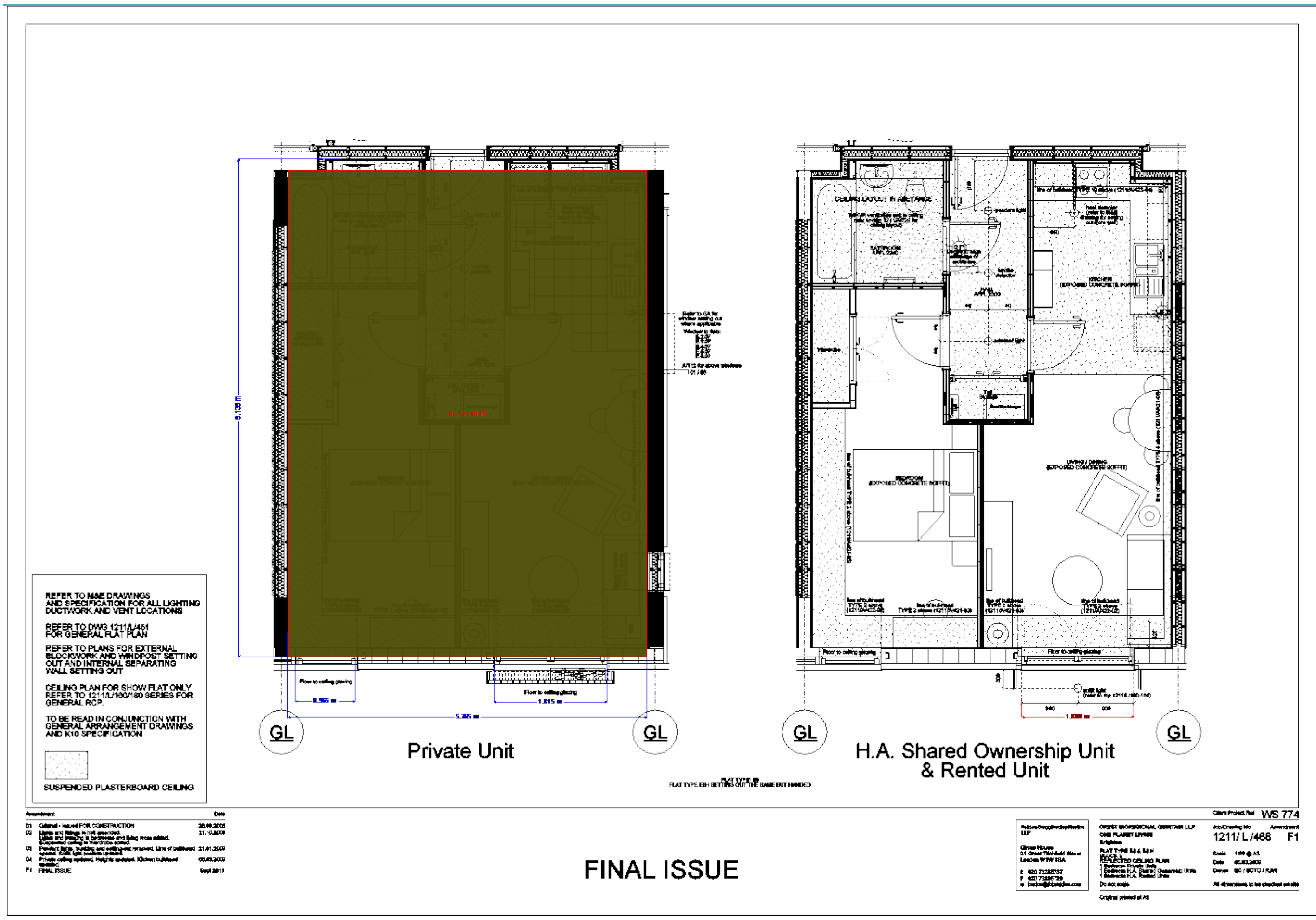


Figure 8 Typical layout of one-bedroom apartments in One Brighton.

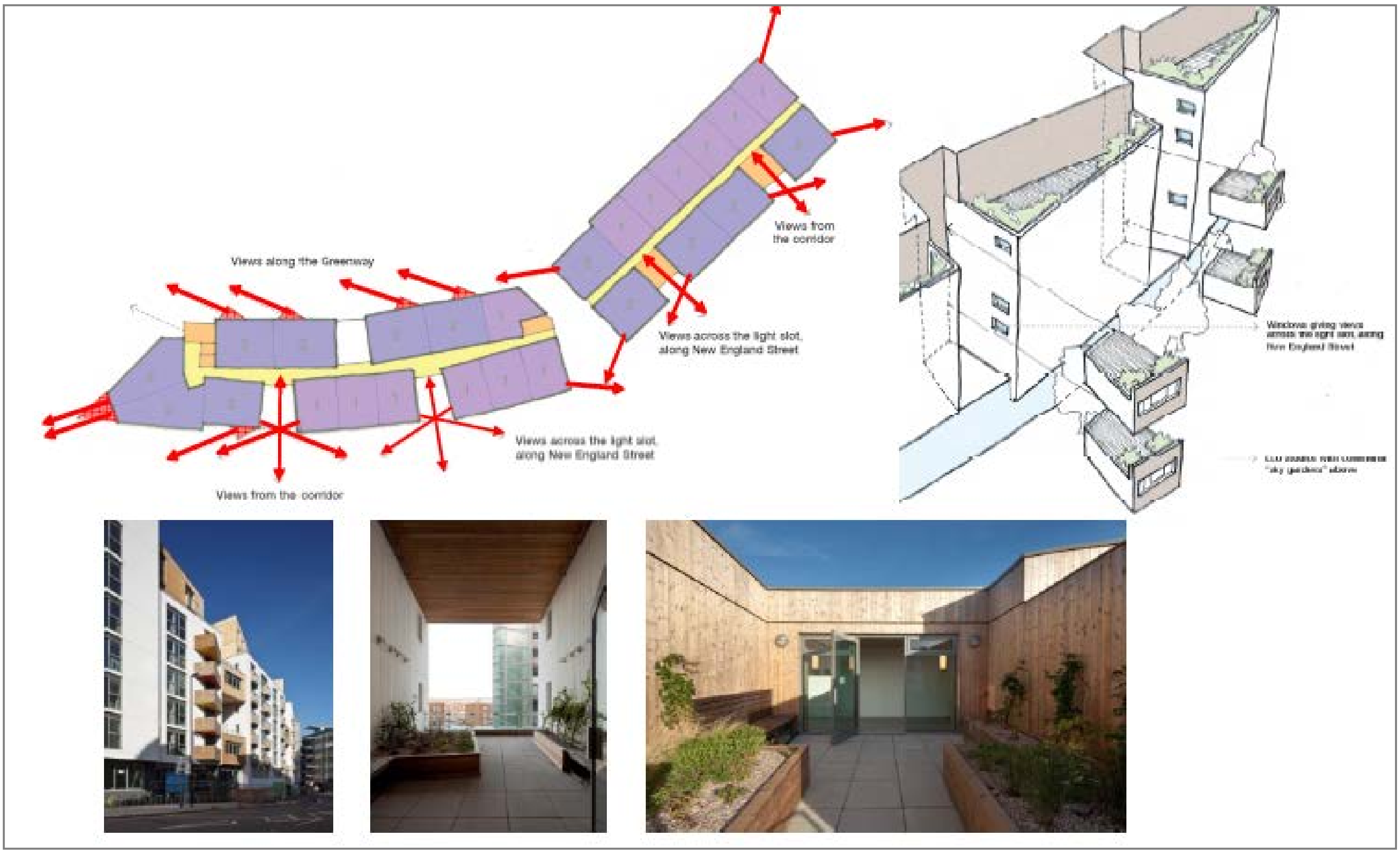


Figure 9: One Brighton – Slots, sky gardens, oblique views and daylight (FCB Studios)

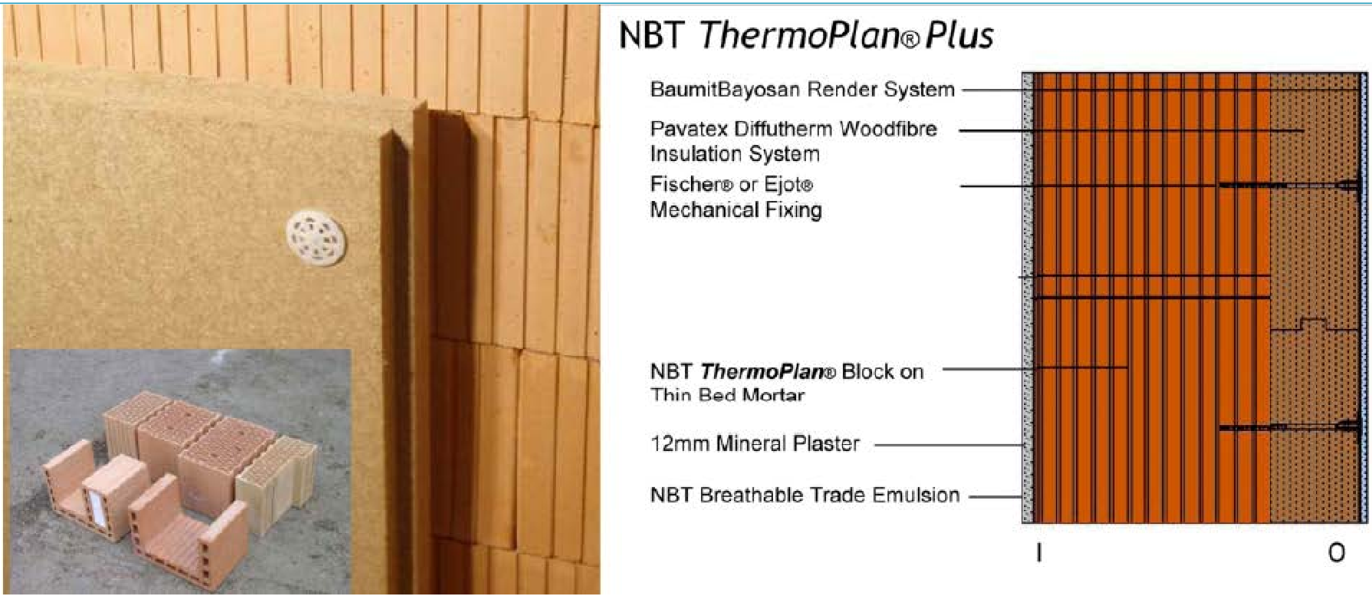


Figure 10 Detail of façade build-up.

Figure 11 Full-height opening window at south end of Floor 5 in Brighton Belle: the waist-height safety railing included in the original design was value-engineered out, prohibiting use of the window for cross-ventilation of the corridors.

2 Climate Change Risks

2.1 Future Climate Risk Exposure Assessment

Probabilistic Climate Profile for Brighton

The probabilistic climate profiles (ProCliP) graphs, developed by CIBSE/UKCIP, provide a graphical presentation of the probabilistic UKCP09 climate projections for a given location (CIBSE 2014). The distribution of each climate variable is plotted, showing its likely and very likely range, against the baseline climate, for three timeslices, (2020s, 2050s and 2080s) and for each of the three UKCP09 emissions scenarios. The original ProCLIPs were produced for the 14 CIBSE weather file locations; the nearest to Brighton are London and Southampton. As part of the current project, a ProCLIP was produced for key climate variables for Brighton. UKCP09 projections for Brighton were extracted from the UKCP09 User Interface and compared to the Met Office gridded baseline data.

Temperature

Keeping Cool in Summer

The indoor conditions in five apartments within the One Brighton development have been monitored as part of the Good Homes Alliance TSB BPE programme. Most of the apartments are very warm. Temperatures in the living room exceed the CIBSE comfort threshold of 25 °C for 23% of the time. The overheating threshold of 28 °C is exceeded for 1% of the year. The bedrooms are even more severely affected. On average, the CIBSE comfort temperature of 25 °C is exceeded for 63% of the time and the overheating threshold, 26 °C, for 14% of the time.

In CIBSE Guide A, overheating is calculated as a percentage of occupied hours, whereas the figures above are based upon the 24-hour day for which the monitored data is collected. In practice, the spaces in the apartment are likely to be occupied for shorter periods. For example, if an occupant is at home during the day, it is likely that they will be in the living room and kitchen during the hottest hours of the day, but not during the night. Therefore the above figures probably underestimate the extent of overheating within the living area.

Due to its coastal location, summers in Brighton are not as hot as in other cities, such as London. The sea breeze provides a valuable cooling resource on hot – and elsewhere still - summer days. Nonetheless, summer thermal comfort is already a key concern. In future, hotter summers are expected to exacerbate this problem.

Projected changes in the mean daily maximum temperature in summer are shown in Figure 12. The baseline (1961-1990) summer mean daily maximum temperature for Brighton is just below 20 °C. By the 2020s (a timeslice which includes the present day), it has already risen to 22 °C (central estimate). By the end of the 21st century, i.e. for the 2080s timeslice, the mean daily maximum temperature in summer is projected to have risen to 25 °C (central estimate) under the medium emissions scenario. In the most extreme scenario, (2080s high emissions, 90%ile), it could be as high as 31 °C by the 2080s.

Keeping Warm in Winter

A ProCLIP graph has been produced for winter mean daily minimum temperature for Brighton (Figure 13). This shows that minimum temperatures are very likely to rise over the course of the century, although not to the same extent as summer maxima. The One Brighton development was designed to and achieved high standards of thermal efficiency. The BUS survey, which was undertaken as part of the BPE programme, showed high levels of satisfaction with the apartments in

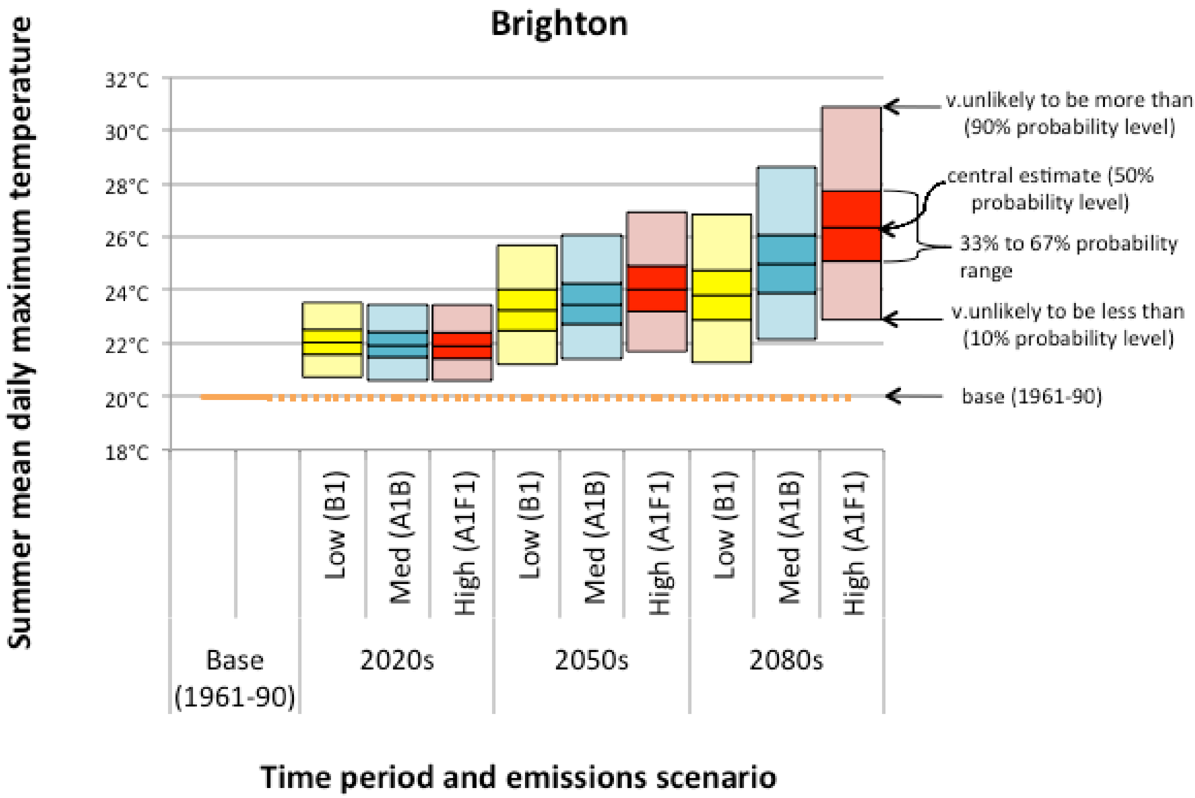


Figure 12 ProCLIP showing UKCP09 projections of Summer mean daily maximum temperature in Brighton.

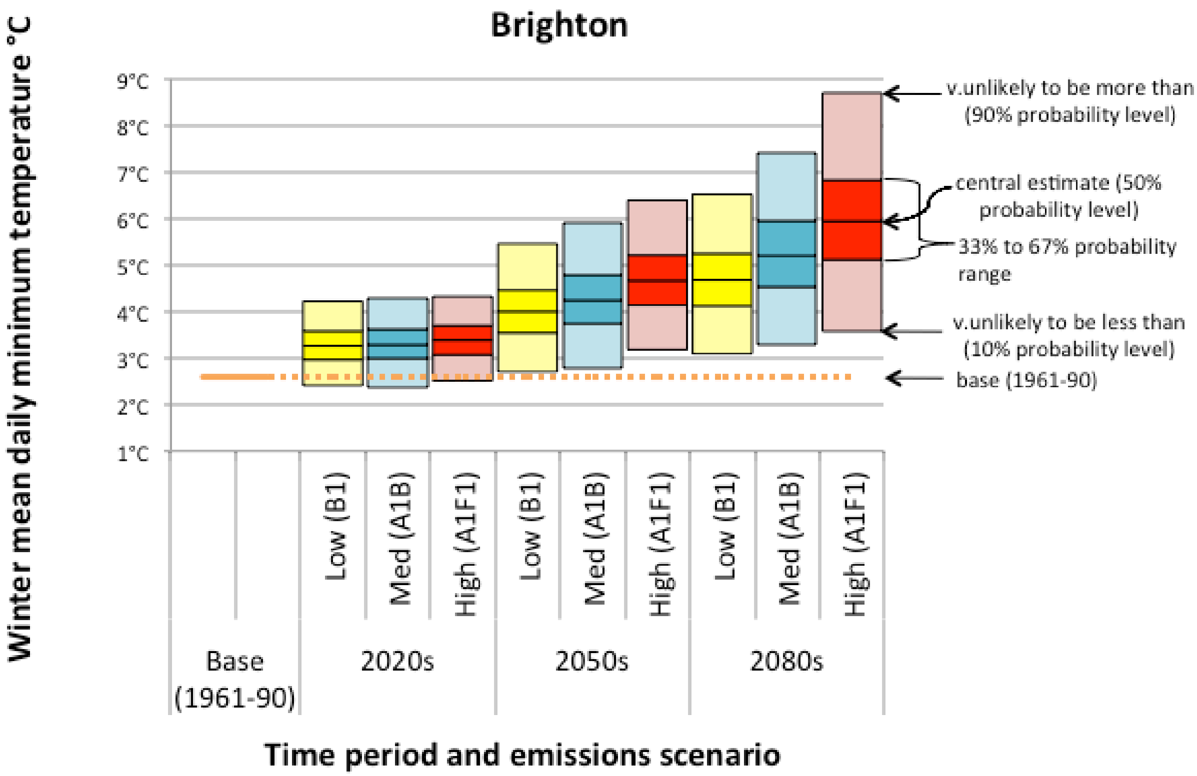


Figure 13 ProCLIP showing UKCP09 projections of Winter mean daily minimum temperature in Brighton.

winter. As winter temperatures increase, there is no reason to expect this to change. Indeed there could be positive benefits, as the heating requirement will be reduced.

Precipitation

Large change in the annual mean precipitation in Brighton is unlikely. The UKCP09 central estimate is close to 0% for all timeslices and emissions scenarios. On the other hand, considerable change is projected in seasonal patterns of precipitation. Winters are expected to be wetter, but summers drier. In particular, an increase of up to 25% is projected in precipitation falling on the wettest day in winter.

These changing precipitation patterns will have implications for both water availability and flood risk.

Water Availability

Mean daily precipitation is projected to reduce in Brighton in future summers (Figure 14). This may increase pressure on water resources, unless more supply and demand measures are taken to close the supply-demand balance.

Several measures to promote sustainable water use were exploited in the One Brighton design. This is one of the One Planet Living principles. Water consumption is reduced through the specification of efficient fittings and appliances, including dual flush toilets and low water use taps/showers throughout the building. Rainwater is also harvested from the roofs and stored in water butts where it can be used for irrigation of the mini-allotments. Consequently, this risk of water stress is not considered further in this report.

Flooding

Winter mean daily precipitation is projected to increase in Brighton (Figure 15). Precipitation falling on the wettest day in winter is projected to increase by 20% (medium emissions, central estimate) to 25% (high emissions, central estimate) by the 2080s.

However, the One Brighton site is on a hill sloping down from station, 30 m above sea level. The subsoil is permeable chalk. Therefore it is not considered to be in a flood risk area (Brighton and Hove Strategic Flood Risk Assessment 2008).

Furthermore, the apartments are located on higher floors, although the plant room and commercial and community lets are located on lower floors.

Flood risk is further reduced by the SUDs (sustainable urban drainage) approach incorporated into the original scheme. The paving in the hard landscaped areas is permeable, minimizing water run off and using soakaways.

Construction

Structural stability

The underlying soils are chalk, therefore the risk of subsidence and heave is low, despite the change in rainfall patterns.

Coastal Location

The coastal location of the development brings with it specific advantages and disadvantages.

On hot summer days, a sea breeze will develop. The city will be cooler and windier compared to inland areas. This sea breeze can be harnessed for additional ventilation and will also prevent or reduce build up of the Urban Heat Island effect experienced in other cities, e.g. London.

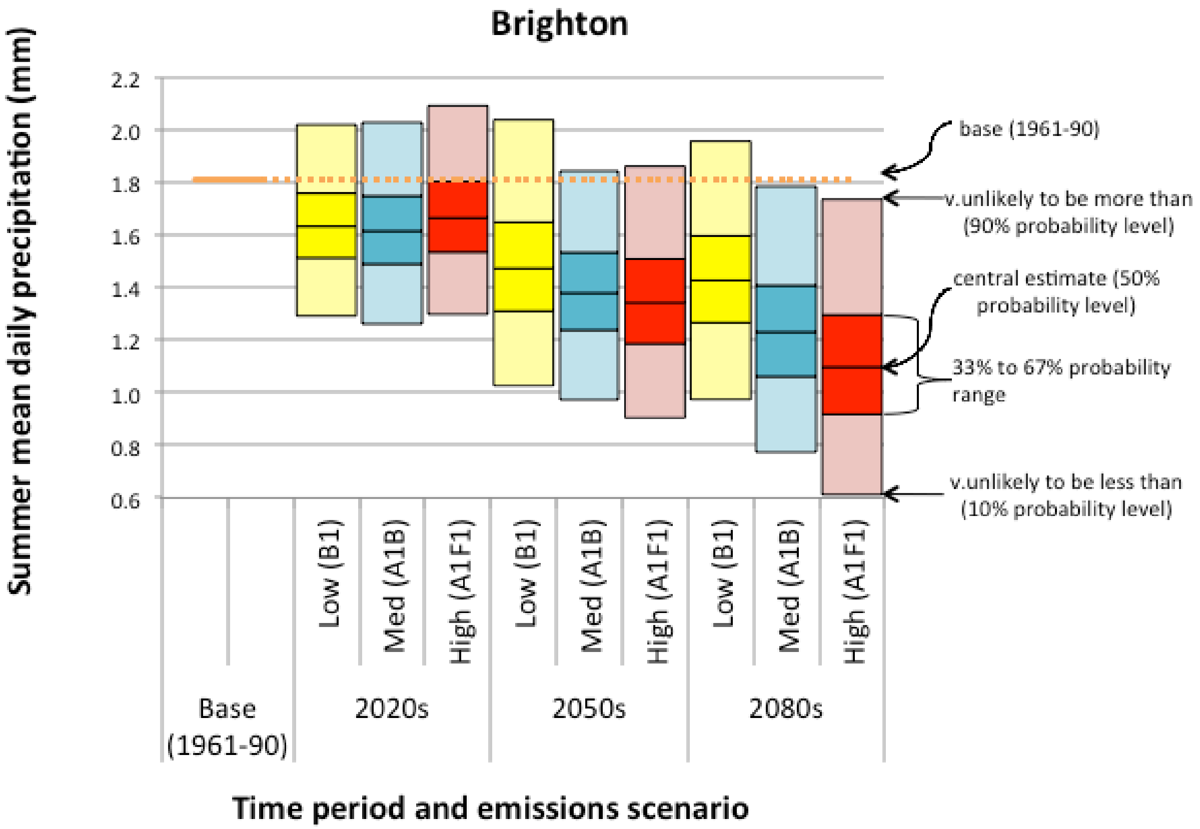


Figure 14 ProCLIP showing UKCP09 projections of summer mean daily precipitation in Brighton.

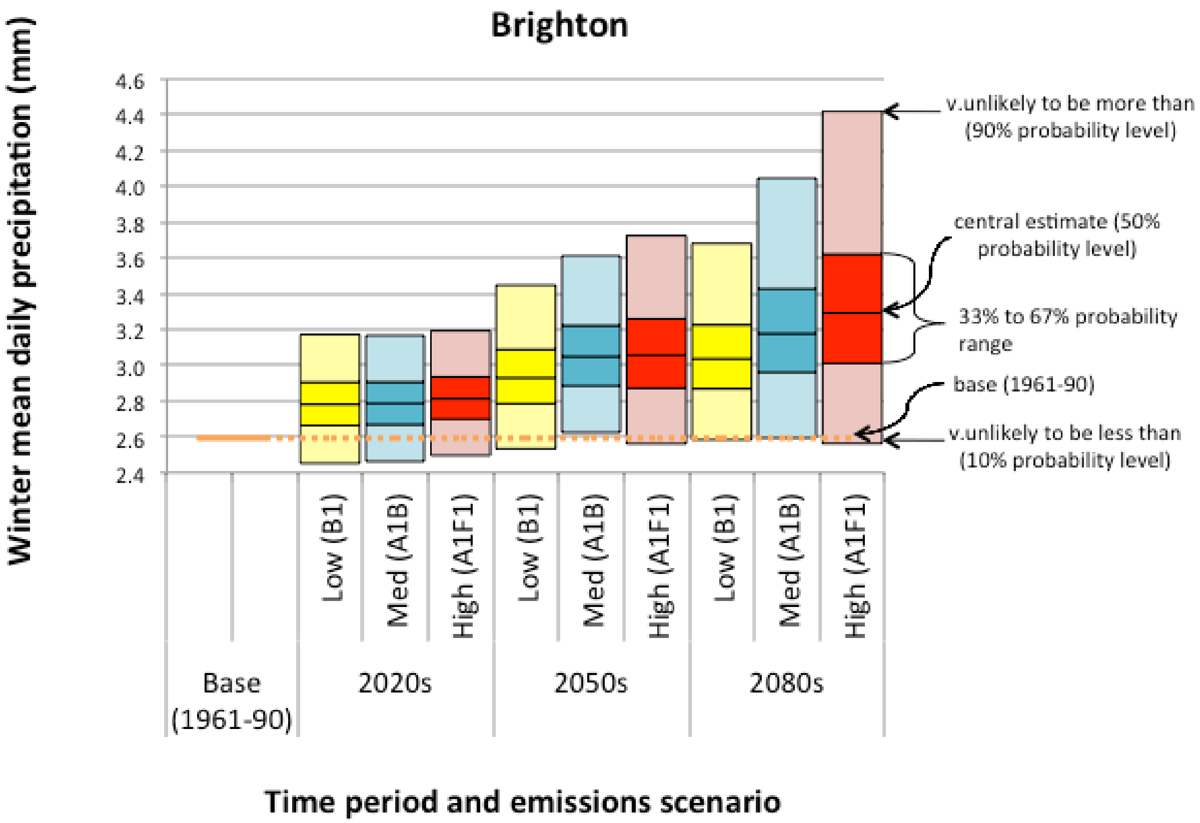


Figure 15 ProCLIP showing UKCP09 projections of winter mean daily precipitation in Brighton.

Material Durability

Harsher weathering of the building would be expected due to its proximity to the sea. However, the building is embedded in a city centre composed of buildings of a huge variety of ages and construction type and quality, some of which are considerably more vulnerable to increased storminess and weathering than One Brighton. Given the lack of agreed standards that take account of projected climate change, and surrounding fabric that can be used as an early warning system, it would be premature to expend effort to develop theoretical strategies for increasing the robustness of the structure and finishes as built. Furthermore, many details of the design, such as the external render, were expressly specified for the marine environment and thus should be more resilient to increased weathering than alternative products.

Sea-level rise

Sea levels in Brighton are projected to rise by up to 0.9m by the end of the century (Figure 16). Although this is likely to impact parts of the city, the One Brighton development is not at risk, as it lies 30m above the present sea level.

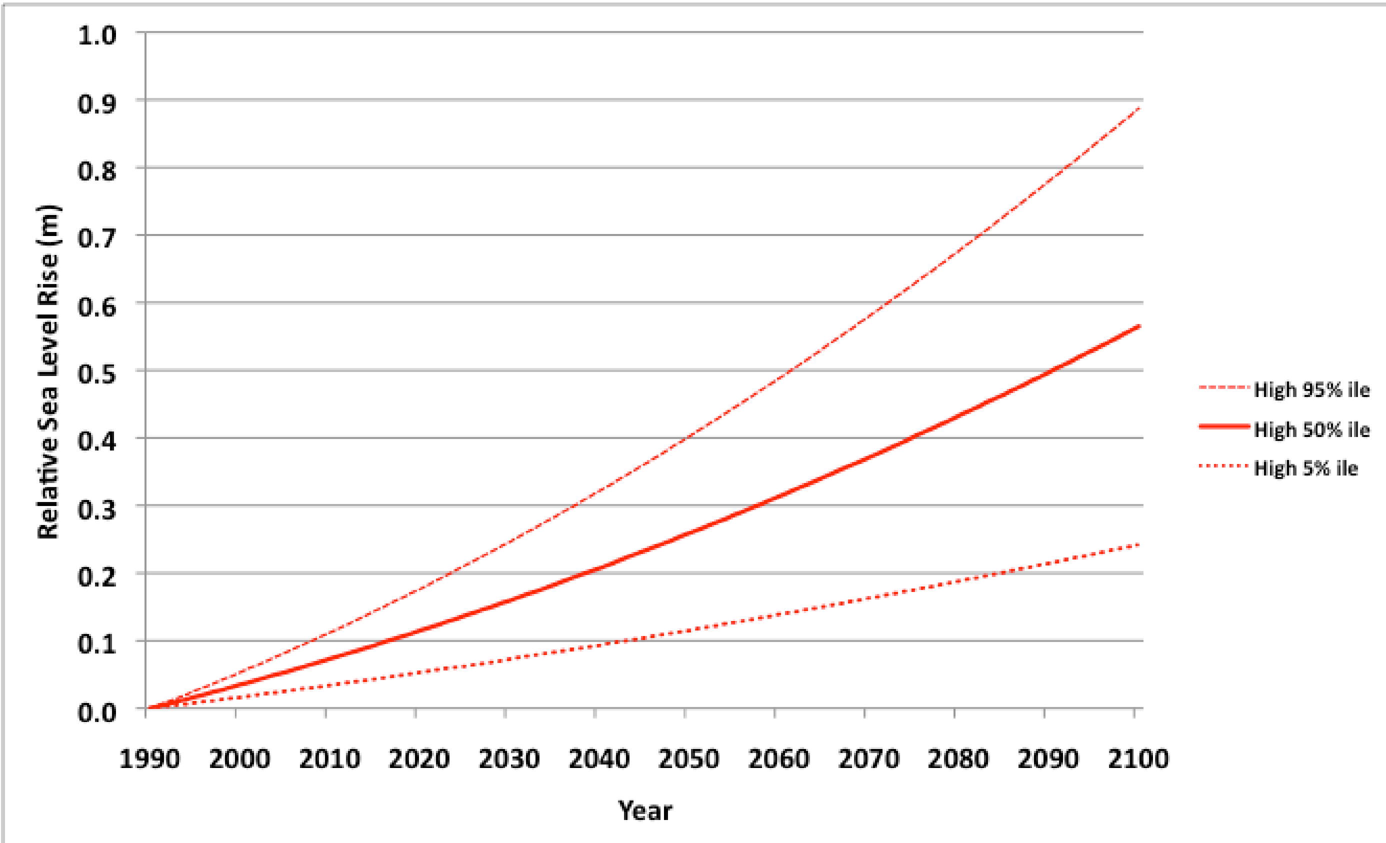


Figure 16 Projected relative sea level rise for 21st century, High emissions scenario (UKCP09 Marine projections, average over grid squares 25152 and 25153).

2.2 Climate Scenarios and Climate Data

Climate Scenarios

The UKCP09 scenarios are probabilistic in nature and have been developed to convey the uncertainty present both in future greenhouse gas emissions and in the representation of physical processes within the climate model. However, this presents the user with a wide range of choices. It would be extremely time-consuming to consider all the possible data available from UKCP09.

Our aim in this project is not to propose a single package of adaptation measures, but rather to develop an adaptive pathway over the 21st century. This allows a more flexible approach, as adaptation can be related to the local change in temperature and climate. The point in time at which specific adaptation measures are implemented can be brought forward or delayed if it becomes apparent that the climate is changing more quickly or slowly than projected.

For the early part of this century, the 2020s, there is little difference in the projections for the different emissions scenarios. For later time periods we need to make a choice of scenario and percentile. The Medium emissions scenario is the most robust scenario in terms of the statistical basis of the UKCP09 projections. However, current carbon emissions are still closely following the High emissions scenario (Global Carbon Project 2013).

We have chosen to use the Medium emissions scenario, central estimate (50%) for three timeslices covering the 21st century, the 2030s, the 2050s and the 2080s. For the 2080s, we also consider the more extreme High emissions scenario, central estimate (50%-ile).

This choice of climate scenarios can be related to both global and local scenarios as summarised in Table 2-1. The scenarios chosen also correspond to global temperature rises of 1°C, 2°C, 3°C and 4°C respectively and thus form a set of steps in the severity of global warming that can be related back to project global changes noted in the IPCC Assessment Reports and the Stern Review. Ultimately, global climate impacts drive international mitigation strategies and global ecosystems. Hence these overall temperature rises provide the context within which local adaptation takes place. Figure 17 shows the scenarios chosen for the 2020s, 2050s and 2080s - corresponding to global temperature rises of 2°C, 3°C and 4°C - superimposed upon IPCC projections of global climate impacts (from IPCC 2007).

Although climate change is a global phenomenon and will have global impacts, it will not occur uniformly over the globe: there will be considerable regional variation. The regional change in climate, expressed in Table 2-1 in terms of the projected rise in summer mean daily maximum temperature, will determine the risk and vulnerability to climate change at a specific location and the corresponding need for adaptation. For a private developer or home occupant, their immediate experience of climate change impacts, such as thermal discomfort due to summer overheating, is likely to be the primary motivation for adaptation.

Prometheus Weather Files

Brighton is not one of the CIBSE weather file locations. We have therefore used the Prometheus weather files for Brighton, which are available free of charge, to perform all the building physics simulations.

Table 2-1 Climate Timeslices and Scenarios Considered for Adaptation in Relation to Global and Local Temperature Rise

Timeslice	**Scenario** **% - emissions**	**Global T rise** **IPCC projections**	**Summer mean daily max T rise for Brighton** **UKCP09 projections**
2030s	(50%) Medium	1 °C	1.9 °C
2050s	(50%) Medium	2 °C	3.5 °C
2080s	(50%) Medium	3 °C	5.0 °C
2080s	(50%) High	4 °C	6.3 °C

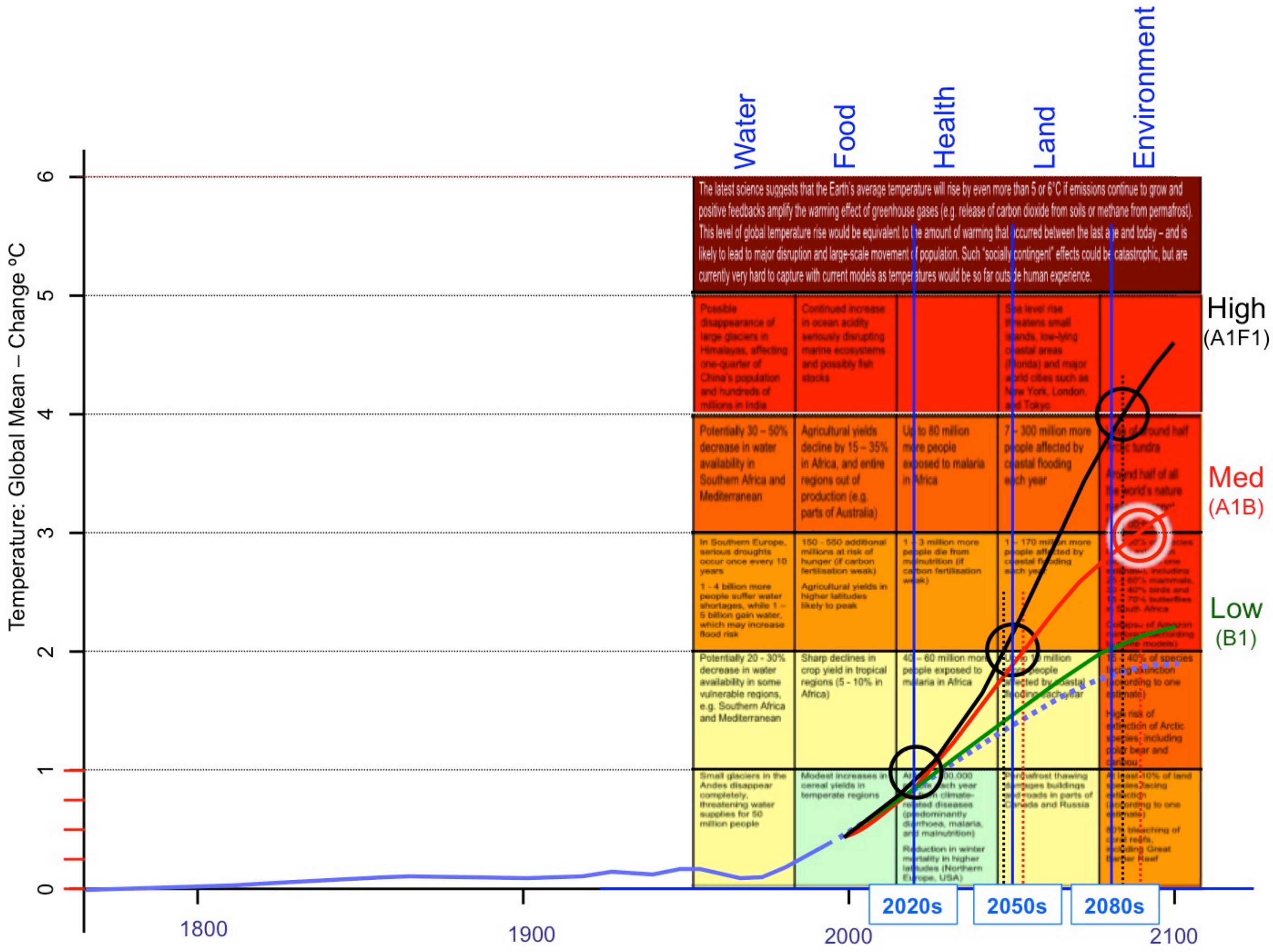


Figure 17 IPCC 2007 Climate scenarios related to global temperature rise and global climate impacts.

2.3 Occupant Vulnerability

The One Brighton development is aimed primarily at first-time buyers. As such, the typical occupant is presumed to be single, reasonably healthy and in full-time employment and therefore less likely to be at home during the day. It is not anticipated that there would be a large number of older people with restricted mobility - and ability to adapt - living there. Nonetheless, some apartments may be occupied by more than one person, for example couples or families. Those who work from home or are unemployed may be present in the apartment for a larger proportion of time, particularly during the hottest hours of the day. Moreover, some of these occupants may be more vulnerable to climate risks due to age or disability, particularly within the social housing units.

For the purposes of the thermal modelling analysis, a worst case occupancy scenario is used, in which a one-bedroom apartment is occupied by two adults who are at home 24 hours a day. However, no allowance has been made for any additional vulnerabilities, (for example due to pre-existing health conditions), of individual occupants.

2.3.1 Overheating Criteria

We have used the CIBSE Guide A comfort and overheating thresholds, i.e. 25°C/28°C for living areas and 23°C/26°C for bedrooms. According to this definition, overheating occurs if the internal temperature within a space exceeds the upper threshold for more than 1% of occupied hours during the year.

These thresholds do not take into account any physiological adaptation. In light of this, CIBSE has developed a new, adaptive, comfort criteria (CIBSE TM52, 2013). We have not adopted this within this project for two reasons. Firstly, the project commenced before CIBSE TM52 was finally published. Secondly, the adaptive comfort criteria have been developed primarily for non-domestic buildings. Further research is required to ascertain how applicable it is to domestic situations, particularly thermal comfort when sleeping at night.

2.3.2 Domestic Thermal Comfort

Thermal comfort research has primarily considered non-domestic buildings, which are mainly used during the daytime. In a domestic situation, such as an apartment, it is necessary to consider both daytime and nighttime thermal comfort.

During the night occupants would want to be at home sleeping. Overheating in the apartment, particularly in the bedroom, may impair sleep, which can lead to loss of productivity. There is a strong correlation between nighttime temperatures and health effects. Analysis of the 2003 heat wave in Paris demonstrated that a lack of relief at night, due to high nighttime temperatures, contributed to increased heat-related mortality (Dousset 2011, Laaidi 2012).

During the daytime, occupants have a greater range of behavioural adaptation options. They can escape to a “climate refuge”, such as a local green space, beach or air-conditioned building. They may not be in the apartment if they go out to work. If they do stay in the apartment, they can increase their thermal comfort by reducing the internal gains, which are much higher during the day, for example by cooking less or switching off other appliances. Reducing the daytime build-up of heat in the space, and in the thermal mass, is also likely to be beneficial for nighttime thermal comfort.

We would therefore argue that nighttime thermal comfort, although less understood and researched than daytime thermal comfort, is more critical when designing urban apartments.

3 Adaptation Strategy

3.1 Thermal Modelling Base Case - As Built Performance and Sensitivity Testing

3.1.1 Introduction

This section reviews the key findings of the TSB BPE programme regarding summer overheating in One Brighton. It then describes the construction of the thermal model geometry and occupancy profiles. Initial simulations were carried out and compared with the monitored BPE data. This revealed highly interesting results regarding the as built performance of the building.

In order to develop an adaptation strategy, sensitivity studies, for example to solar gain, were carried out using the thermal model. These were then used, together with preliminary supply chain analysis and cost estimates to select adaptation measures for which detail design work was undertaken (section 3.5). The full thermal model report can be found in Appendix 3.

Four of the five apartments monitored in the BPE programme are one-bedroom apartments. Overall, one-bedroom apartments comprise 40% of the units within One Brighton. Such small apartments are at high risk of overheating due to the concentration of internal gains and their single aspect. In this study we have therefore focussed on modelling overheating for one-bedroom apartments in One Brighton, although any adaptation measures recommended would be carried out throughout the building.

3.1.2 TSB funded Building Performance Evaluation

Within the TSB BPE programme, five flats were monitored and modelled. These have been anonymised for publication and are labelled, A, B, C, D & E. (Apartment E later withdrew from the study and is therefore not shown in all the plots in this section.)

Of these, Flats A and E suffer from overheating in the living room. However, all five flats suffer from significant overheating in the bedroom (Table 3-1). Figure 18 shows monitored conditions within the bedroom of Flat C on the hottest day of 2012. The temperature in the bedroom is several degrees higher than the external temperature, even during the middle of the day and does not fall below 28°C even at night.

According to the BUS survey, 75% of occupants said that temperatures were hot or too hot in summer. There were also 28 negative comments (out of 62 respondents) regarding the ventilation system. The comments related to excessive dust, poor control and poor flow design. Many occupants find it necessary to open windows to keep cool. This was originally assumed in the design: the MVHR was not intended as the primary summertime comfort control system. Nonetheless, some occupants are reluctant to open their windows due to safety and security concerns and these tend to suffer from greater overheating.

3.1.3 Flat Layout

Flats A and B are west facing at upper ground floor level and have the same [mirrored] internal layout. As they are at upper ground floor level, they do not have full height windows, unlike most of the apartments on higher levels. They also both have an external side wall without windows.

Flats C, D & E are on upper levels on the east facing façade and share the same internal layout (Figure 19). Flats D and E have an external side wall onto one of the sky gardens (see Figure 9), which also has a small opening window from the living room. Flat C is sandwiched between two other apartments and has no side windows; it is the only genuinely single sided apartment of those monitored.

Figure 20 shows the internal layouts of Flats A and D, as modelled in the building physics software, TAS. In these images, green indicates an internal wall, orange an insulated wall, whereas grey walls are virtual partitions (made of thin air) used to divide spaces with differing activities or servicing. The windows are also colour coded with green frames indicating an opening window.

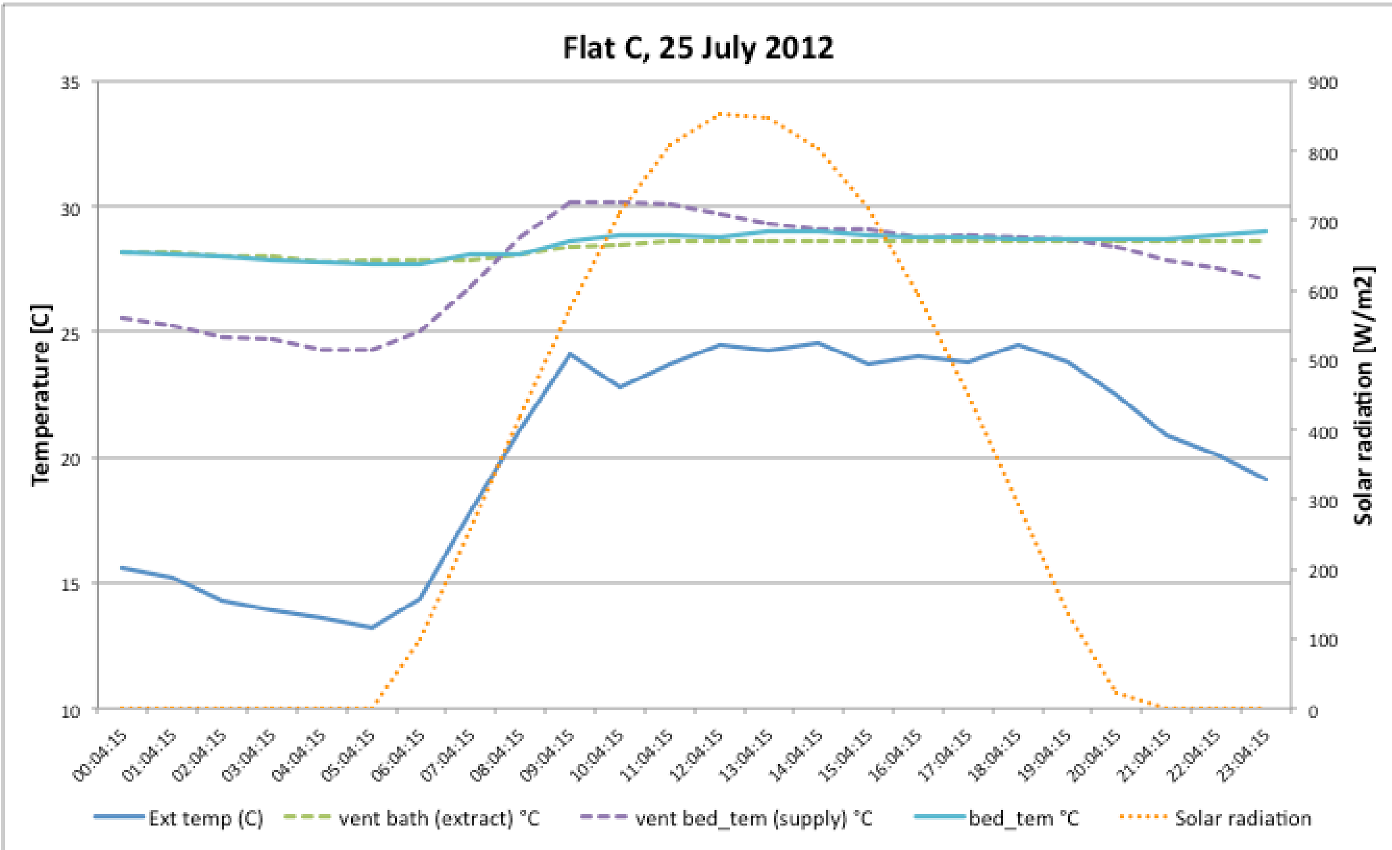


Figure 18 Monitored conditions in bedroom of Flat C on hottest day of 2012.

Table 3-1 Percentage of all hours for which CIBSE comfort and overheating temperature thresholds are exceeded, from 24/7 monitored data averaged over five apartments.

		Living room		Bedroom	
		Comfort %>25 °C	Overheating %>28 °C	Comfort %>23 °C	Overheating %>26 °C
Flat	**A**	**16%**	**1%**	**30%**	**4%**
	B	**28%**	**0%**	**86%**	**11%**
	C	**15%**	**0%**	**73%**	**11%**
	D	**16%**	**0%**	**52%**	**16%**
	E	**43%**	**2%**	**77%**	**29%**
AVERAGE		**23%**	**1%**	**63%**	**14%**

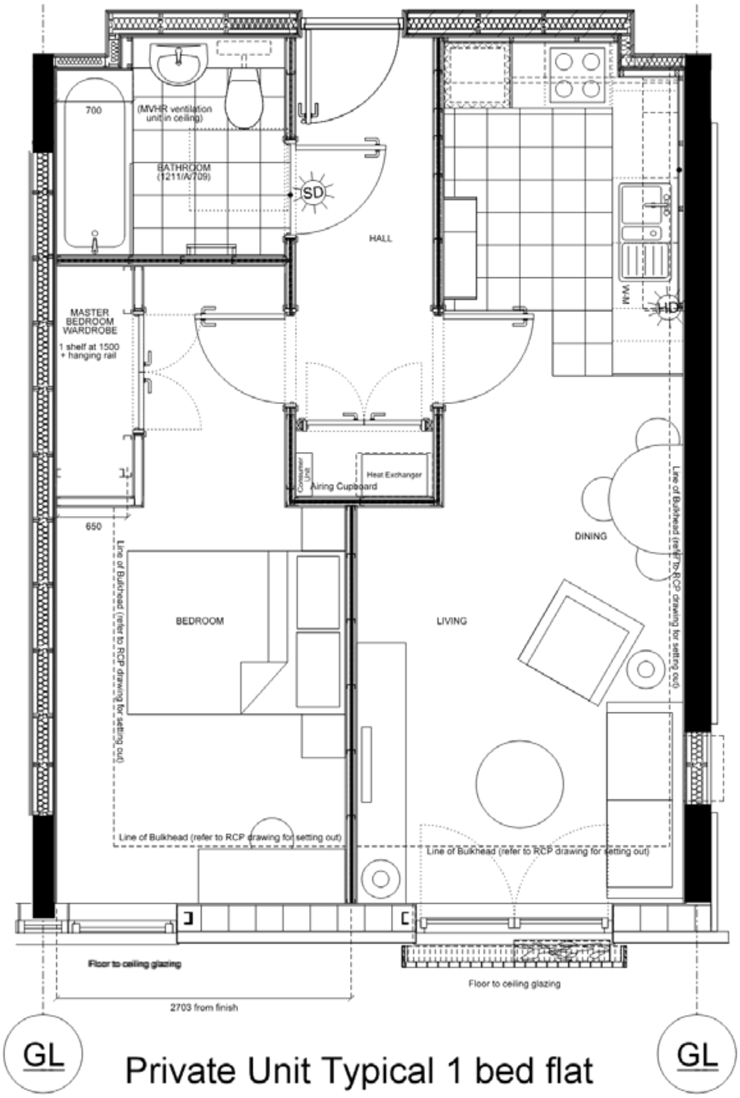


Figure 19 Layout of 1-bedroom Flats C, D and E. Flat C has internal party walls on 3 sides: only the glazed façade is an external wall. Flats D and E have a small window in the side wall, which opens onto the sky garden.

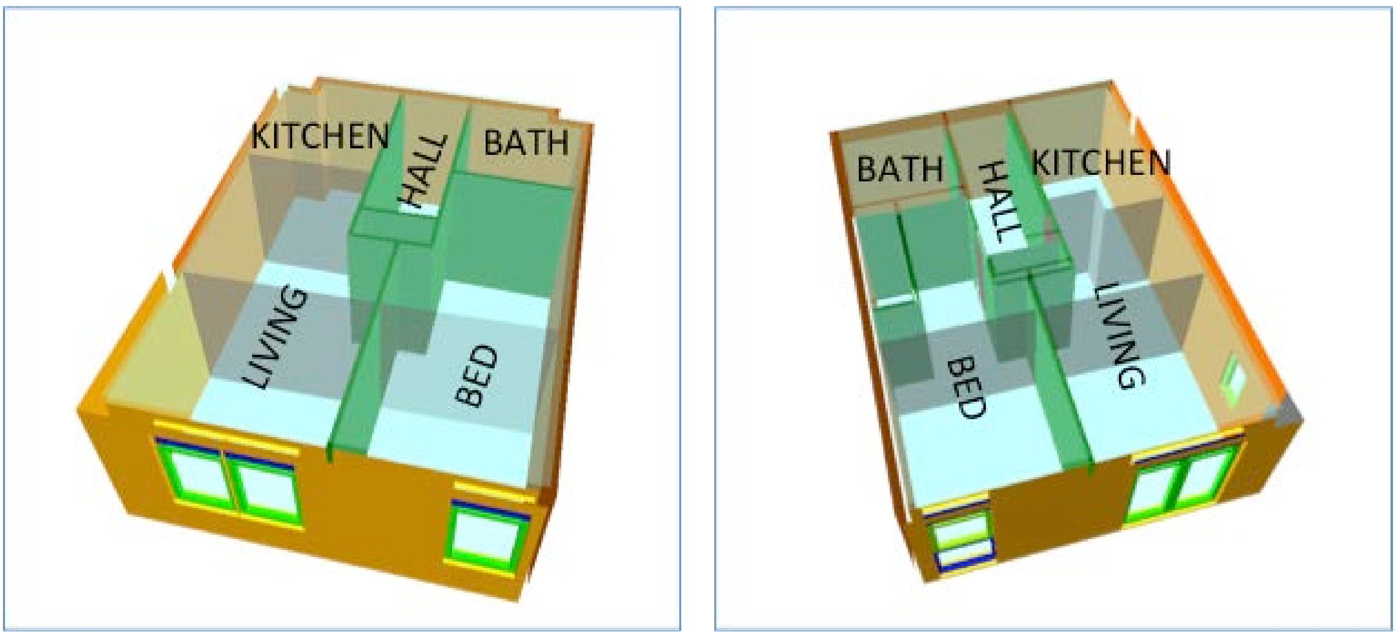


Figure 20 West-facing upper ground floor flat, East-facing middle floor flat with side wall and window onto sky garden. Opening windows are indicated by green frames.

3.1.4 Occupancy Profile

Internal gains

There is a concern within parts of the industry that standard occupancy profiles - based upon a larger house or dwelling - may not accurately represent the internal gains within smaller dwellings. A one-bedroom apartment is likely to contain many of the same domestic appliances, but concentrated within a much smaller floor area.

Electricity consumption was measured for each of the monitored apartments (Table 3-2, Figure 23). However, this did not provide sufficient information to build bespoke occupancy profiles for each test apartment. Instead, generic profiles were developed - in consultation with the Zero Carbon Hub - to represent reasonable occupancy levels and patterns for a one-bedroom apartment. Appropriate internal gains were derived from the electrical consumption for a single non-pensioner household in the Defra Household Electricity Use Survey (2012) (Figure 21). (The findings of this survey are summarized in the Energy Saving Trust's 2012 report "Powering the Nation"). These gains give an electrical consumption of 1609 kWh/annum or 134 kWh/month. This is consistent with the total measured electrical consumption of one of the monitored apartments (Flat D), which has the median apartment energy consumption (Table 3-2). It is also known to have occupants who are absent during the day.

An appliance audit was also carried out as part of the TSB BPE programme. The results were not available until after the occupancy profile for the current project had been developed. Nonetheless, they showed a reasonable level of agreement with the assumptions made.

This profile was then extrapolated to cover two scenarios: one where the occupants are assumed to be out all day every day (between 8am and 6pm), and another where occupants are assumed to be at home all day. In both cases, we assumed that two people were sharing the apartment. When modelling adaptation options, we used the home all day profile as a worst-case scenario. The gains for this occupancy profile are shown in Figure 22.

Table 3-2 Monthly Electricity Consumption (kWh) in monitored apartments for Nov 2011 to Jan 2012

	A	B	C	D	E
Nov	80	165	119	118	236
Dec	94	215	105	131	265
Jan	100	226	110	143	252
Total	274	606	334	392	753

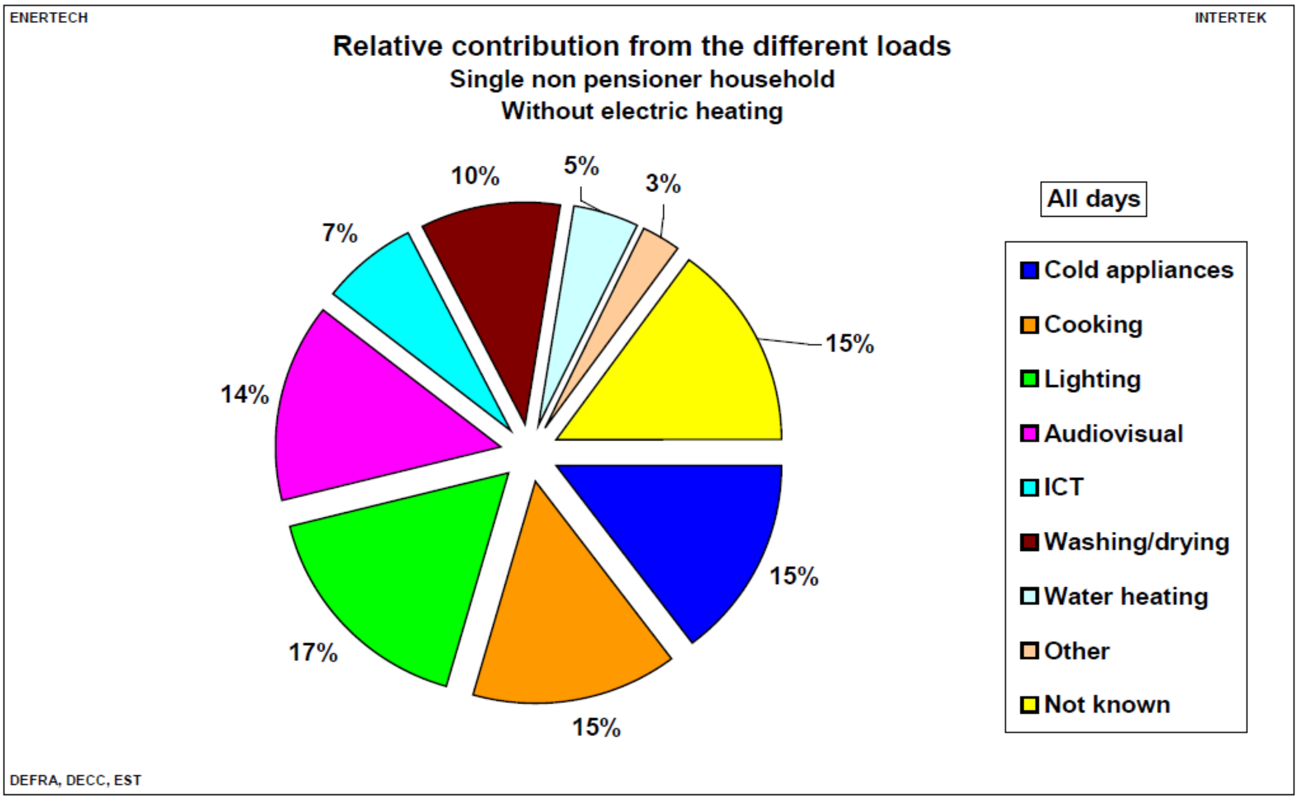


Figure 21 Relative Contribution from the different loads over all days for a single non-pensioner household without electric heating from Household Electricity Use Survey, Defra (2012).

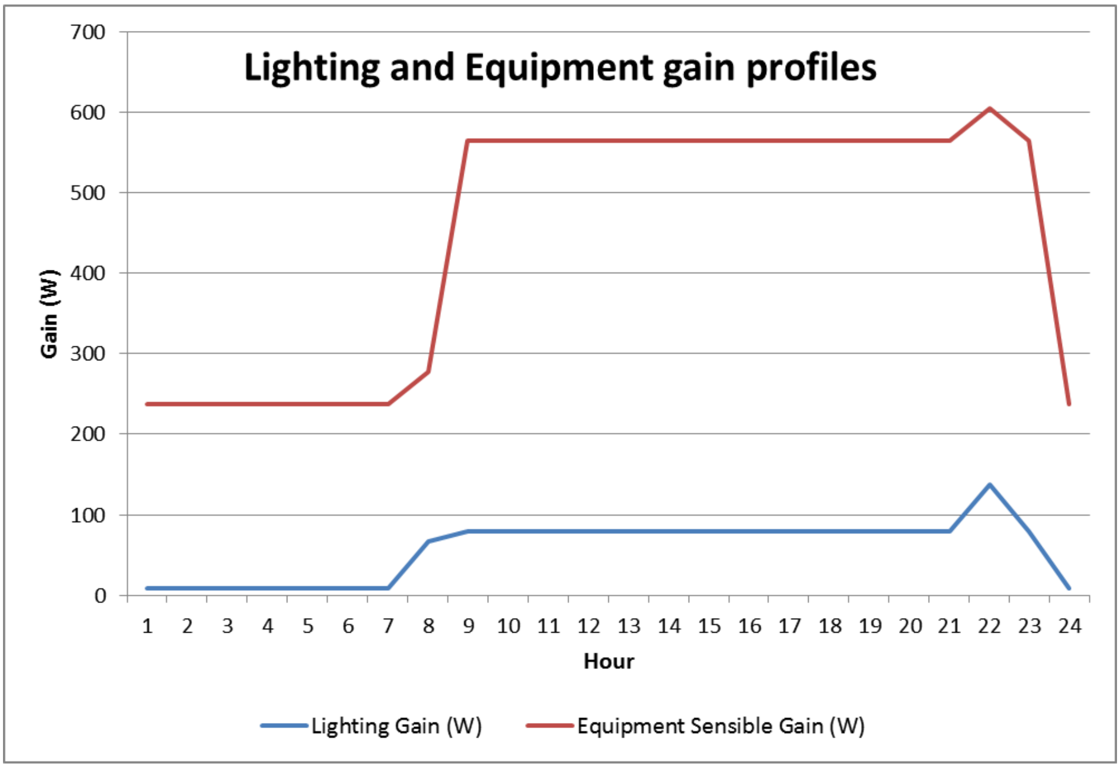


Figure 22 Electricity use profiles for a single apartment with occupants at home all day.

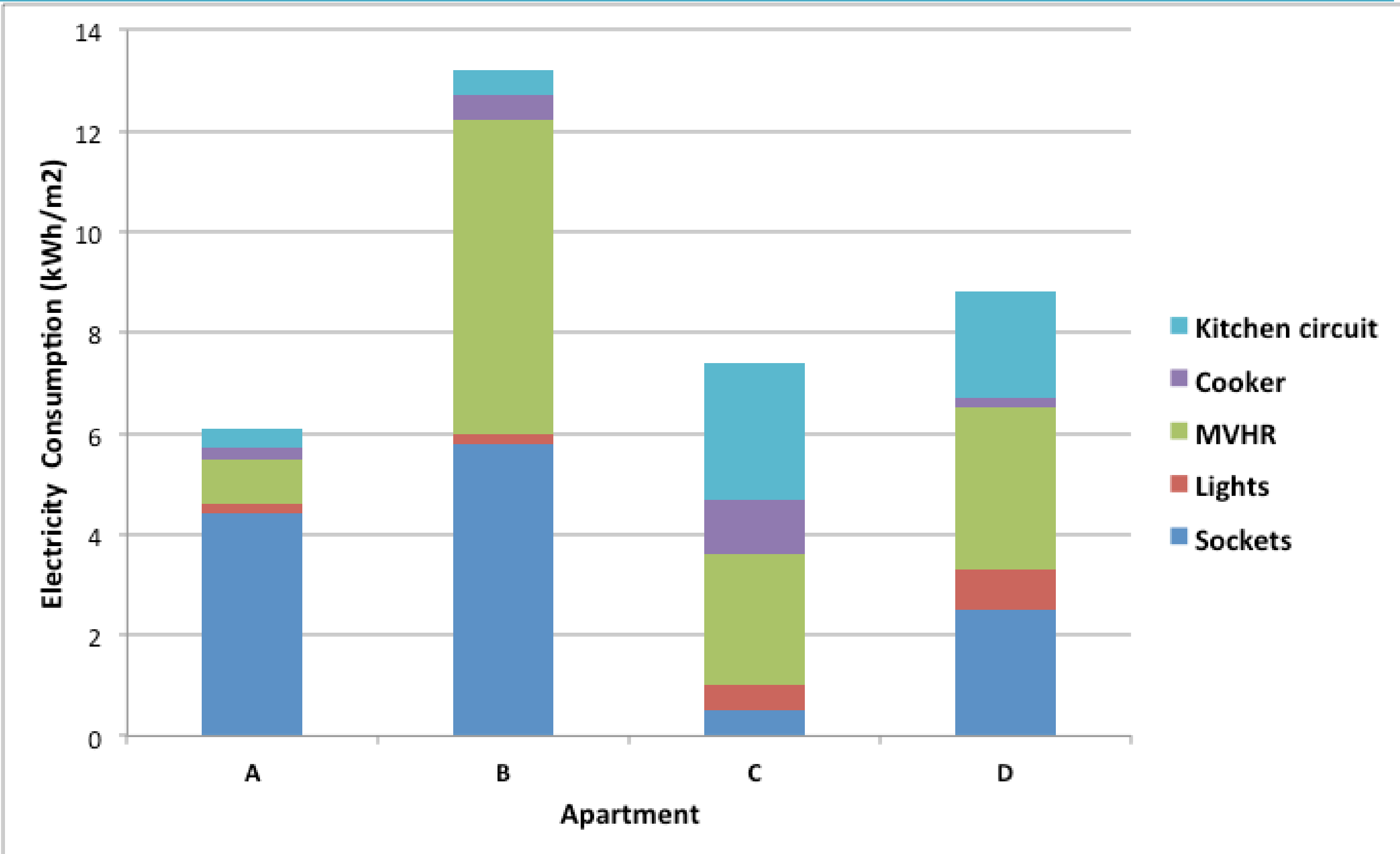


Figure 23 Electricity Consumption in monitored apartments for Nov 2011 to Jan 2012.

MVHR Related Gains

Although insulated, there will be some heat losses from the hot water pipework and the heat exchanger installed within each apartment to take heat from the centralised system. These will increase the internal gains within each apartment. The losses from the pipework were calculated to be 8.4 W/m over 16.4 m of pipework. Together with an estimated 16 W heat loss from the heat exchanger itself, these contribute 153.8 W of heat gain to the apartment 24/7.

Operation of the MVHR system will also contribute substantially to the energy use as evidenced by the monitored electricity consumption for Quarter 2 (Figure 23). The MVHR fan has a power rating of 200W in boost mode. Although this gain was omitted from the occupancy profile used in the thermal model, it is compensated for by generous estimates for other internal gains, particularly cooking and appliance use.

Much of the excess heat originating from the MVHR fan and also from the hot water pipes will go into ceiling voids and bulkheads as opposed to directly into the apartment. The overall energy consumption of the modelled occupancy profiles is consistent with the monitored data.

Infiltration

One Brighton was built to an air-tightness specification of less than 5 $m^3/hr/m^2$ @ 50Pa. In practice, values of 4 to 4.2 $m^3/hr/m^2$ were achieved. These were approximated to an infiltration rate of 0.15 ach for the perimeter spaces.

Window Opening

Window opening habits vary considerably between occupants. Concerns about noise or safety mean that some rarely open their windows, whereas other occupants may like opening the windows wide and having high ventilation rates. The opening windows have restrictors, but these can be and are over-ridden if an occupant wishes to open the windows wider. For the base case, it was assumed that occupants open the windows as far as the restrictors allow when internal temperatures exceed 22°C and the apartment is occupied. It is also assumed that they will open the balcony doors by a similar amount, giving a total free area of approximately 5% of the window area.

3.1.5 MVHR Actual Performance versus Design

Initial thermal modelling assumed that the MVHR fan was operating at the design flow rates (40 l/s in the living rooms and 36 l/s in bedrooms). However, this did not reproduce the high temperatures or degree of overheating observed in many of the monitored flats during the TSB funded BPE programme on One Brighton. It was only by reducing the ventilation rate in the model significantly that the modelled performance approached the observed data. It was therefore, decided to examine the MVHR installation in more detail.

In order to investigate the operation of the MVHR system, BSRIA were commissioned to take readings of the actual flow rates being achieved on site. The site inspection revealed a variety of factors, which were shown to be compromising the MVHR including dirty filters, crushed, kinky or badly sealed ductwork and units failing to go into bypass mode for summer operation.

Although only two flats were assessed in the site visit, both were found to have MVHR flow rates closer to the Part F minimum standard (13 l/s in living rooms and 8 l/s in bedrooms). These lower flow rates were then input into the thermal model. The subsequent model results were in much better agreement with the levels of overheating observed within One Brighton.

This highlights the need for careful installation and commissioning of MVHR systems and user-friendly operation instructions and controls. Regular maintenance is also vital. Filters should be cleaned regularly, ideally every 6 months, and therefore need to be easily accessible. This is not the case in One Brighton, where they are located behind a flush panel on the bathroom ceiling.

3.1.6 ‘Future’ Base Case Choice

Apartment

Of the five monitored apartments, the only one which is truly single-sided is Flat C. All the others have external side walls, for example onto the sky gardens. In practice, Flat C suffers from the severest overheating (see section 0 below). We therefore use this apartment layout as a worst-case scenario in the thermal modelling of future adaptation options (although all the monitored apartments were modelled for baseline performance).

MVHR Flow Rates

Rectifying any shortcomings of the MVHR system is an issue for the management company and lies outside the scope of this project. For modelling purposes, we assume that the MVHR functions as designed and can achieve the specified boost flow rates of 40 l/s in the living rooms and 36 l/s in bedrooms on demand. For the base case, we therefore choose to model Flat C, with the home-all-day occupancy profile as described in section 3.1.4 and illustrated in Figure 22. We assume that the MVHR provides ventilation rates consistent with Part F but goes into boost mode once the internal temperature exceeds 22°C as designed. The windows are also opened by 5% at internal temperatures greater than 22°C, when the flat is occupied.

Weather File

Initial modelling of this base case, using the baseline Prometheus DSY for Brighton, indicates that - in the current climate - overheating occurs in the living room but not in the bedroom. The base case has also been modelled using a selection of Prometheus future weather years for Brighton (Table 3-3). By the 2050s, (using the Medium emission scenario 50%-ile), the current CIBSE overheating threshold temperatures are exceeded for more than 10% of occupied hours in all areas of the apartment. The Prometheus 2050s Medium 50% DSY weather file has been selected to use in the ‘future’ base case model. Initial thermal modelling of adaptation options was undertaken using this weather file. Results were compared against this 'future' base case and used in the cost-benefit analysis (section 3.4).

Table 3-3 Occupied hours for which CIBSE comfort and overheating thresholds are exceeded for Flat C, modelled using Prometheus weather data for Brighton for current and selected future climate scenarios.

Occupied % hours of exceedence	Bedrooms		Living Room+ Kitchen	
Temperature Band (°C)	**%>23°C**	**%>26°C**	**%>25°C**	**%>28°C**
Prometheus – Baseline (1961-1990) DSY	**34.2%**	**0.2%**	**21.0%**	**1.5%**
Prometheus - 2030s Medium 50% DSY	**44.1%**	**3.8%**	**34.0%**	**6.6%**
Prometheus - 2050s Medium 50% DSY	**46.1%**	**10.3%**	**37.3%**	**13.3%**
Prometheus - 2080s Medium 50% DSY	**49.6%**	**19.4%**	**42.1%**	**21.5%**
Prometheus - 2080s High 50% DSY	**51.0%**	**21.0%**	**45.1%**	**23.1%**

3.1.7 Sensitivity Studies

The building physics model was used to quantify the sensitivity of overheating risk to various generic adaptation measures. For some measures, i.e. shading, increased natural or mechanical ventilation, enhanced thermal mass and active cooling options, specific designs were then developed. These are described in the next section of this report.

Results regarding sensitivity of overheating to form and orientation are described here, as they relate to the as-built performance. Form in particular is pertinent to selection of base case. Although these aspects of the design cannot be changed for One Brighton, learning from these sensitivity studies can be extended to other buildings (section 5). Further modelling considered variation in the internal gains and dual aspect ventilation. These results are also discussed in section 5).

Form - Sky Gardens

In the first instance, each of the five monitored apartments was modelled using the base case configuration and also using the future weather files (as in Table 3-3). There was considerable variation in the amount of overheating experienced. Flats A and B experienced the least overheating. These apartments face west and are on the upper ground floor level. Therefore they are more over-shadowed. They also both have smaller windows and external side walls. The worst overheating occurs in Flat C, which is the only apartment out of those monitored which is truly single-sided (outlined in red in the photograph in Figure 24). Flats D and E face east, like Flat C, but they have a wall and small window onto the sky gardens (as illustrated by the blue outline in Figure 24).

A sensitivity test was carried out in which first the side windows and then the external wall onto the sky garden were removed from the thermal model for Flats D and E. The results are shown in Figure 25. Removing the side windows caused a small increase in overheating. When the sky gardens were removed, Flats D and E overheated as much as Flat C. This illustrates that having a greater external wall area – part of which is shaded during the day - reduces the risk of overheating.

Form - Orientation

To test the sensitivity of overheating to orientation, a series of model runs was carried out for which Flat C was relocated to the top floor and the building rotated through different angles. Results are given in Table 3-4. In terms of overheating risk, the worst-case orientation is predicted to be southeast facing. The lowest incidence of overheating is in the north-facing apartment, although this will also have reduced solar gain and daylight which may be disadvantages in the winter. For single-sided apartments, the east-west alignment used at One Brighton is the most favourable orientation.

Figure 24 East-facing façade with Flat C type single-sided one-bedroom apartment outlined in red. The apartment outlined in blue is also one-bedroom, but has a side wall with small opening window onto the sky garden (Flat D/E type).

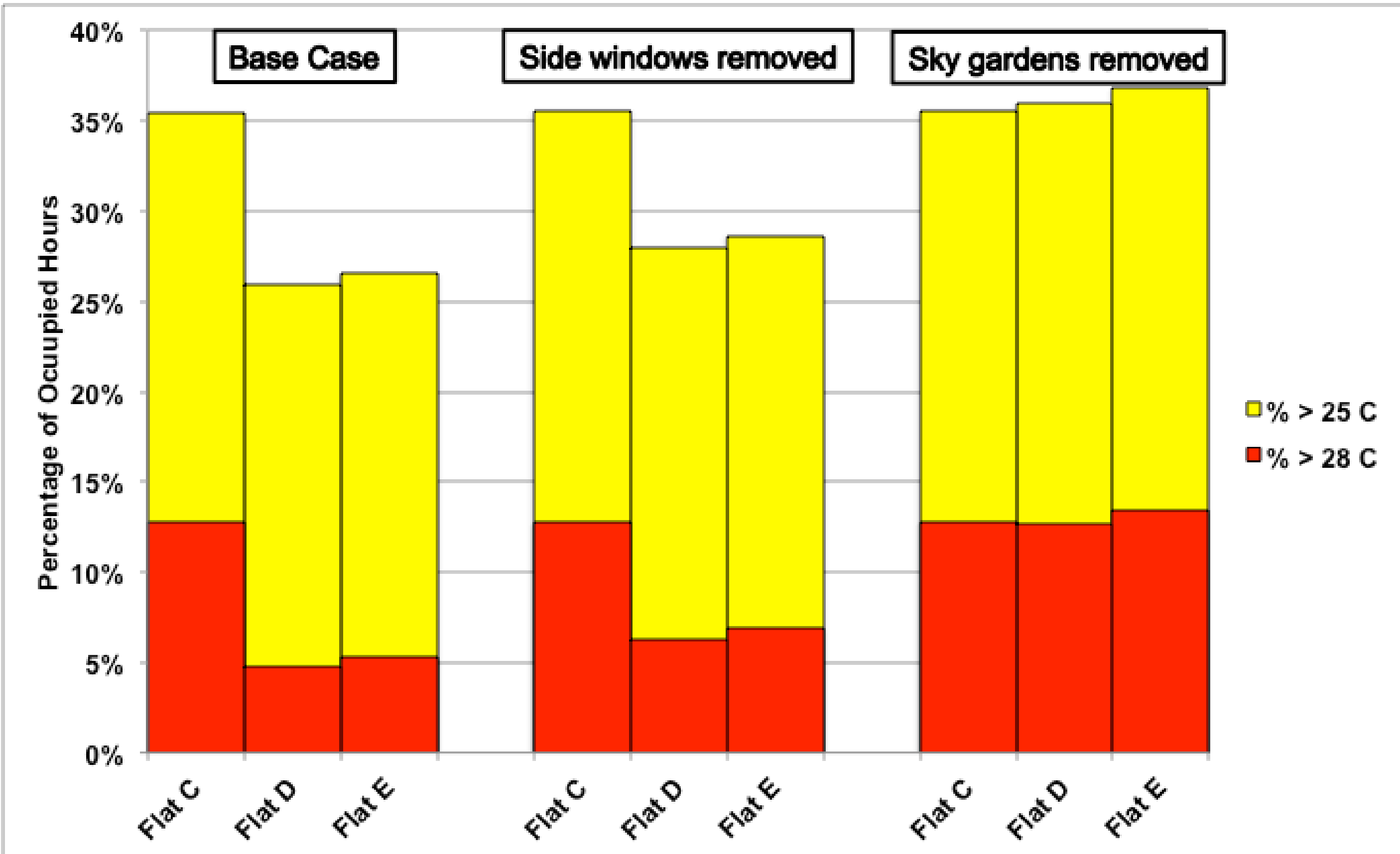
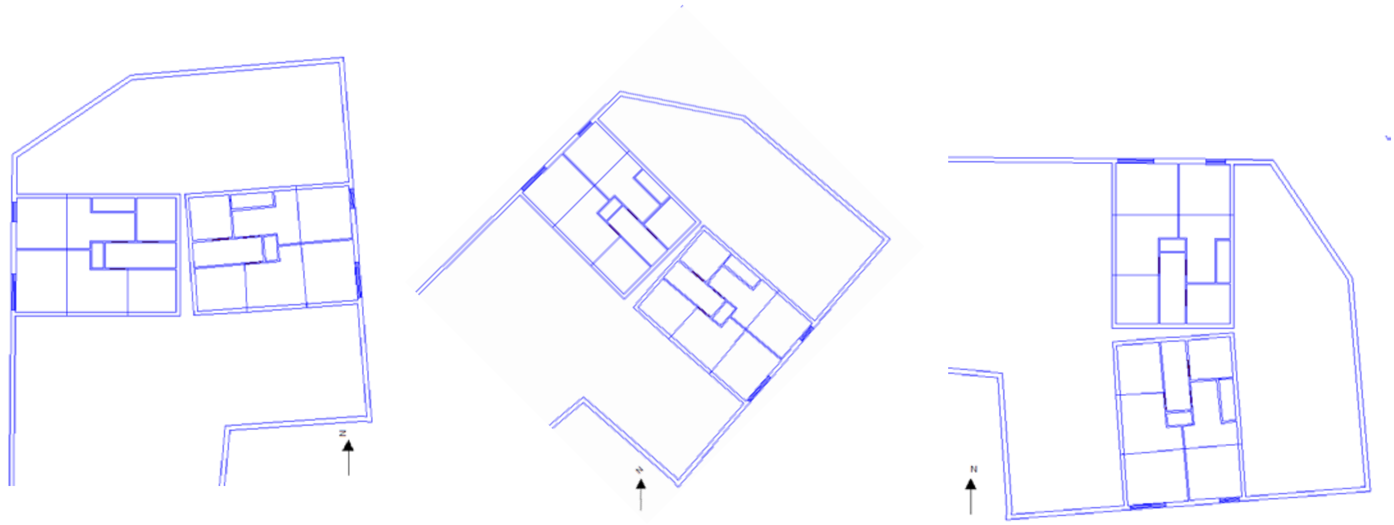


Figure 25 Percentage of occupied hours over 25 °C (but less than 28) and over 28 °C for Living Room of Flats C, D and E from TAS Thermal Model, showing the impact of removing the side window and then the external wall onto the sky garden. These results are for the 'future' base case, using the Prometheus 2050s Medium 50% DSY weather file and assuming the MVHR is functioning as designed.



W	E	NW	SE	N	S
11.1%	13.3%	9.3%	14.0%	7.5%	13.4%

Table 3-4 Percentage of occupied hours for which average living room temperature exceeds 28°C for a top-floor single-sided apartment with different orientations.

3.2 Adaptation Strategy

3.2.1 Philosophy

The management company is concerned to best target its investment in adaptation, informed by this project. Our aim is not to propose a single package of adaptation measures, but rather to develop an adaptive pathway over the 21st century. This allows a more flexible approach, as adaptation can be related to the local change in temperature and climate. The point in time at which specific adaptation measures are implemented can be brought forward or delayed if it becomes apparent that the climate is changing more quickly or slowly than projected.

Furthermore, if we adapt early to increase the adaptive capacity of the building, it is more likely to cope with an exceptionally hot summer. Residents will also be able learn how to utilise the adaptive measures installed to control their environment before extreme temperatures strike.

If, on the other hand, a period of exceptionally hot weather occurs in Brighton before any adaptation has been carried out, there is a risk of maladaptation. Residents may rush out and buy portable air conditioning units. They may become over-reliant on these units and will be less motivated to buy into the adaptation strategy proposed here.

3.2.2 Maintenance plan

Any building must be maintained in order to continue to function well. Typical Life Expectancies for different building elements in One Brighton are included in Appendix 3. The windows have an expected lifespan of at least 30 years. Window replacement is anticipated in 2040 and again in 2070. The MVHR units and the biomass and gas boilers have a slightly shorter expected lifespan of 15-25 years.

Where an adaptation measure is an improvement upon the current specification, for example an opaque window panel or electrochromic glazing, it makes sense to implement it when replacement would have been due anyway. This will reduce additional preliminary costs, such as for scaffolding the building. The cost of adaptation can then be compared to the cost of a like-for-like replacement.

3.2.3 Recommendations

Strategy A

The thermal modelling analysis shows that, for One Brighton, ventilation on its own is more effective than the shading options alone. The building can perform well in the relatively cool Brighton climate, provided windows are opened *and* the MVHR is working and pulling fresh air into and through the apartment. Without the MVHR, air would stagnate in the back of the single-sided apartments and overheating may occur even if the windows are opened. Although residents may have legitimate concerns about opening windows, there are ways this can be done safely. Some issues may be resolved by other means in future. For example, electric buses are quieter and less polluting.

Therefore our first recommendation is that residents are educated about opening their windows. This could be done through the green caretaker. The Exeter St Loyes Extra Care Home, Design for Future Climate project recommended the installation of individual temperature sensors within residents' rooms. Although appropriate for an extra care setting, this would probably be excessive in One Brighton. A much cheaper strategy is for the green caretaker to display current weather forecasts in the foyer, together with specific recommendations for the day about whether and when residents are advised to open their windows to keep cool.

During very hot periods, closing internal blinds or curtains can provide additional benefit. This is an especially useful strategy if residents are out during the day, as they will not be affected by the reduced daylight and are unlikely to leave their windows open in any case. If they wish to open their windows at the same time as shading them, they could fit internal framed blinds (adaptation option 02). In either case, the green caretaker should also provide advice about optimum closing of internal blinds or curtains on hot sunny days.

Strategy B

Strategy A is sufficient to prevent overheating beyond 2050, under the medium emissions scenario central estimate. As a next step, we would recommend making the windows more secure, in order to encourage people to open them, and installing ceiling fans.

Section 3.5, adaptation option 06, considers ways of improving natural ventilation. Barriers to opening windows include concerns about safety and security – especially at night or when occupants are out. There are several means for making windows more secure when open, for example using security grills or reducing the number of patio doors, which can be difficult to fix open. At present, we have not made a specific recommendation for secure ventilation out of the choices considered in adaptation option 06. Our hope is that - as a result of supply chain innovation – a wider range of products will be available by the time this measure is implemented.

Ceiling fans (adaptation option 08) are a very cost-effective adaptation measure, in terms of the perceived cooling benefit they provide. Furthermore, in the event of a failure in the MVHR unit, they provide an additional means of circulating the air within the apartment and drawing fresh air deep into the space. The thermal modelling showed that this is vital to the natural ventilation strategy using opening windows.

Strategy C

The third step in our strategy is to implement external shading, to hinder transmission of solar gain into the apartment. By 2080 this becomes necessary to prevent overheating, particularly in the living room. Several options were considered (see section 3.5), including fixed horizontal shading, e.g. a brise soleil, or interstitial blinds (adaptation option 04), but some of these are not suitable for this building. For example, it is difficult to provide effective shading using a brise soleil on the east or west facing facades. Electrochromic glass (adaptation option 03) and external blinds (adaptation option 05) were determined to be the most appropriate adaptation measures for One Brighton. Both are effective in preventing overheating, even under the 2080s High emission scenario central estimate. Our recommended option is electrochromic glass, (together with an opaque panel in the lower bedroom window – adaptation option 01). Although EC glass is currently more expensive than external blinds, by 2070 prices may be more competitive. It does not conflict with the ventilation strategy, whereas external blinds would restrict the amount of ventilation. EC glass also complements the contemporary aesthetic of the buildings.

Summary of Adaptation Strategy

Strategy A - Up to 2040

- Educate residents about opening their windows to provide optimal natural ventilation.
- Educate residents to close internal blinds or curtains during hot, sunny weather.
- Provide daily weather forecast information, together with recommended action, via the green caretaker. This information could be displayed in the foyer or even disseminated via a smartphone app.

Strategy B - 2040 Window Replacement

- Implement measures to allow more secure window opening for natural ventilation.
- Install ceiling fans to provide perceived cooling benefit.

Strategy C - 2070 Window Replacement

- Install ElectroChromic glass - and opaque panel in lower pane of bedroom window - to provide shading from solar gain.

3.3 Timescales

3.3.1 Trigger Points for Implementation

In line with our philosophy of adapting early, we recommend implementing the successive steps in our strategy at the time points when window replacement is scheduled within the maintenance plan, i.e. 2040 and 2070. This is illustrated in Figure 27.

However, the adaptation strategy should also be triggered by what is happening to the climate, not purely by time. So we may need to implement the adaptation measures sooner if the climate changes more quickly. Although we have calculated against the Medium emissions scenario 50 percentile, this is fairly conservative. In practice emissions are still following higher trajectories, so it is likely to get hotter sooner rather than later.

Figure 27 also indicates the projected local and global temperature rise corresponding to the different points in the implementation timeline. We recommend that the management company consider the climatological changes in temperature on a ten-yearly cycle, as released by the Met Office. If average daily maximum temperatures in summer are rising more quickly, earlier implementation may be necessary. For example, it would be judicious to implement Strategy C, electrochromic glass, as soon as the rise in average summer daily maximum approaches 5°C above the 1960 to 1990 baseline.

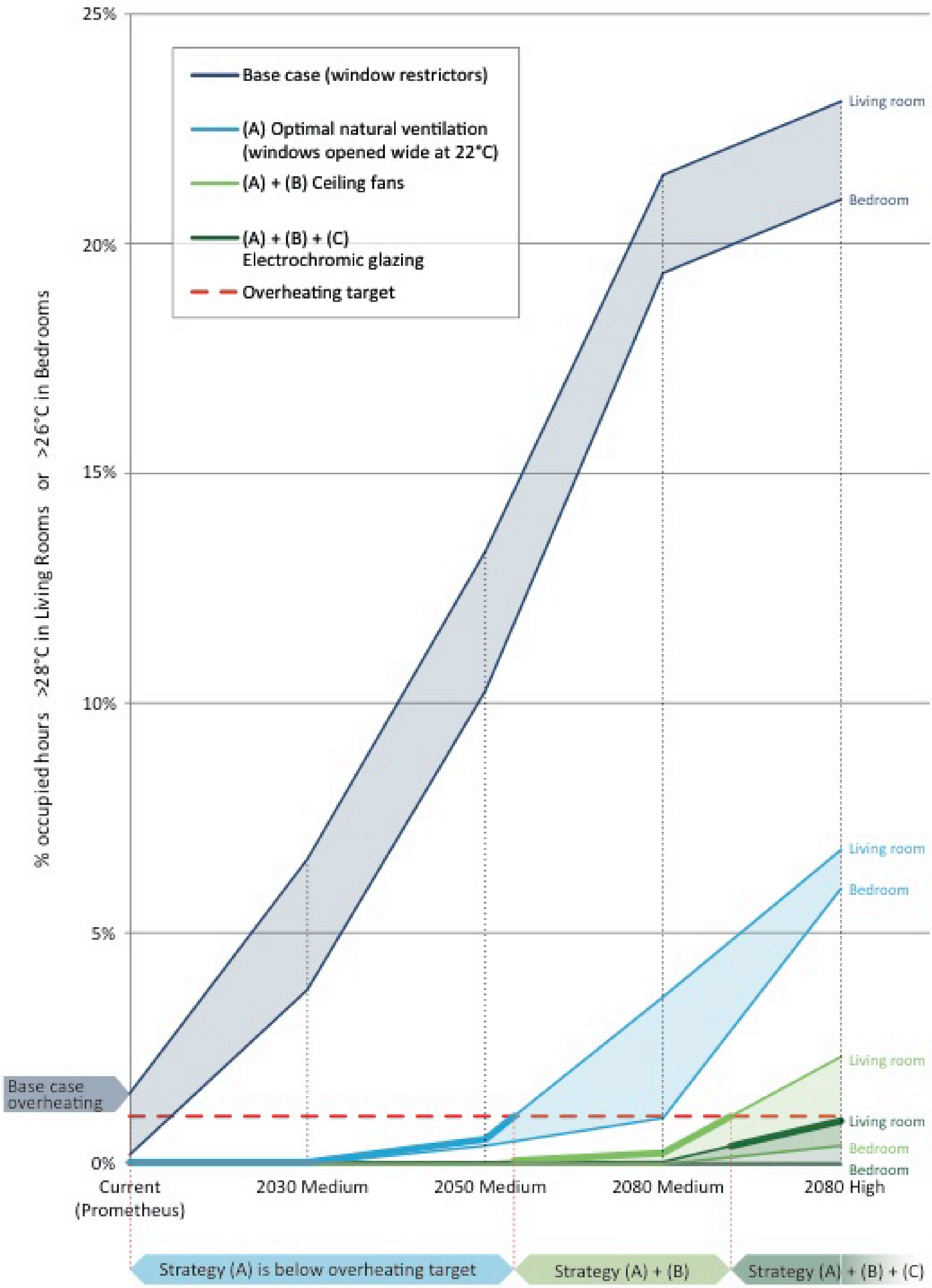


Figure 26 Proposed adaptation strategy to reduce overheating risk in One Brighton.

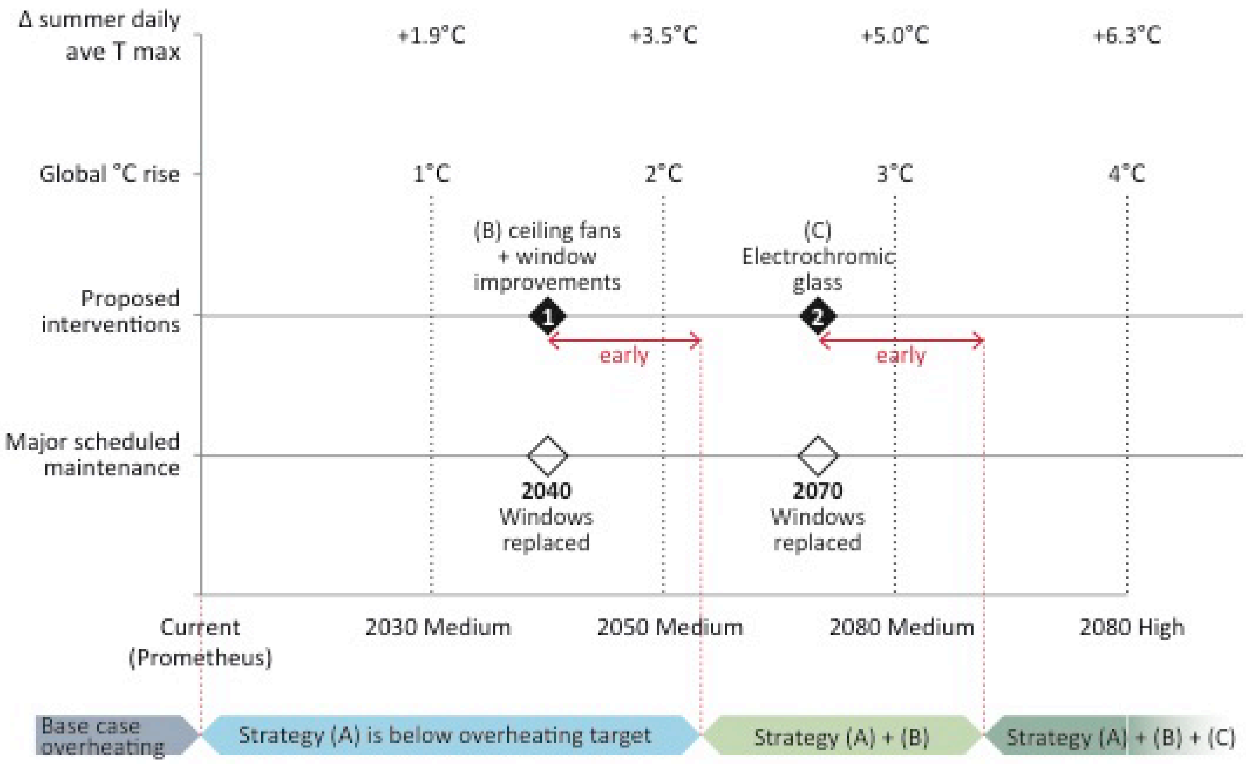


Figure 27 Proposed timeline for implementation of successive adaptation steps for One Brighton.

Maintenance requirements may also allow or demand further flexibility in the adaptation strategy. Although the windows are scheduled for replacement in 2040, it is possible they may not need replacing until later, e.g. 2070. However the glazing may fail at an earlier stage and need replacing. In this instance, it might be appropriate to consider installing electrochromic glass as a replacement sooner than 2070.

3.4 Cost Benefit Analysis

3.4.1 Cost Calculations

Table 3-5 Adaptation Measures: Cost (over and above planned like-for-like replacements) and overheating risk.

Case/ Option	Adaptation Measure	Extra cost/unit	Bedroom % occupied hours > 26 °C	Living room % occupied hours > 28 °C
Base	Base case	£0	10.3%	13.3%
	Portable AC including electricity consumption	£2,407		
01	Opaque Window Pane	£232	6.4%	11.8%
02	Internal Blinds + Opaque Window Pane	£1,233	4.3%	8.7%
03	EC Glass + Opaque Window Pane	£4,047	1.4%	2.5%
04	Interstitial Blinds	£2,285	5.1%	8.1%
05	External Blinds/Shutters	£2,425	1.4%	2.5%
06b	Security Grilles	£936	0.4%	0.5%
06c	Fewer balcony doors	£4,791	0.4%	0.5%
06g	Security Mesh/Screen	£494	0.4%	0.5%
07	Extra Mech Vent	£9,356	0.2%	0.5%
08	Ceiling Fan	£2,221	0.9%	1.8%
10	AC Linked to the MVHR	£6,675	0.5%	0.1%
11	Central Absorbtion Chiller	£12,616	0.0%	0.0%
12	Boreholes and Central GSHP	£14,270	0.0%	0.0%

Table 3-5 gives the costs calculated for each of the adaptation measures in terms of the extra cost/unit. It is assumed that options 3-5 would be implemented at planned window replacement points and options 10-12 would be implemented at planned MVHR and LPHW replacement points. Therefore the cost given is the additional cost of implementing adaptive measures at these points, rather than installing a like-for-like replacement. Detailed calculations are included in the Costing Report in Appendix 3.

If the management company does not implement any adaptation measures, occupants are likely to take action themselves, for example by buying portable air conditioning units. For comparison purposes, costs have been calculated for this option for a 30-year period, 2055-2085. We have assumed that occupants purchase only one unit and that this unit has a lifetime of 10 years. (In theory, they could move the unit between rooms, but this is likely to be impractical, especially repositioning the flexible exhaust duct). Electricity is costed at current prices (15p/kWh) but consumption has been calculated using future climate scenarios, 2050s Medium 50% and 2080s Medium 50%.

Electricity consumption has not been calculated for other, more expensive, energy intensive options, i.e. 7, 10 or 11.

3.4.2 Cost Benefit Analysis

For each of the adaptation measures considered, the extra cost per apartment has been plotted against the modelled overheating risk for the 2050s Medium 50% scenario (Figure 28). Optimal natural ventilation, i.e. opening the windows wide (options 06), is shown as a dashed blue line.

The percentage of occupied hours for which the CIBSE overheating threshold is exceeded is shown for both bedrooms and living rooms together with the CIBSE Guide A limit of 1%. As discussed in section 2.3.2, nighttime thermal comfort has a strong influence on health effects and is also harder to alleviate by behavioural adaptation. It is therefore critical to reduce overheating risk in the bedroom.

The most cost-effective measures are those which deliver a substantial reduction in overheating risk at relatively low cost. On the graph this is indicated by the green shaded area. Measures which fall within the yellow shading are either expensive or deliver insufficient benefit in terms of thermal comfort.

This graph enables us to assess which measures are most cost-effective.

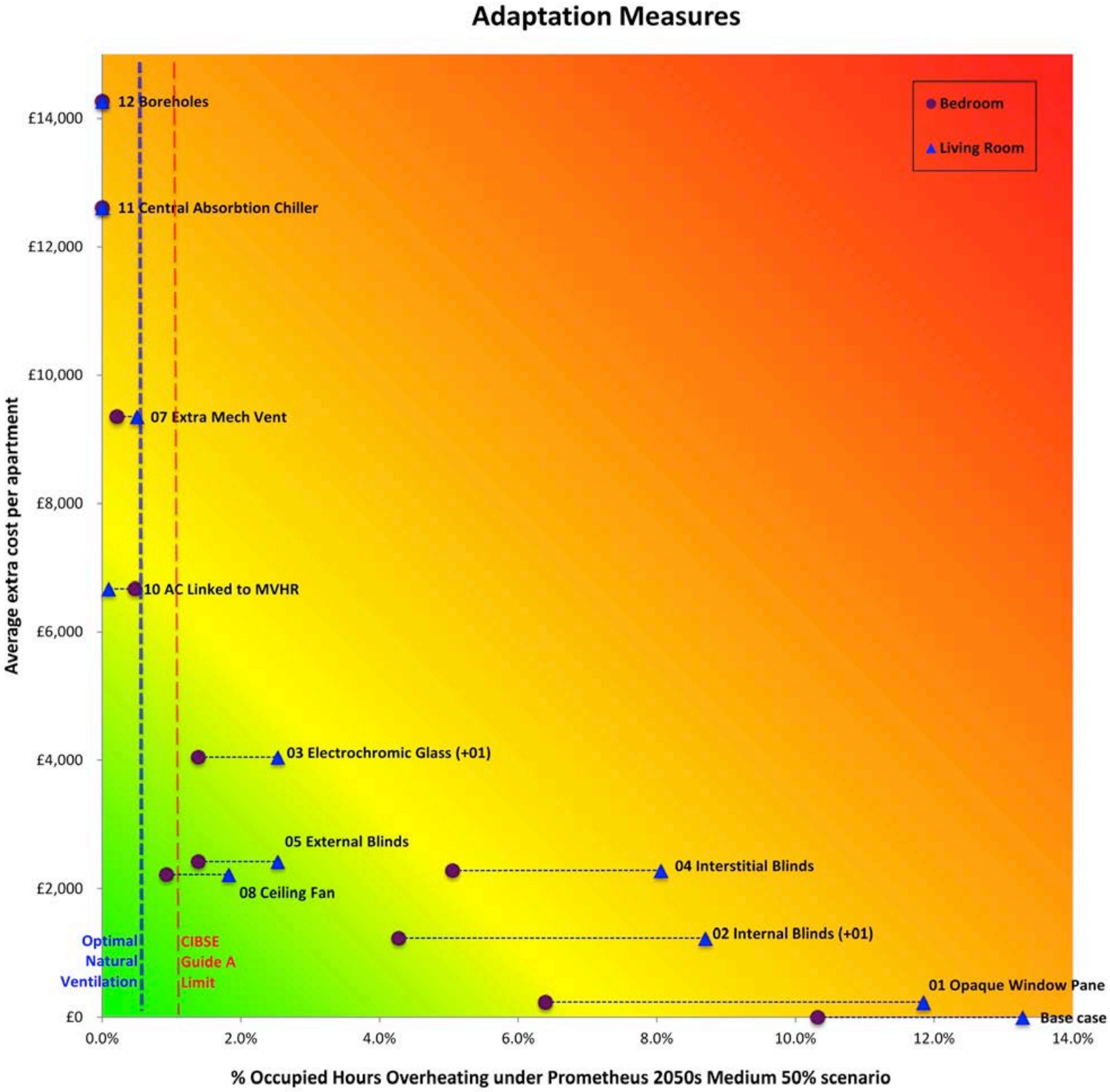


Figure 28 Extra cost versus overheating risk under 2050s Medium 50% scenario for shortlisted adaptation measures at One Brighton.

3.5 Adaptation Measures Considered

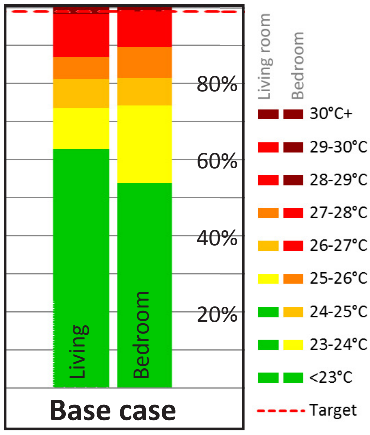
Introduction

This section of the report describes twelve specific design options, which were developed in response to the sensitivity studies carried out with the building physics model. The adaptation measures described here were also costed and remodelled in TAS. A cost-benefit analysis was carried out in order to develop the adaptation strategy.

This section of the report has been condensed for ease of reference, and the technical information about the specification and product details of the proposed measures is now included in full in Appendix 3.

A summary of the overheating results and cost for each measure is included at the bottom of each page where relevant. The graphs take the form of bar graphs that are colour coded to refelct the comfort thresholds. An example and key are shown here (right). Keys are not included on each adaptation measure page due to space.

Please refer to the full thermal modelling and cost reports in Appendix 3.



No.	Adaptation measure	Strategy type
1	Make lower window panes opaque	Reducing solar gains
2	Internal, framed blind fixed to windows	
3	Electrochromic glass	
4	Interstitial blind	
5	External blind / shutter	
6	Better natural ventilation by addressing the reasons people don't want to open their windows: a. Better Restrictors b. Security screens c. Attenuated louvers etc	Greater ventilation
7	Extra mechanical ventilation	
8	Ceiling fan	Perceived cooling
9	Phase change materials	Thermal mass
10	Air conditioning unit linked to MVHR	Active cooling
11	Central cooling from an absorbtion chiller, running off Biomass boiler	
12	Central cooling from boreholes with interseasonal storage	

Recommended Adaptation Measures

Table 3 6 summarises the adaptation strategy and the measures recommended. A full adaptation checklist is included in Appendix 3.

Adaptation Strategy	**Time Frame/** **Recommended Measure**
Strategy A	**Up to 2040**
Educate residents about opening their windows to provide optimal natural ventilation.	Adaptation Option 06
Educate residents to close internal blinds or curtains during hot, sunny weather.	Adaptation Option 02
Provide daily weather forecast information, together with recommended action, via the green caretaker. This information could be displayed in the foyer or even disseminated via a smartphone app.	
Strategy B	**2040** **Planned Window Replacement**
Implement measures to allow more secure window opening for natural ventilation.	Adaptation Option 06
Install ceiling fans to provide perceived cooling benefit.	Adaptation Option 08
Strategy C	**2070** **Planned Window Replacement**
Install ElectroChromic glass to provide shading from solar gain (except in lower pane of bedroom window).	Adaptation Option 03
Install opaque panel in lower pane of bedroom window to provide shading from solar gain.	Adaptation Option 01

Adaptation 01 - Opaque lower window panes

Overview

Many of the bedroom windows have a horizontal transom at 1100mm with the lower pane fixed and the upper part an openable windows. It is proposed that the bottom pane of glass could be made opaque as it contributes as much solar gain as the top part but with little benefit to the daylighting of the room.

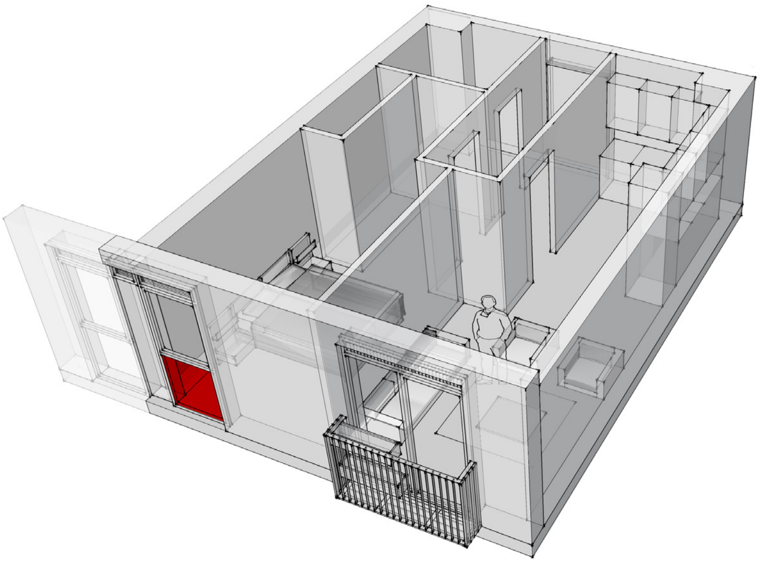
On a typical 1-bed flat this would be one pane of glass as shown in the diagram below.

Detailed Design

For practical reasons of access, installation would need to be from outside using a cherry picker.

Opaque films applied to the existing glazing would need to be on the external face of the glass, which would result in a shorter life span and inconsistent finish. It is therefore proposed to replace the glazed unit with an opaque one with dark blue ceramisized finish to match the existing opaque panels. The glazed unit would be triple glazed, argon filled, to match existing specification & performance.

Warranty for 10 years; Expected life span of 20-25 years. No maintenance required other than normal cleaning.

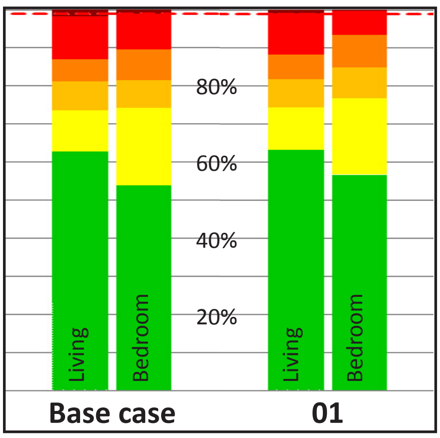


1 = Existing opaque glass panel

2 = Proposed opaque glass panel

Overheating results (summary)

		Base case	01
Living Rooms	>25°C	37%	37%
	>28°C	13%	12%
	Peak	32°C	32°C
Bed-rooms	>23°C	46%	43%
	>26°C	10%	6.4%
	Peak	30°C	29°C



Cost

£/m2 NIA	£4
£/flat	£232
£ Total	£39,920
Build time	6 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 02 - Internal, framed blind fixed to windows

Overview

It is proposed that internal, framed blinds could be fitted to the existing windows. The advantage of this over curtains or blinds that have already been installed by occupants is that the blinds stay attached to the windows or doors as they open and so offer solar shading without reducing natural ventilation.

It is proposed that this is used in combination with opaque lower window panes (adaptive measure 01) to avoid installing impractical blinds at low level.

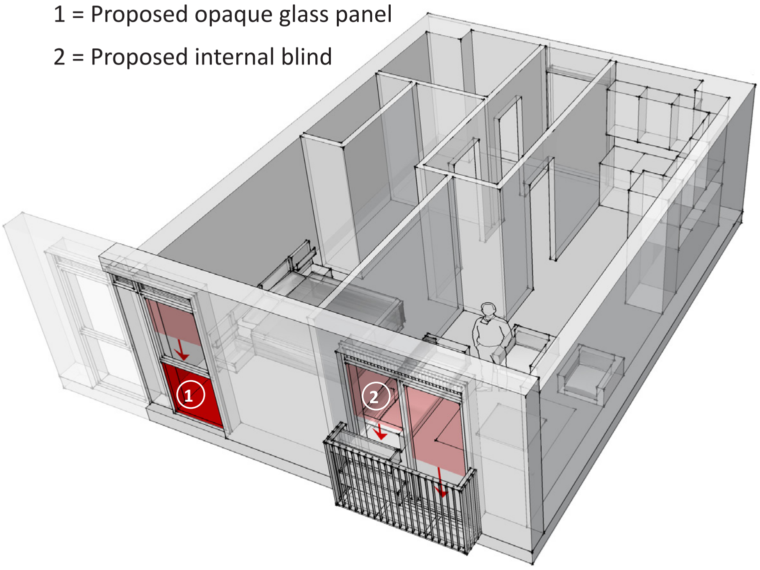
They could be installed from inside at relatively low cost, but this raises issues of access through privately owned flats. There would be nothing stopping some owners or tenants taking them off in the future or, indeed, or occupants installing them independently.

Detailed Design

A venetian blind gives maximum flexibility for solar and daylight control. Blinds should be silvered to maximise the light reflected back out the window and minimise the heat gain.

1 = Proposed opaque glass panel

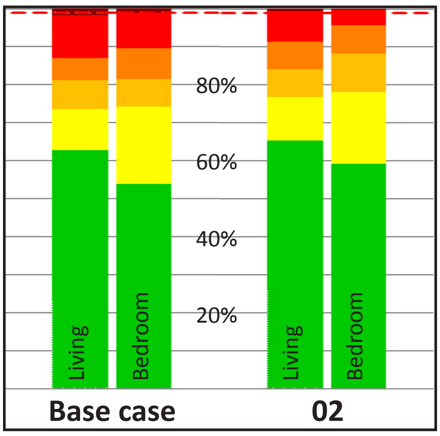
2 = Proposed internal blind



Examples of framed internal blinds

Overheating results (summary)

		Base case	02
Living Rooms	>25°C	37%	35%
	>28°C	13%	8.7%
	Peak	32°C	31°C
Bed-rooms	>23°C	46%	41%
	>26°C	10%	4.3%
	Peak	30°C	28°C



Cost

£/m2 NIA	£23
£/flat	£1,233
£ Total	£212,076
Build time	7 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 03 - Electrochromic Glass

Overview

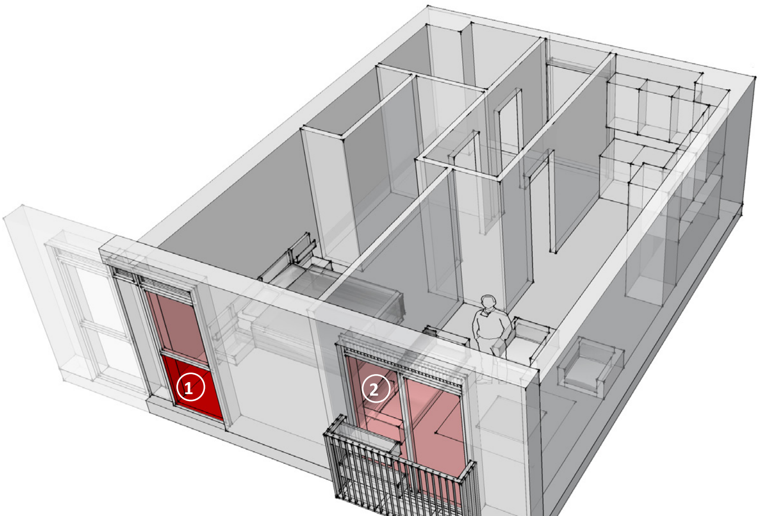
Electrochromic glass is a type of 'smart glass' or 'dynamic glazing', which changes its light transmission properties when a voltage is applied across it. The electrochromic layer in the glass changes between a coloured, translucent state (usually blue) and transparent. A burst of electricity is required to change its opacity, but no electricity is needed to maintain either state. Darkening can take several minutes.

It is proposed that this is used in combination with opaque lower window panes (adaptive measure 01) to reduce costs.

Detailed Design

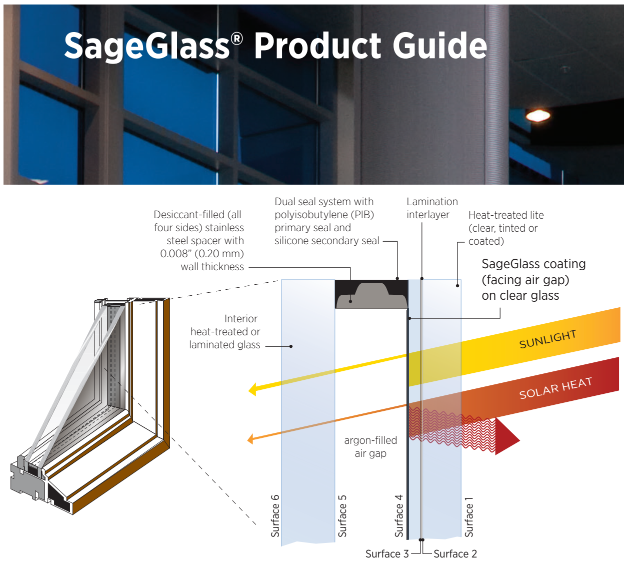
Costings and analysis are based on Sage Glass by Saint Gobain. The glazing unit would be triple glazed and argon filled, as existing. Electrical power is supplied by thin film photovoltaic cells mounted onto each pane of glass. These take up 5% of the area of each window pane. The visible light transmission changes from 54% to 1% between states.

It is possible to retrofit into the existing frames and avoid replacement of the whole window unit. It is anticipated that currently high costs are likely to reduce significantly by the time the intervention needs to be made. The expected life span is 20-25 years and no maintenance is required other than normal cleaning.



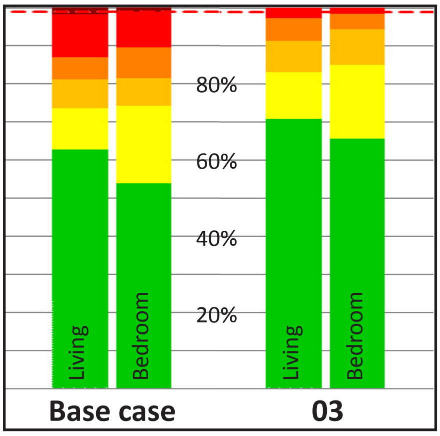
1 = Proposed opaque glass panel

2 = Proposed electrochromic glass



Overheating results (summary)

		Base case	03
Living Rooms	>25°C	37%	29%
	>28°C	13%	2.5%
	Peak	32°C	30°C
Bed-rooms	>23°C	46%	34%
	>26°C	10%	1.4%
	Peak	30°C	27°C



Cost

£/m2 NIA	£75
£/flat	£4,047
£ Total	£696,044
Build time	12 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 04 - Interstitial Blinds

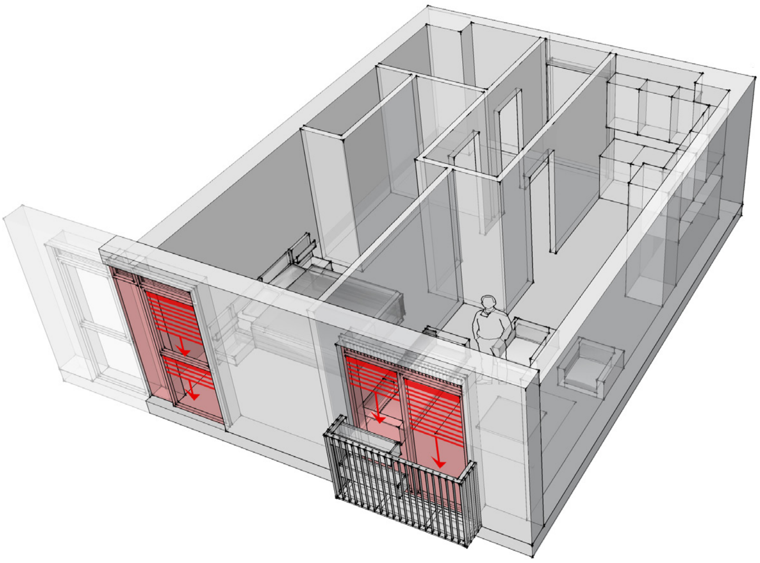
Overview

Interstitial blinds are more efficient at keeping out the heat than internal blinds as the heat is stopped before it has entered the flat. They trap heat close to the window so would result in slightly more heat transfer than a fully external blind / shutter. The advantage it has over an external blind is that the blind can be down when the window is open without impeding the ventilation.

Detailed Design

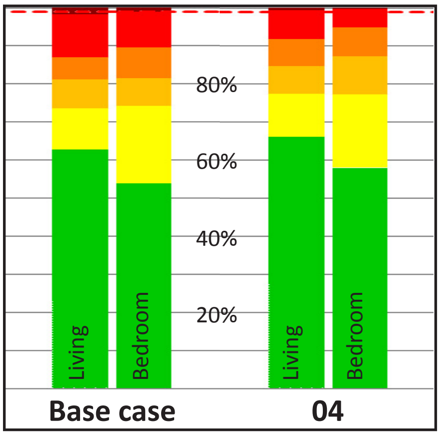
Fitting interstitial blinds would require the replacement of the whole window unit as it is not possible to fit one within the existing frame due to the extra thickness of the 4 panes of glass plus blind. Maintenance possible from inside due to inward opening window units and openable pane to access the blind.

Pricing and analysis is based on an Internorm (HV 240, Varion 4 Flush), with timber / aluminium composite window frame, and a triple glazed unit, as shown.



Overheating results (summary)

		Base case	04
Living Rooms	>25°C	37%	34%
	>28°C	13%	8.1%
	Peak	32°C	31°C
Bed-rooms	>23°C	46%	42%
	>26°C	10%	5.1%
	Peak	30°C	29°C



Cost

£/m2 NIA	£42
£/flat	£2,285
£ Total	£392,980
Build time	12 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

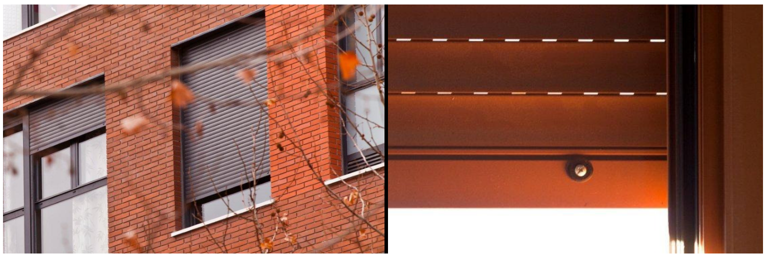
Adaptation 05 - External blinds & shading

Overview

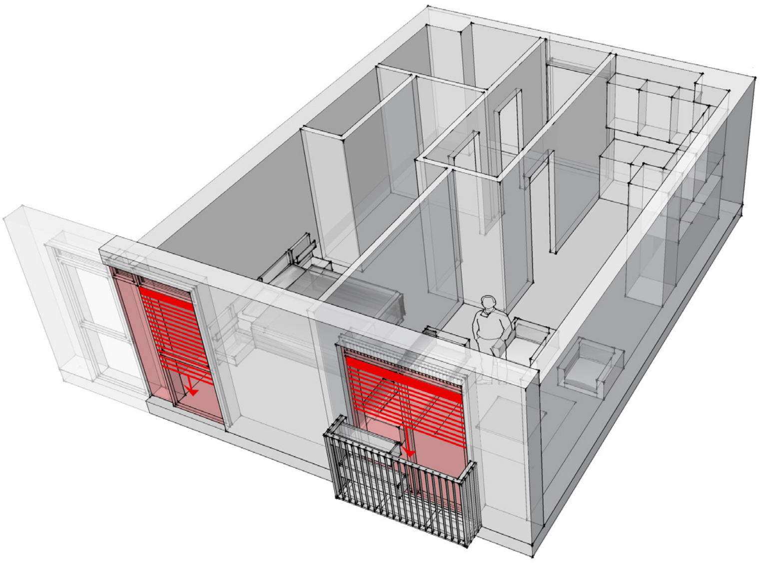
External blinds or shading is the most thermally effective method of reducing solar gains. There are numerous options, but most posed problems for retrofit installation. Horizontal brise soleil are not effective for east-west facades. A bolt-on external blind was rejected because it would cover the intake / extract for the MVHR.

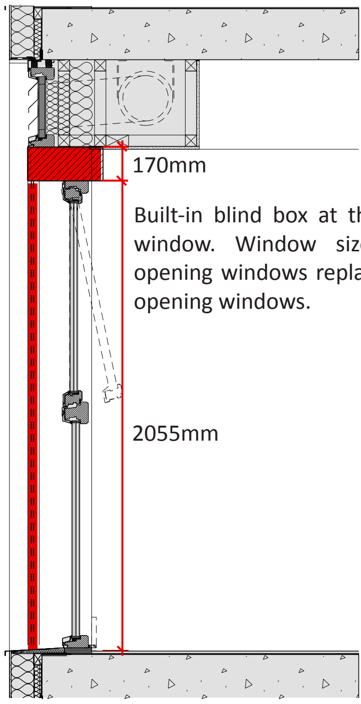
Detailed Design

The solution proposed and costed is a built-in external shutter blind by Enviroblinds and requires the replacement of the whole window unit to incorporate the new blind. Warranty is for 5 years and expected life span is 25 years. Built-in blind allows maintenance from the inside.



Left: Enviroblind brochure images. Top right shows the small holes in the blind when not fully collapsed. These allow 5% free areas.

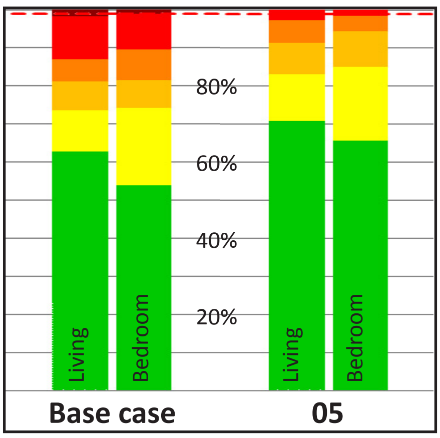




Built-in blind box at the head of each window. Window size reduced and opening windows replaced with inward opening windows.

Overheating results (summary)

		Base case	05
Living Rooms	>25°C	37%	29%
	>28°C	13%	2.5%
	Peak	32°C	30°C
Bed-rooms	>23°C	46%	34%
	>26°C	10%	1.4%
	Peak	30°C	27°C



Cost

£/m2 NIA	£45
£/flat	£2,425
£ Total	£417,060
Build time	12 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 06 - Better Natural Ventilation

Overview

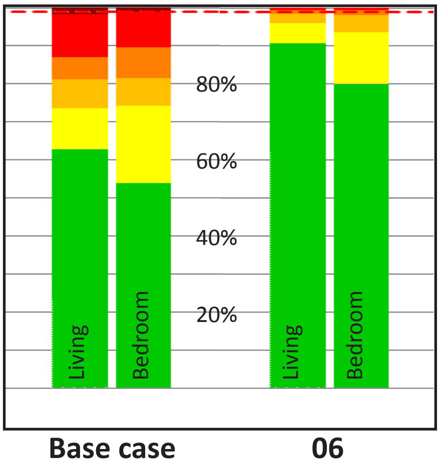
Optimal natural ventilation for the apartment was modelled by assuming that all windows are opened wide, overriding the restrictors, when the internal temperature exceeds 22°C. The balcony doors were assumed to be open to a maximum of 90% free area when the living room is occupied (all day) and the remaining windows were assumed to be opened to a maximum of 50% free area when the flat is occupied (all the time for this case).

Role of MVHR

It was a surprising and important finding that the MVHR system has an important function in the natural ventilation strategy in helping to draw the window ventilation deeper into the spaces. Without the MVHR running, opening the windows wide is much less effective in preventing overheating, especially in the bedroom.

Overheating results (summary)

		Base case	06	06 (no MVHR)
Living Rooms	>25°C	37%	9.2%	15%
	>28°C	13%	0.5%	1.6%
	Peak	32°C	29°C	31°C
Bed-rooms	>23°C	46%	20%	45%
	>26°C	10%	0.4%	9.7%
	Peak	30°C	27°C	30°C



Limitations

The results for optimum natural ventilation show that this is an effective strategy for reducing overheating. In practice, however, there are several reasons why people might not want to open their windows for ventilation even when it would be beneficial for their thermal comfort. Many of these are inter-linked.

Security - Do occupants not want to ventilate their flats at night for security reasons?

Safety - One occupant has expressed concern about their pet falling out. This might also be a concern for occupants with young children, although restrictors, balustrades and window heights should avoid this.

Control - Do windows have enough options in how much they are opened or restrained? Patio doors are included in ventilation calculations but these don't have any restrictors, so do not provide fine control.

Noise Particularly from New England Street – occupants have complained that it is too noisy to open their windows. Overheating is less likely to happen when these conditions are present anyway.

Wind & Rain - Is it possible for people to still use windows and doors for ventilation if it is windy? Do they let the rain in?

Bugs & pollen - Less of a problem on this site but could be a reason for occupants to use windows less.

A number of adaptation measures are suggested below to tackle these issues. It is not possible to model what impact any of these adaptations would have as they affect occupant behaviour rather than building physics.

	Security	Safety	Control	Noise	Wind & Rain	Bugs & Pollen
Existing Design						
06.a) Restrictors						
06.b) Security Grills						
06.c) Fewer doors						
06.d) Attenuated ventilation						
06.f) Dual aspect						
06.g) Mesh screen						

Existing Design

The existing window restrictors are shown on the photo below. They allow 100mm of movement, which leaves a 50-60mm gap between the frames in the open position, and are released by pressing a button (A). They are designed as a safety mechanism to protect children and are not secure against burglars. The windows are top hung, open out, which gives the best protection against rain and wind with the windows open.

06.a) Restrictors (Security, Safety, Control, Wind)

Available restrictors were researched in some detail and there appears to be significant potential potential for innovation in this market .

The window manufacturers advised that even the most robust restrictor mechanism would be unlikely to obtain security certification owing to the leverage available to a determined intruder once the window was ajar.

Options to address this might include: The development of restrictors with variable opening settings. Although these might not achieve full security certification, they might provide sufficient reassurance to occupiers for them to leave windows open at night for example.

Standard parallel opening window

Parallel opening window with extra opening mechanisms to create a secure and safe opening

Product development needed from the industry:

Secure restrictors. Even if these don't pass security tests or standards they are still valuable to prevent opportune break-ins and to give people a sense of security. The only ones currently available seem to be ugly add-ons. It should be possible to have one integrated with the restrictor.

Variable restrictors. Restrictors that you can choose the amount of movement. For example if your window is in a 150mm reveal, a restrictor allowing 200mm of movement could still allow a 'safe' gap of less than 100mm. There are some of these on the market but need to be more widespread.

Restrictors with multiple restrictor distances. This would be particularly useful in tall buildings where occupants may want to open their windows more for ventilation without the risk of them blowing around.

For parallel motion windows – could there be extra 'X' shaped pivot mechanisms that could allow a large free area but keep the window secure? This could feel a bit prison-like?

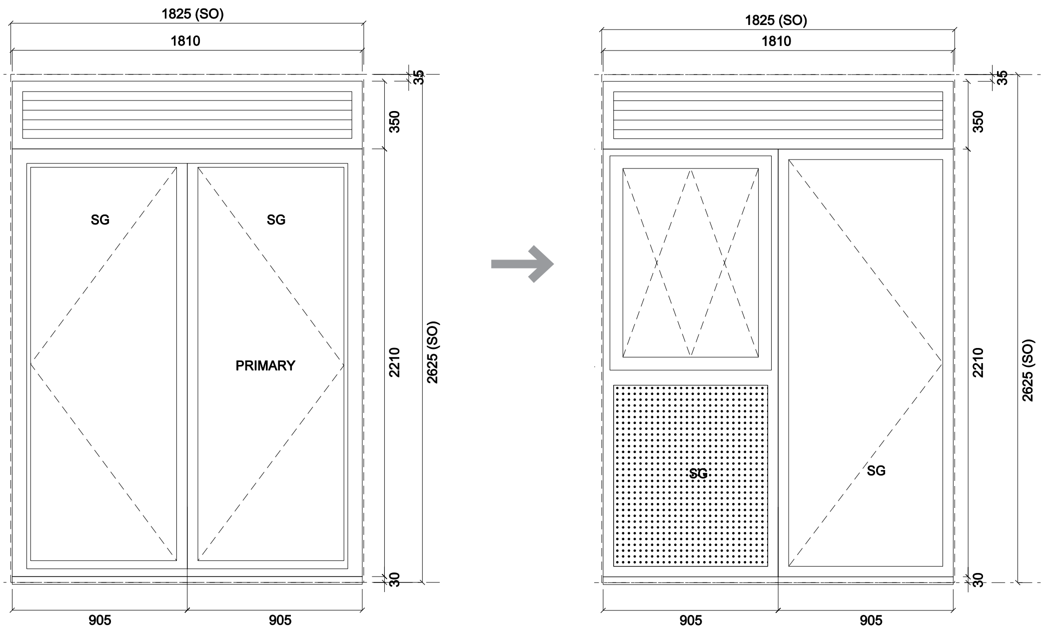
06.b) Security grills (Security, Safety)

Internal security grills that fold back to the sides are effective, and a popular option in crime areas but can be unsightly and make people feel 'imprisoned'. Fixed ones such as the example pictured below can be better designed but cut out a most of the light to the opening window, which makes them less practical for housing, and not very viable as a retrofit option. They are more useful for small, high level windows to provide secure night time ventilation.

Fixed louvre over an opening window on Drapers' Academy, by Feilden Clegg Bradley Studios provides secure and weather proof ventilation.

06.c) Fewer doors, more windows (Security, Safety, Control, Wind)

Patio doors cannot be secured whilst still providing ventilation. Changing some of the doors (e.g. one of a double door) into a window with a fixed pane below would improve this, as it would be possible to use just the window on a restrictor for ventilation.



06.d) Attenuated natural ventilation (Security, Safety, Noise, Wind)

Attenuated (noise reduced) natural ventilation can be provided by extending the air path and passing it through acoustically absorptive material. This is normally achieved by an external louvre with a large attenuated box behind. The inside face of the box would have an opening 'door' which could be left open for quiet natural ventilation. No detailed studies have been done, but from other examples, boxes could be up to 0.5m deep. This would reduce a lot of daylight and take up a lot of space. It is difficult to achieve large free areas by this method.

Britton Pears Museum, by Stanton Williams

f) Dual aspect (Control, Noise)

Dual aspect flats allow cross ventilation, which is more effective at pulling the air through the space. Dual aspect properties mitigate against noise problems if at least one aspect is quieter. Although not a retrofit option for One Brighton, it should be considered for new build.

g) Mesh screens (Safety, Wind, Bugs & Pollen)

These can be hinged panels or blinds with sealed edges. The disadvantage is a reduction in free area.

Adaptation 07 - Extra Mechanical Ventilation

Overview

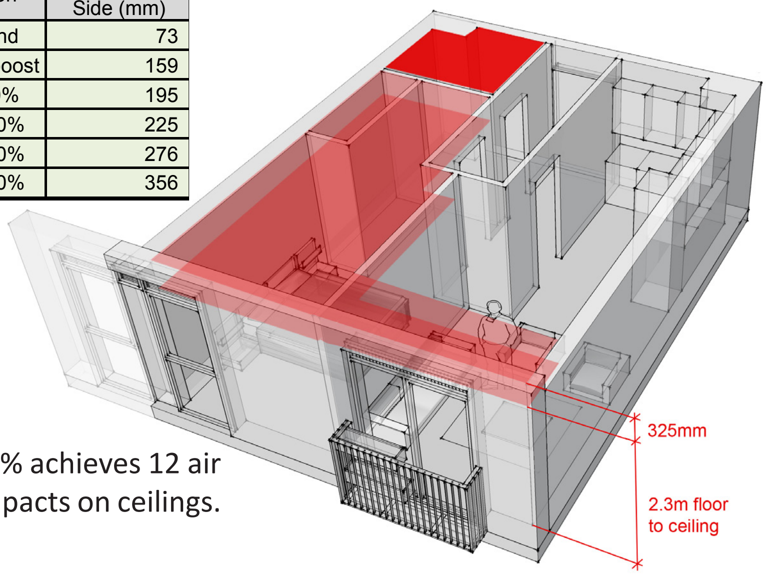
Mechanical ventilation is already provided via the MVHR units. Mechanical ventilation solves most of the problems with natural ventilation that were identified in 06 above, but comes at the cost of energy and space.

The theory with this adaptation strategy was to increase the duct size and fan power to allow the MVHR to provide greater purge ventilation without making it unacceptably noisy.

Detailed Design

Increase the boosted MVHR flow rate to achieve greater air changes / hour. Air speed in the ducts should be limited to 3 m/s to avoid the system becoming too noisy. This in turn requires larger ducts and larger grill areas over the external windows. See table below:

Flat area (m²)	Height (m)	Air ch /hr	Vent rate relative to base	Description	Square duct Side (mm)
45.7	2.55	0.5	21%	Background	73
45.7	2.55	2.4	100%	Base case boost	159
45.7	2.55	3.5	150%	Boost +50%	195
45.7	2.55	4.7	200%	Boost +100%	225
45.7	2.55	7.0	300%	Boost +200%	276
45.7	2.55	11.8	500%	Boost +400%	356



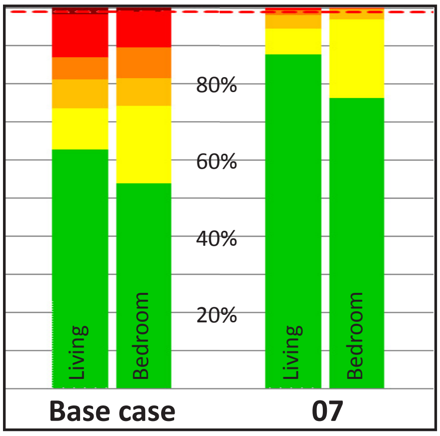
Boost flow rates +400% achieves 12 air changes / hour but impacts on ceilings.

For example, original boost flow rates +400% achieve about 12 air changes / hour, but requires supply and exhaust ducts that are 400mm diameter or equivalent. Shallower, wider ducts could be used but require the whole bedroom to be covered with ceiling, and the MVHR itself to get larger too.

Installation would be extremely disruptive for occupants and might not be possible via the lease agreements. Maintenance of MVHR unit is occupant responsibility.

Overheating results (summary)

		Base case	07
Living Rooms	>25°C	37%	12%
	>28°C	13%	0.5%
	Peak	32°C	29°C
Bed-rooms	>23°C	46%	24%
	>26°C	10%	0.0%
	Peak	30°C	26°C



Cost

£/m2 NIA	£173
£/flat	£9,356
£ Total	£1,609,232
Build time	12 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 08 - Ceiling Fan

Overview

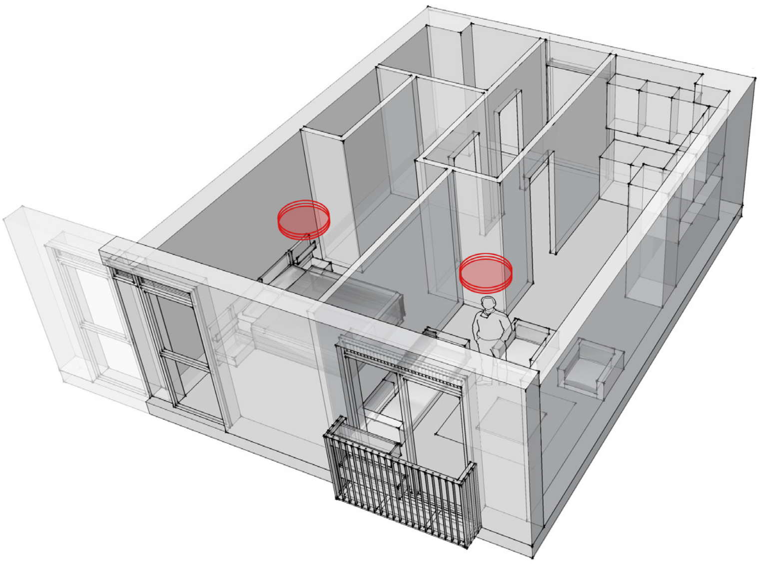
Ceiling fans don't actually cool spaces, but they provide perceived cooling due to the evaporative effect of the air movement on occupants.

Perceived cooling varies depending on the conditions and in hot, dry climates, can be as much as 5-6°C. After comparing various data, a 2°C cooling effect has been applied for the fan. The results shown are the base case data off-set by 2°C.

Detailed Design

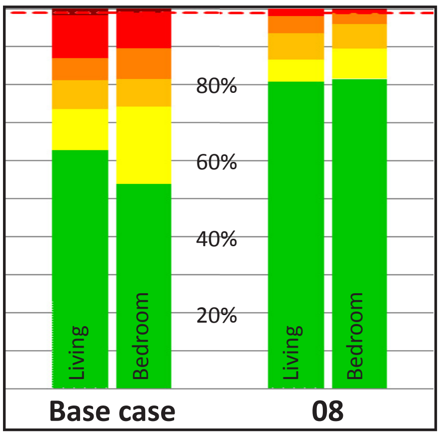
Although ceiling heights are 2.62m which should allow the installation of a conventional ceiling fan to provide 2.3 m clearance beneath it (the recommended minimum), it might still be within the reach of a tall person so a bladeless fan is proposed.

The costing is based on an Exhale bladeless ceiling fan for each habitable room, which is 864mm wide x 184mm high, and operated by remote control.



Overheating results (summary)

		Base case	08
Living Rooms	>25°C	37%	19%
	>28°C	13%	1.8%
	Peak	32°C	n/a
Bed-rooms	>23°C	46%	18%
	>26°C	10%	0.9%
	Peak	30°C	n/a



Cost

£/m2 NIA	£41
£/flat	£2,221
£ Total	£382,012
Build time	5 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 09 - Phase Change Materials

Overview

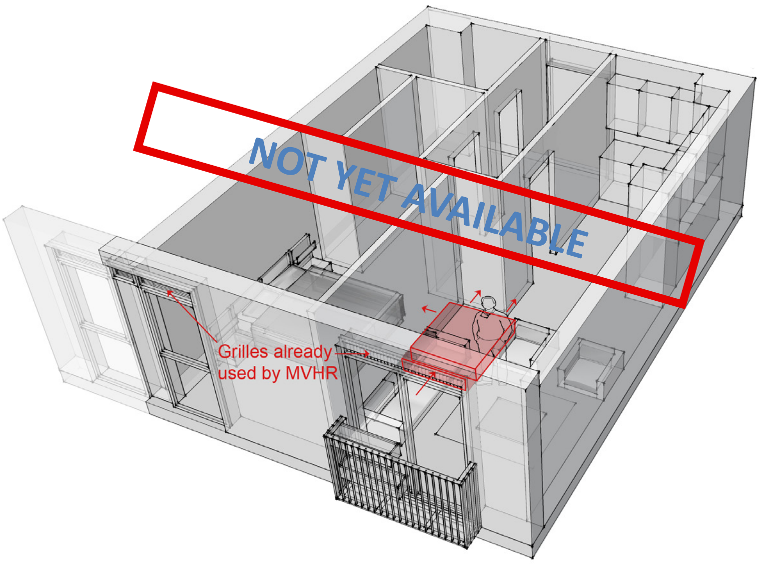
It was established by thermal modelling that the thermal mass of the concrete soffit in One Brighton was beneficial for thermal comfort (see section 8 of the thermal modelling report). However the benefit is dependent on good ventilation to make use of it. Phase change materials used passively on their own, such as plasterboard containing microencapsulated phase change materials, would therefore offer little additional benefit.

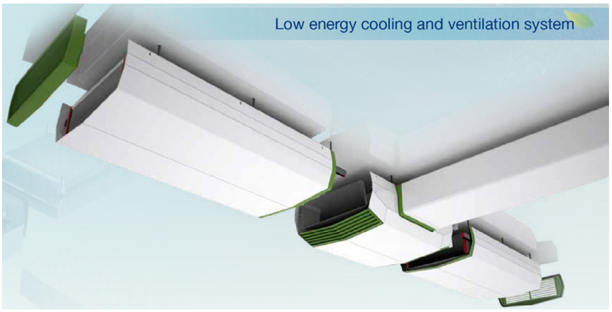
There are products that incorporate phase change materials with active mechanical ventilation, such as Monodraught's Cool-phase systems. Unfortunately these make too much noise when recharging at night to be suitable for residential properties and are only recommended for buildings that are unoccupied at night. The ceiling unit is also too large and the smaller wall unit has been discontinued.

There are currently no suitable products to propose.

Product development needed from the industry:

A smaller, residential compatible version of the Cool-phase unit would be a welcome industry innovation.





Monodraught Cool-phase units make too much noise when recharging at night to be suitable for residential properties and are only recommended for buildings that are unoccupied at night. A smaller, residential compatible version would be a welcome industry innovation.

Adaptation 10 - Air Conditioning Unit linked to MVHR

Overview

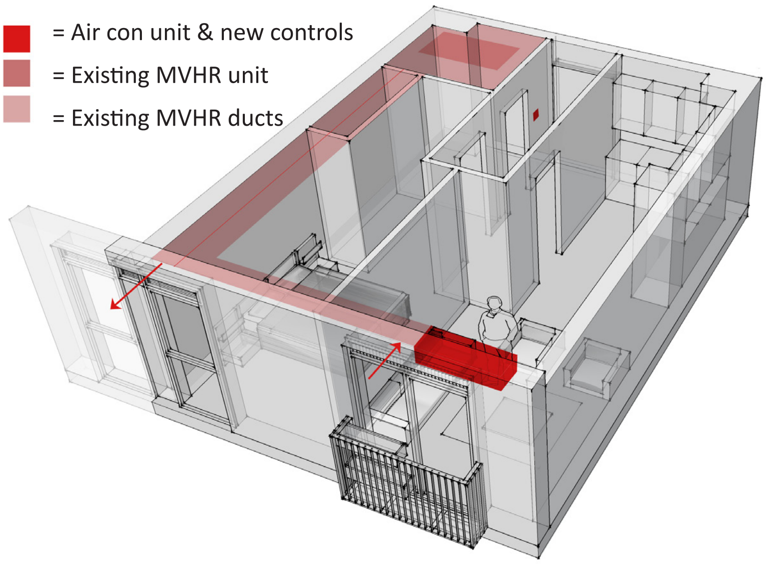
In extreme future climate scenarios it may not be possible to solve overheating in the properties without active cooling measures. Low and zero carbon options for active cooling are proposed in adaptation measure 11, but these involve site-wide strategies and major infrastructure investment.

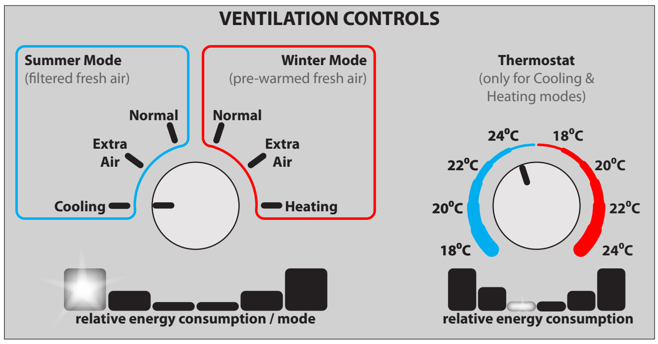
The least energy intensive method of providing local cooling for each flat is thought to be a small air conditioning unit linked to the intake air for the MVHR. This would avoid the need for an extra box or fan on the outside of the building.

Detailed Design

The unit would be sized to peak-lop the temperatures, not provide full temperature control. Controls for the unit would be incorporated into a revised control switch for the MVHR unit (see proposed interface, right).

Warranty typically 5 years. Expected life span typically 15-20 years.



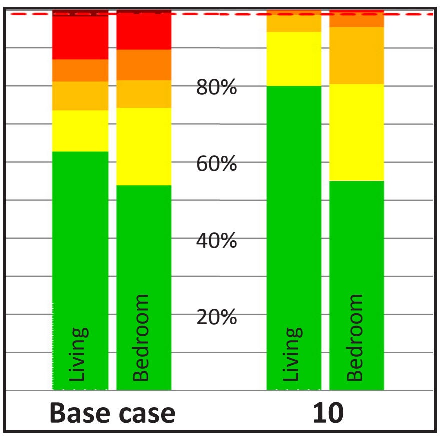


Above: Diagram of what some ideal controls could look like for the proposed system.

(based on ideas from: BCIA publication "Controls for End Users" by Bill Bordass, Adrian Leaman and Roderic Bunn)

Overheating results (summary)

		Base case	10
Living Rooms	>25°C	37%	20%
	>28°C	13%	0.1%
	Peak	32°C	28°C
Bed-rooms	>23°C	46%	45%
	>26°C	10%	0.5%
	Peak	30°C	27°C



Cost

£/m2 NIA	£124
£/flat	£6,675
£ Total	£1,148,016
Build time	12 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 11 - Central Absorption Chiller

Overview

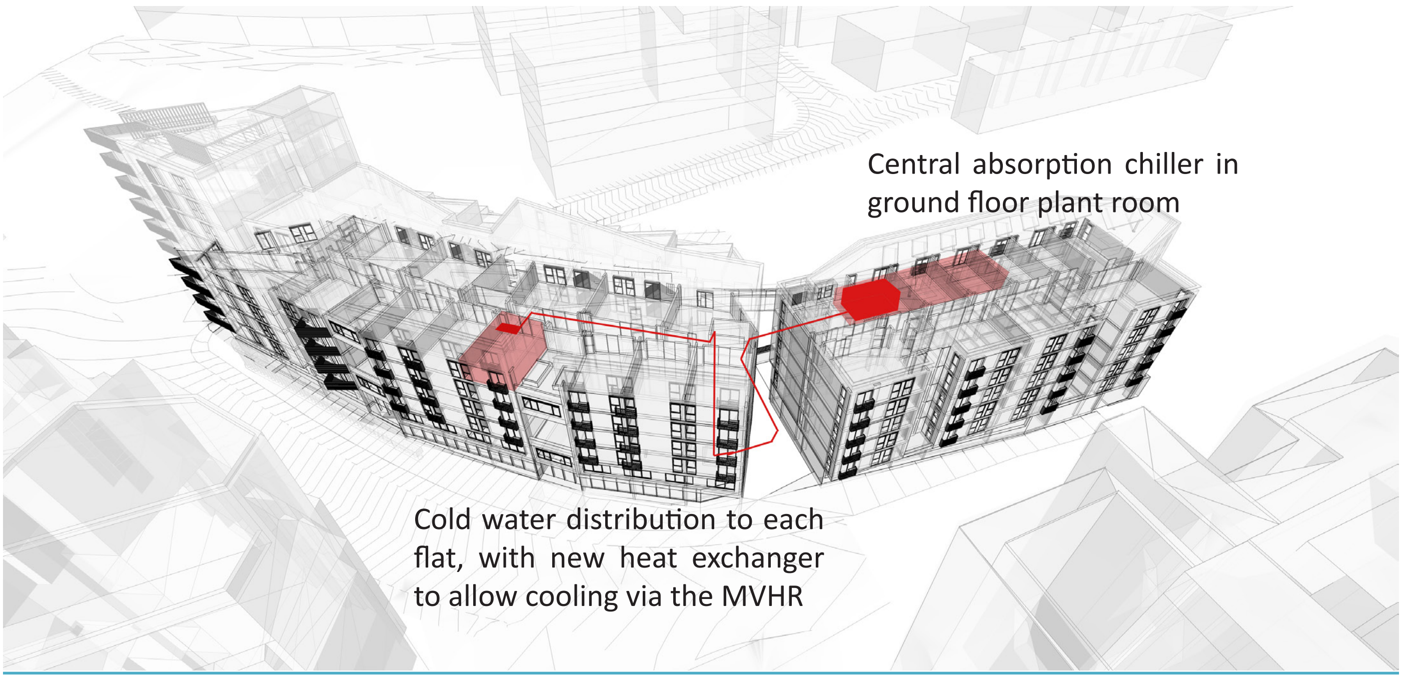
This adaptation measure involves installing an absorption chiller powered by the biomass boiler, which could supply low-carbon cooling to all the flats.

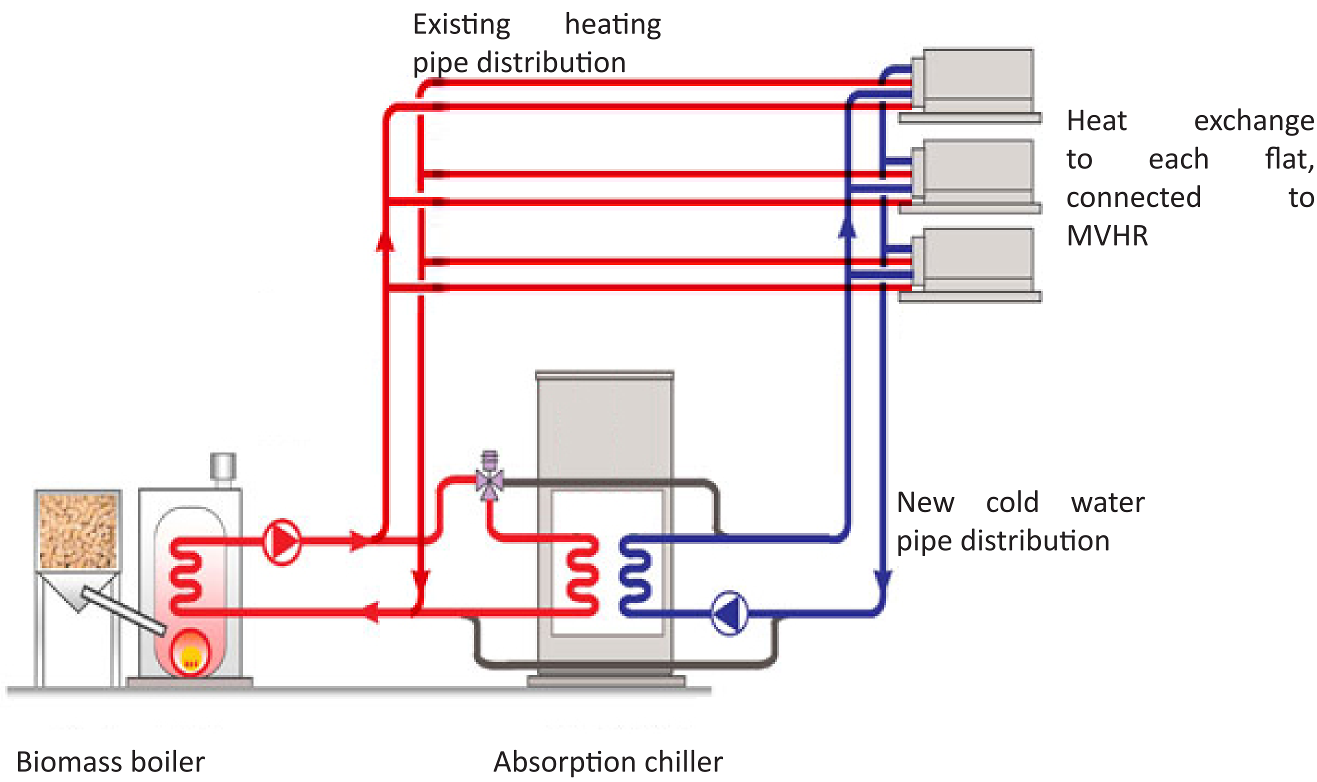
The supply would involve new services distribution of cold water (or possibly variable flow refrigerant) pipes to all flats from the central plant room. The heat exchange unit in every flat would have to be replaced, or an extra one added, to be able to exchange coolth as well as heat from central pipes to local pipes. The MVHR units would also need replacing to be able to exchange coolth as well as heat into the air supply.

Detailed Design

The peak cooling load for our worst case flat is approximately 1.3kW. As a worst case, and with some diversity applied, it might be reasonable to assume the peak cooling load for an absorption chiller would be in the order of 100-150 kW.

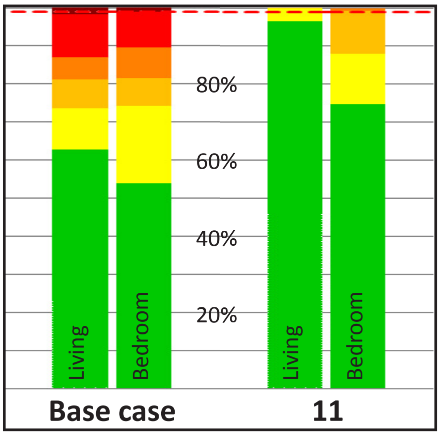
Warranty typically 5 years. Expected life span typically 15-20 years.





Overheating results (summary)

		Base case	11
Living Rooms	>25°C	37%	3.4%
	>28°C	13%	0.0%
	Peak	32°C	25°C
Bed-rooms	>23°C	46%	25%
	>26°C	10%	0.0%
	Peak	30°C	26°C



Cost

£/m2 NIA	£234
£/flat	£12,616
£ Total	£2,170,020
Build time	20 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Adaptation 12 - Boreholes & central ground source heat pump

Overview

This adaptation measure involves drilling geothermal boreholes, linked to a ground source heat pump, which could supply low-carbon cooling to all the flats.

As with the absorption chiller (see section 11, above), the supply would involve new services distribution of cold water pipes to all flats from the central plant room. The heat exchange unit in every flat would have to be replaced, or an extra one added, to be able to exchange coolth as well as heat from central pipes to local pipes. The MVHR units would also need replacing to be able to exchange coolth as well as heat into the air supply.

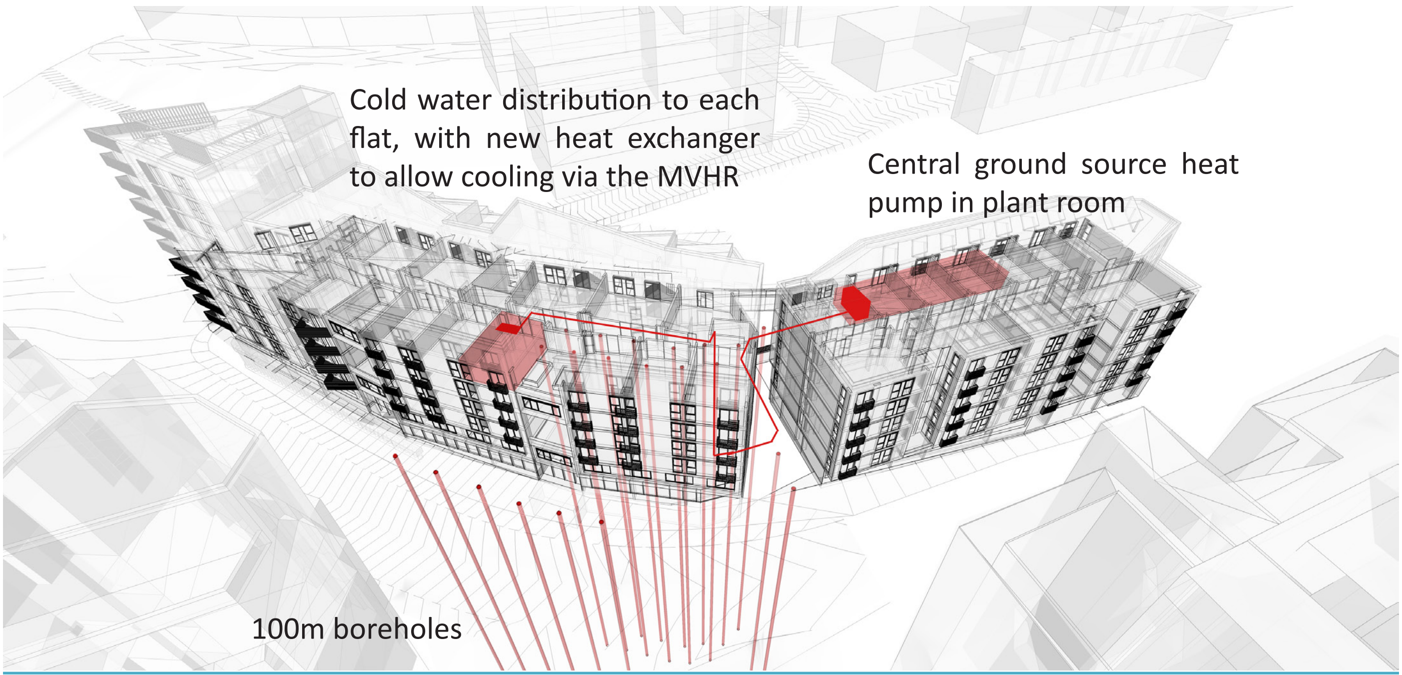
Detailed Design

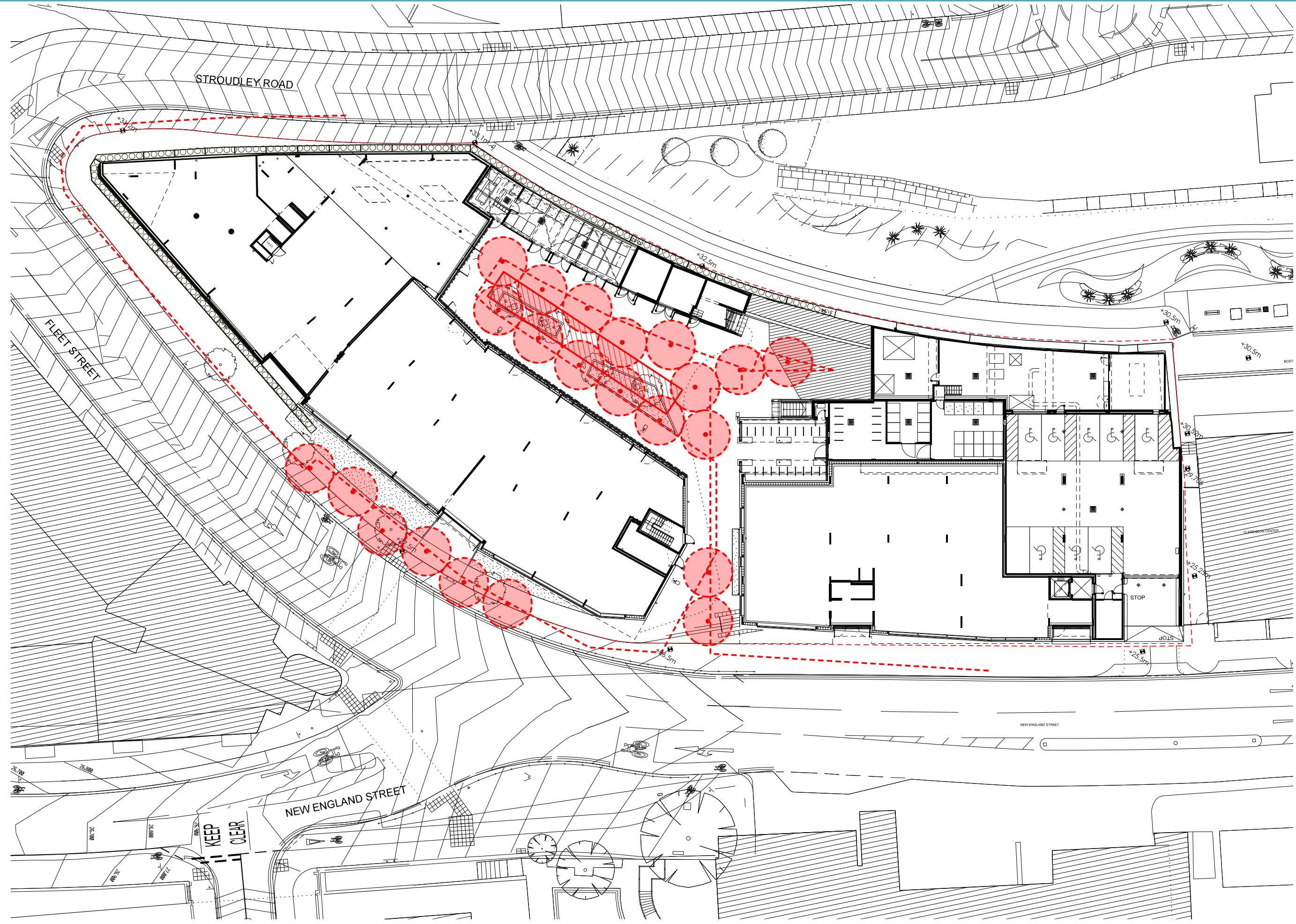
The peak cooling load for our worst case flat is approximately 1.3kW. The maximum capacity of a borehole cooling system divided by the number of flats would give them 0.36kW of cooling each if they all use cooling simultaneously. If a 2/3 diversity is applied, the capacity would be 0.54kW which would not be sufficient to maintain design temperatures in peak summer conditions, but might be a useful contribution to keeping overheating hours below 1%. More detailed design would be necessary to establish whether this was a viable option.

Estimated borehole cooling capacity		
No. of boreholes (estimate)	22	
Depth of boreholes	100	m
Specific heat extraction rate (estimate)	40	W/m
Extracted cooling capacity	88	kW
System efficiency (estimate)	0.7	
Delivered cooling capacity	62	kW
Delivered cooling capacity / flat	358	W

Cooling on normal ventilation speed (typical flat)		
Cooling Capacity:	358	W
Air Specific Heat Capacity:	1.21	J/l/K
Flow Rate:	17	l/s
Delta T (of supply air)	17.4	^{o}C

Cooling on boost ventilation speed (typical flat)		
Cooling Capacity:	358	W
Air Specific Heat Capacity:	1.21	J/l/K
Flow Rate:	76	l/s
Delta T (of supply air)	3.9	^{o}C

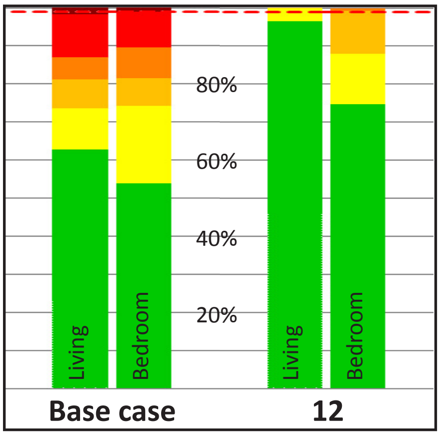




= Borehole with 5m diameter zone
= min 3m distance from existing building
= soak-away

Overheating results (summary)

		Base case	12
Living Rooms	>25°C	37%	3.4%
	>28°C	13%	0.0%
	Peak	32°C	25°C
Bed-rooms	>23°C	46%	25%
	>26°C	10%	0.0%
	Peak	30°C	26°C



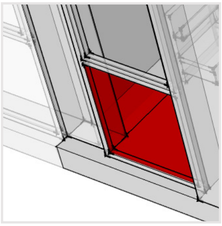
Cost

£/m2 NIA	£264
£/flat	£14,270
£ Total	£2,454,427
Build time	20 weeks

Graph (left) is an excerpt. See the final comparison graph at the end of Section 3 for a larger scale version with annotation and key.

Existing Building (base case)

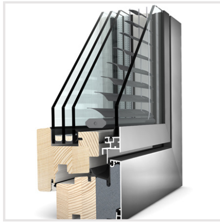
01 Lower panes opaque



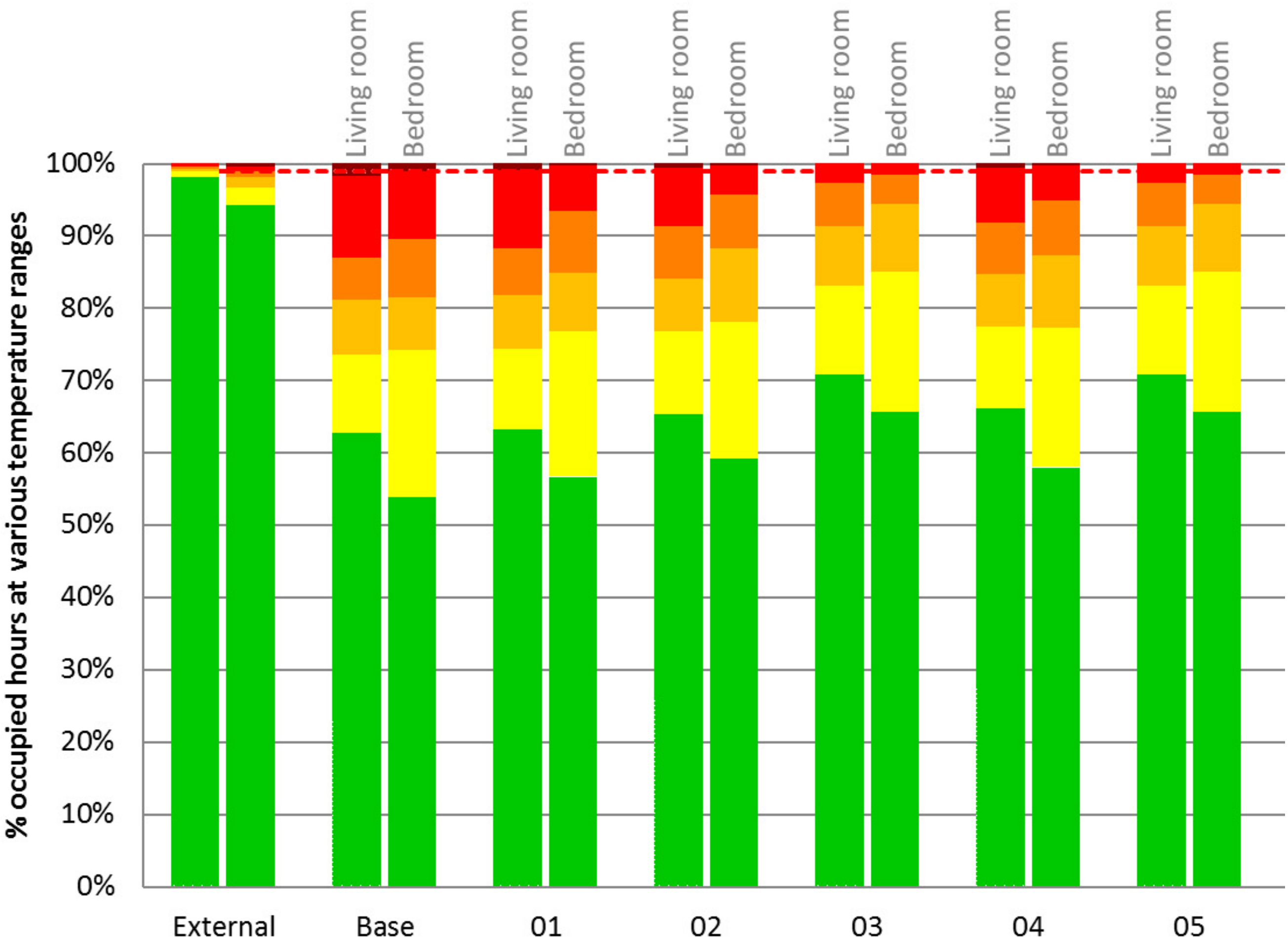
02 Internal framed blinds

03 Electro-chromic glass

04 Interstitial blinds



05 External blinds

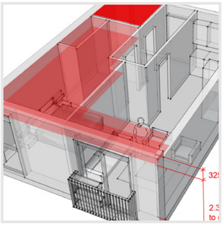


		Base case	01	02	03	04	05
Living Rooms	>25°C	37%	37%	35%	29%	34%	29%
	>28°C	13%	12%	8.7%	2.5%	8.1%	2.5%
	Peak	32°C	32°C	31°C	30°C	31°C	30°C
Bed-rooms	>23°C	46%	43%	41%	34%	42%	34%
	>26°C	10%	6.4%	4.3%	1.4%	5.1%	1.4%
	Peak	30°C	29°C	28°C	27°C	29°C	27°C

£/m2 NIA	-	£4	£23	£75	£42	£45
£/flat	-	£232	£1,233	£4,047	£2,285	£2,425
£ Total	-	£39,920	£212,076	£696,044	£392,980	£417,060
Build time	-	6 weeks	7 weeks	12 weeks	12 weeks	12 weeks

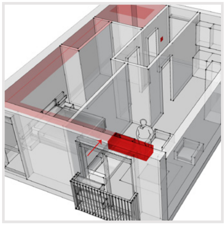
06 Optimum natural ventilation

07 Extra mech ventilation

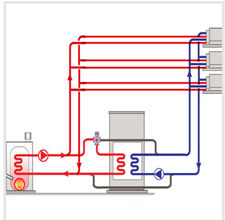


08 Ceiling fan

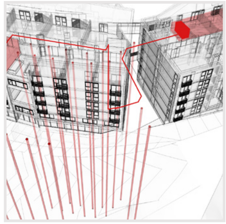
10 AC linked to MVHR

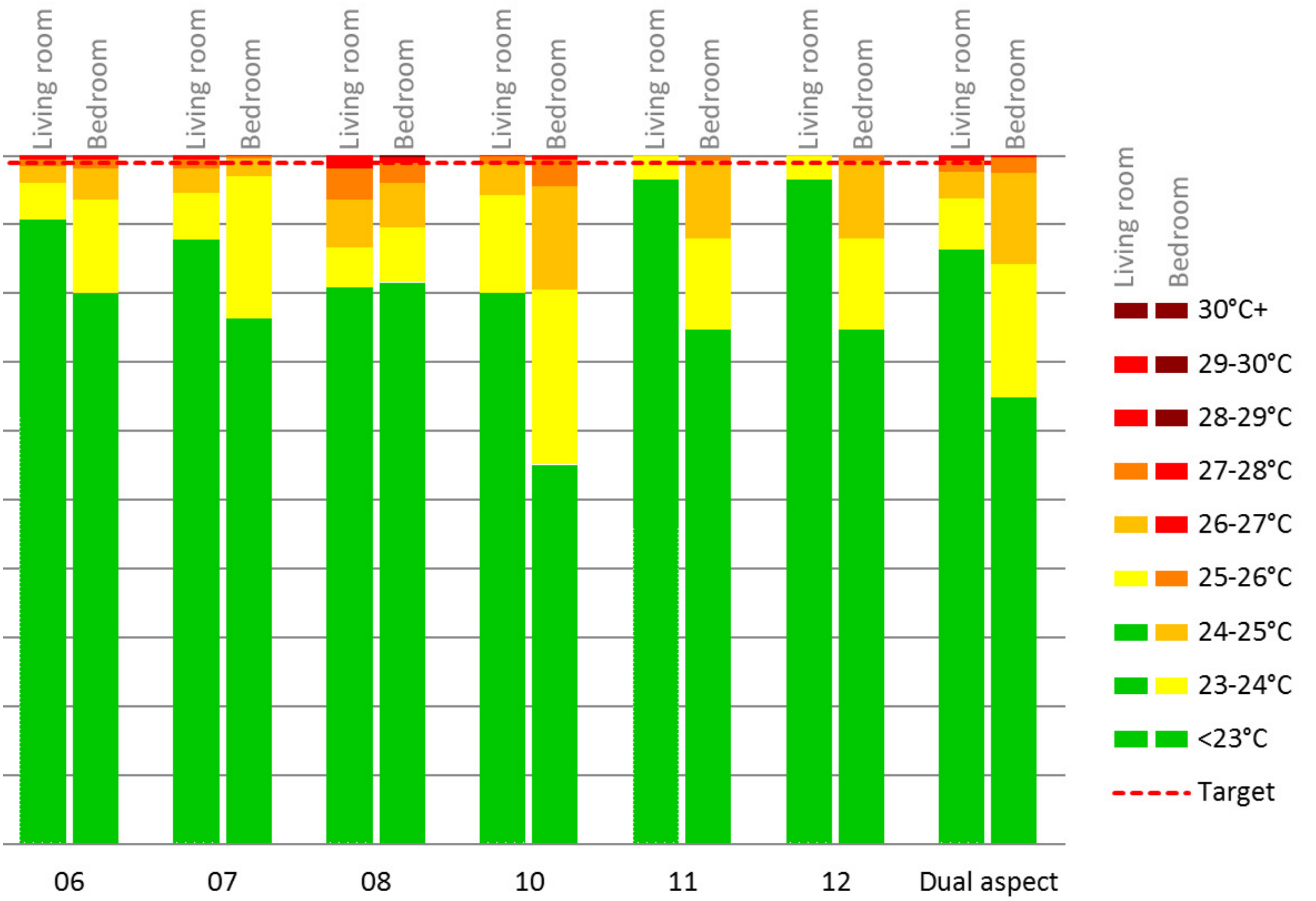


11 Central absorption chiller



12 Boreholes





06	07	08	10	11	12		
9.2%	12%	19%	20%	3.4%	3.4%	>25°C	Living Rooms
0.5%	0.5%	1.8%	0.1%	0.0%	0.0%	>28°C	
29°C	29°C	n/a	28°C	25°C	25°C	Peak	
20%	24%	18%	45%	25%	25%	>23°C	Bed-rooms
0.4%	0.0%	0.9%	0.5%	0.0%	0.0%	>26°C	
27°C	26°C	n/a	27°C	26°C	26°C	Peak	

varies	£173	£41	£124	£234	£264	£/m2 NIA
varies	£9,356	£2,221	£6,675	£12,616	£14,270	£/flat
varies	£1,609,232	£382,012	£1,148,016	£2,170,020	£2,454,427	£ Total
varies	12 weeks	5 weeks	12 weeks	20 weeks	20 weeks	Build time

4 Learning from this project

4.1 Approach to adaptation design

This project was unusual within the Design for Future Climate programme, in that it studied a new building for which construction was already complete. The project was led by the Good Homes Alliance and directed by its chairman, Peter Halsall who was managing director of Bioregional Quintain, the original developer of the scheme and now a director of the building's management company (One Brighton Management Company (OBMC)).

It had two principal overarching aims:

1. To support the development of a climate adaptation strategy for OBMC so that they could plan for implementing cost-effective measures over time,
2. To support the development of industry guidance on climate adaptation for the design and construction of similar high density urban apartments.

There was also considerable overlap between the project team and the original design team as shown in Table 4-1.

This project also offered a unique opportunity. Real performance data was being gathered for 5 different apartments in the One Brighton development under the TSB BPE Programme. This data indicated that the building is already subject to overheating in the current climate. Evaluation of future climate risks also identified keeping cool in summer as a vitally important issue. Hence the primary focus of this project was on thermal comfort in summer.

The first part of this project was to use dynamic thermal simulation software to investigate the reasons for the current overheating experienced in One Brighton. Data obtained from the BPE programme would be used to generate both weather data and internal gains and occupancy profiles to be input into the TAS model. The internal environmental conditions output from the TAS model would then be compared with observed conditions in the 5 monitored apartments and any discrepancies identified and investigated.

The second part of the project was to develop a climate change adaptation strategy to ensure that the risk of overheating would also be minimised in the future. The plan was to use the same dynamic thermal simulation model to test the sensitivity of the building's thermal performance to different adaptation measures, such as shading, orientation and ventilation. At the same time, supply chain options would be investigated to give an initial indication of costs. Both these elements were to feed into the selection of a shortlist of specific retrofit adaptation measures, for which detailed designs were developed.

The efficacy of the shortlisted measures in reducing overheating risk was tested using the TAS model. The measures were simulated alone and in combination, for both current and future climate scenarios. Detailed costings provided the additional information required to carry out a cost-benefit analysis. The final recommendations for choice of adaptation measures and a strategy for implementing them were incorporated into the planned maintenance schedule for the development.

As a key part of the project dissemination, the findings from the research were shared at an industry conference, which aimed to inform and stimulate supply chain interest and investment in type of the adaptation measures recommended. A guidance document, aimed at key industry sectors, which highlights the risk of overheating and applies the lessons learnt to the design and adaptation of similar contemporary urban apartment blocks, is also being written.

4.2 Design for Future Climate Project Team

Good Homes Alliance

The Good Homes Alliance (GHA) is a group of housing developers, building professionals and other industry supporters whose aim is to close the gap between aspiration and reality by showing how to build and monitor homes, which are sustainable in the broadest sense. The GHA led the project team, directed by its Chairman, Pete Halsall. Pete is also the former Managing Director of BioRegional Quintain, the developer of the scheme and is still a director of the One Brighton Management Company. Rachel Capon, a climate scientist, was the technical project manager and selected climate scenarios for use in the project. Chris Eaton, a mechanical engineer, led the TSB BPE project on One Brighton and provided advice on the services including the MVHR system.

Feilden Clegg Bradley Studios

FCB Studios were the project architects for One Brighton. For this study, Alina White and Andrew Macintosh, who both worked on the original design for One Brighton, provided designs for retrofit adaptation measures, as well as advice on the original design for thermal modelling.

Bill Gething

Bill, an architect and sustainability consultant, authored the original ‘Design for Future Climate’ report and was engaged as an advisor on this project.

Inkling LLP - Susie Diamond

Inkling, a Building Physics Consultancy, carried out the dynamic thermal modelling to simulate building thermal performance, to test the current sensitivity of the development to overheating and under climate change and to examine the effectiveness of various adaptation measures.

Baily Garner

Baily Garner, Quantity Surveyors and Cost Consultants, carried out the cost analysis. During construction of One Brighton, they acted as the Employer’s Agent for Moat Housing Association on Pullman Haul, the social housing block within the development. In addition, the One Brighton Management Company appointed them to produce the planned maintenance schedules for the development. This enabled integration of the proposed climate change adaptation measures into the maintenance schedules so that they could be considered in the context of long term financial planning, rather than just initial capital cost.

4.2.1 Interaction with Original Design Team

The table below indicates the overlaps between the original design team responsible for the One Brighton development (see Section 1.4) and the Design For Future Climate Team (highlighted). As described above, there was continuity between the two teams in terms of the client and the architects. Baily Garner were the cost consultants for the Design for Future Climate project, but also acted as Employer’s Agent for the social housing units. However, none of the original M & E team were involved in the Design for Future Climate project.

Table 4-1 Project Teams for Original Design of One Brighton and Design for Future Climate Project

ORIGINAL DESIGN TEAM		**DESIGN FOR FUTURE CLIMATE TEAM**	
Client	Crest Nicholson	One Brighton Management Company (Pete Halsall)	**Client**
	BioRegional Quintain LLP (Pete Halsall)		
Main Contractor	Denne Construction	Good Homes Alliance	**Main Contractor**
Architect	Feilden Clegg Bradley Studios		**Architect**
		Bill Gething	**Consultant**
M&E Engineer	Fulcrum / MLM	Inkling LLP	**Building Physics**
		Good Homes Alliance (Chris Eaton)	**M&E Engineer**
Cost Consultant	Jones Lang LaSalle	Baily Garner	**Cost Consultant**
Employers Agent for Moat Housing	Baily Garner		
Structural Engineer	Cameron Taylor		
Landscape Architect	Nicholas Pearson Associates		
Planning Consultant	Planning Perspectives		

4.3 The Initial Project Plan

The project plan was divided into seven work packages:

WP1. Information Gathering
WP2. Baseline Model Creation
WP3. Design Review and Selection of Adaptation Measures
WP4. Thermal Modelling
WP5. Cost effectiveness
WP6. Adaptation Strategy
WP7. Dissemination

WP1 was the initial phase of the project, including information gathering and project planning.

In WP2 we aimed to set up a base case model in TAS and use this to verify the monitored performance of the 5 different apartments. Ideally, we wanted to use data from the BPE monitoring programme to create both weather data and occupancy profiles for input into the TAS model. This would allow us to simulate the internal gains and external weather conditions as closely as possible.

There was considerable overlap between Work Packages 3 to 5. WP3 started with a design review. An initial selection of adaptation measures was made with the help of the Adaptation Checklist. For the thermal modelling in WP4, initial sensitivity tests were carried out for various options, e.g. shading, ventilation, occupant behaviour. More detailed designs were then developed (as part of WP3) and costed (WP5). Further modelling was then carried out.

All this activity fed into the adaptation strategy (WP6).

All the dissemination activities in WP7, i.e. the industry conference and production of the guidance document, were initially planned to take place at the end of the project.

4.4 Evolution of the Project Plan and Lessons Learnt

4.4.1 Usefulness of Monitored BPE data

The monitored data from the BPE programme provided valuable information, both qualitative and quantitative, about the performance of the occupied One Brighton development and the occurrence of overheating.

Nonetheless, it quickly became apparent that it was impractical to use any of the monitored BPE data to generate weather files or occupancy profiles for use in the TAS model. There were several reasons for this:

1. The data was collected in 5 minute intervals, as required by the TSB BPE programme. However, only hourly data was needed to create a weather file and occupancy profiles for use in the TAS model.
2. The data was downloaded remotely from the data loggers installed in One Brighton. This was a manual process, which necessitated stopping and re-starting the data loggers. Consequently, the data timings between consecutive files were not contiguous. This was exacerbated by the fact that each data file only included one week's worth of data due to the very frequent measurements.
3. From the monitored weather data only global radiation was available, rather than the diffuse and direct radiation components which are required for TAS. TAS also requires a cloud cover input. Although empirical algorithms exist to derive all these quantities from the global radiation, it was found to be too time consuming to use them to convert the global radiation data into the specified quantities.
4. It was also difficult to build consistent uniform occupancy profiles from the monitored data, due to its formatting and the fact that occupants may vary their habits considerably from day to day or week to week.

4.4.2 Buildings Do Not Always Perform as Designed!

As discussed in section 3, verification of the base case did not go as planned. The modelled performance was much better than the monitored performance of the building with respect to overheating. This required further investigation including a site visit by BSRIA, following which the under-performance of the MVHR system was confirmed as a key factor contributing to overheating in One Brighton. This performance gap issue would not have been identified without the knowledge gained from the TSB BPE programme and further funding from the TSB Design for Future Climate programme.

4.4.3 The Modelling and Design Process

The strategy of performing initial sensitivity tests for different factors, such as solar gain, worked well in understanding the building's thermal performance. However, it is important to consider such hypothetical thermal performance in conjunction with practical considerations such as viable design solutions and cost. For a while we considered a strategy of increasing the MVHR boost ventilation rate by up to 400%. We might have ruled out this option sooner, had we thought about the practical design implications – that the ventilation ducts would then cover the whole ceiling - at the same time.

4.4.4 Dissemination

Due to the evolution of the project as it went along, in particular the delays due to the MVHR site investigation, the industry conference took place well before the completion of the project. However, this had several benefits, not least the feedback the project team received from a wider audience.

4.5 Resources Used

4.5.1 ProCLIP and UKCP09 Data

The probabilistic climate profiles (ProCLIP) graphs, developed by CIBSE/UKCIP (CIBSE 2014), provide a graphical presentation of the probabilistic UKCP09 climate projections. They are a very useful tool for assessing climate risk in a specific location and selecting future climate scenarios. However, CIBSE/UKCIP only produced the graphs for the fourteen CIBSE weather file locations.

As part of the project, we created a ProCLIP graph for Brighton, from a template Excel spreadsheet provided by Maria Shamash, the original author of the ProCLIP graph. This necessitated downloading a large number of UKCP09 data files. In practice, it would be better if ProCLIP graphs could be created for each weather file location by the weather file creators, for example the Prometheus team. This would avoid duplication of effort and they would be readily available for use by engineers and architects.

4.5.2 PROMETHEUS

The PROMETHEUS weather files are probabilisitic future reference years for dynamic thermal simulations created using the outputs of UKCP09. They are freely available and cover multiple timeslices, scenarios and probability percentiles. They can be requested and generated for any site. The download procedure requires registration but is straightforward.

http://emps.exeter.ac.uk/research/energy-environment/cee/projects/prometheus/

4.5.3 TAS

Tas is a widely-used commercially available dynamic building simulation software. Their technical support department provided very helpful responses to queries about how weather data, for example cloud cover, was used within the software.

http://www.edsl.net/main/software/Designer.aspx

4.5.4 Thermal Comfort Criteria

There was some discussion at the beginning of the project as to which criteria should be adopted to measure overheating risk; the absolute thresholds of the CIBSE Guide A criteria or the adaptive comfort criteria described in CIBSE TM52. As the latter was still unpublished at the start of the project, it was decided to adopt the conventional thresholds of CIBSE Guide A. However, the population may adapt physiologically to higher temperatures and these thresholds become less applicable, especially later in the 21st century.

4.6 Client Relationship

The project was proposed by Pete Halsall, Chief Executive of the Good Homes Alliance. Pete is also the former Managing Director of BioRegional Quintain, the scheme developer and still a director of the One Brighton Management Company. Hence, this project is unusual in that the client is the lead partner in the development of the adaptation study. The primary motivation for the project came from the client, who had the desire to derive the optimum learning from the BPE monitoring undertaken and to future-proof the development by incorporating the recommended adaptation strategy in the future maintenance plan.

The ongoing relationship between the Good Homes Alliance, OBMC, the green caretaker and residents of One Brighton facilitated several aspects of the study. Information and data from the BPE programme was readily available. Furthermore, when the initial thermal modelling work indicated that the MVHR was not functioning optimally, the GHA and OBMC were able to commission a site visit to investigate the problem. The green caretaker found and contacted residents who were willing for their flats to be visited and their MVHR systems tested.

The analysis undertaken is extremely valuable to OBMC in terms of financial management and planning. The recommended adaptation strategy is integrated into the future maintenance plan but is also provided in a form flexible enough to allow variations in its implementation – either in terms of time or measures implemented. By being made aware of the financial implications of implementing the recommended adaptation strategy, they can choose to build up capital reserves for future adaptation via the service charge on lessees.

4.7 Recommended Resources

We would recommend that all design teams make full use of the resources listed in section 4.5 or suitable alternatives. In particular, given the proliferation of data available from the UKCP09 projections and the correspondingly large number of options for future weather data files, and in the absence of alternative guidance, the ProCLIP graphs are invaluable in selecting future climate scenarios and levels of risk appropriate to a particular project. Where a ProCLIP is not available for the specific site, it is possible to create one from UKCP09 data. However, for most design teams using the nearest CIBSE weather location will be a more practical approach.

5 Extending Adaptation to Other Buildings

5.1 Extending Adaptation to Other Urban Apartment Blocks

This project has illustrated the special consideration that must be given to the design of high-density urban apartment blocks. Relatively deep single-sided apartments are particularly prone to overheating for several reasons including the difficulty of getting adequate ventilation throughout the apartment, a concentration of electronic appliances, equipment and occupants within a relatively small footprint and the possible build-up of excess heat from centrally provided services and in communal spaces.

Overheating can be reduced to a certain extent by design. However, urban apartment blocks are by their nature much more complex buildings than low-rise houses. We therefore recommend that specialists, such as mechanical services engineers and building physicists, be engaged as part of the design team as they would be in any large commercial development.

5.1.1 Reducing Overheating by Design

Orientation

The orientation of urban apartment blocks governs the amount of solar radiation directly incident on the façade. Solar gain and daylight are generally conceived to be beneficial during the British winter, but they must be controlled during the summer if overheating is to be avoided. In the case of single-sided apartments backed onto a central corridor, a north-facing apartment will receive limited daylight, whereas a south-facing apartment is at risk of overheating very quickly. The East-West orientation used in One Brighton provides an even distribution of solar gains between the two sides of the building.

Natural and Mechanical Ventilation

In any apartment scheme aiming to maximise passive cooling the ventilation strategy is paramount. If openings are sufficiently large, natural ventilation through the windows can provide substantial free cooling. However, in a deep single-sided apartment, opening the windows alone may not be enough. Additional strategies are required to circulate the air and draw fresh air into the back of the space. This could be a MVHR system, as used in One Brighton, or a fan.

Where open windows are to be used for natural ventilation, noise and security issues must be considered for the specific site. Occupants should also be educated as to when to open and close windows for optimal free cooling. In One Brighton, it is envisaged that the green caretaker will provide this advice, together with daily notifications relating to the current weather forecast. An alternative, but more expensive, mechanism is to provide individual temperature sensors in each apartment (as in the Exeter St Loyes Extra Care scheme). Or dissemination of this information could take place via a smartphone adaptation app.

Where MVHR systems are used, this project has demonstrated the paramount importance of careful design, installation, commissioning and maintenance. Occupants deserve clear controls and comprehensible user manuals. Easily accessible filters should also be a priority.

Form

Dual aspect apartments, in which windows can be opened on opposite sides of the dwelling, allow for cross-ventilation. However, this approach is not usually favoured by commercial developers, due to the extra costs involved. Without a central corridor running along the spine of the building, additional lift shafts are required. Deck access is an alternative method of providing cross-ventilation.

In One Brighton, the façade is punctuated by sky gardens. These have opening windows to provide natural ventilation to the communal circulation spaces. We have demonstrated that the risk of overheating is considerably lower in apartments adjacent to the sky gardens. Similar architectural slots could be used in other single-sided double-backed apartment blocks.

Shading

Due to its coastal location, the climate in Brighton is cooler in summer than in other cities, e.g. London. Nonetheless, later in the century, ventilation alone will not be enough to keep the building cool. Some form of shading is required to reduce the solar gains in summer.

On an east or west facing façade, fixed shading, for example in the form of a brise-soleil, is not effective in blocking solar radiation. Furthermore on a tight urban plot, there may be planning issues due to pavement overhanging.

External blinds are a cost-effective option for reducing solar gain. The blinds considered here need to be integrated into the window frame. If they are not implemented at the design stage, retrofit may necessitate replacement of the whole window unit.

Electrochromic glass is another option. At the moment, it is relatively expensive and only used on commercial buildings. However, if production becomes more widespread, prices will come down. It is easier to retrofit, as it only requires replacement of the glass. Occupants can still open their windows at will, unlike with external blinds. For contemporary apartment blocks, it is an attractive option both functionally and aesthetically.

Internal Gains

Reducing the level of internal gains from electrical equipment within the apartment will reduce the risk of overheating and would be advised, especially on hot days. However this has not been included in the formal adaptation strategy, as the level of internal gains is heavily dependent upon occupant behaviour and therefore difficult to control. Indeed, occupants should reasonably expect to be able to cook and use their other appliances within the apartment, even in hot weather. Furthermore, future patterns of energy consumption are difficult to estimate, although projections have been made by the Energy Saving Trust (2011) in their report, 'The Elephant in the Living Room' (Table 5-1). Their findings illustrate the complexity of the issue. For some types of appliances, such as lighting and refrigeration, increases in energy efficiency are expected to reduce the overall energy consumption. For other uses, such as consumer electronics and home computing, any efficiency gains will be outweighed by increased consumer demand and proliferation of appliances.

Collaborative Consumption

Nonetheless, some strategic opportunities for reducing internal gains do exist in the form of collaborative consumption. Communal laundries do away with the need for each occupant to purchase their own washing machine. This has multiple potential benefits for occupants:

1. Internal gains within the apartment are reduced. According to the EST report, electricity consumption for washing is projected to increase in future (Table 5-1).
2. Noise from an appliance located in the kitchen or living room is no longer an issue.
3. First-time buyers may be relieved not to have to purchase a washing machine, which represents an appreciable capital outlay.

Table 5-1 Electricity use, and projected demand, for domestic products from 1990 to 2020, Energy Saving Trust (2011).

Product group	Energy use in 1990 (TWh)	Energy use in 2005 (TWh)	Energy use in 2009 (TWh)	Projected energy use in 2020 (TWh)
Lighting	**16.6**	**17.5**	**15.8**	**11.7**

Refrigeration	**16.8**	**15.9**	**14.5**	**10.5**
Cooking	**11.7**	**13.0**	**13.3**	**13.3**
Washing	**11.8**	**13.6**	**14.2**	**15.7**
Consumer Electronics	**12.1**	**19.9**	**20.8**	**21.9**
Home Computing	**1.3**	**5.4**	**6.5**	**6.9**
Total	**70.3**	**85.3**	**85.1**	**80**

5.1.2 Active Cooling

Passive measures, as described above, can be effectively employed to protect against overheating risk. However some form of active cooling may become essential in the future. This will be very dependent both upon the development and upon site-specific factors, such as the local climate, noise and pollution issues.

The need for active cooling should be anticipated at design stage. The availability of renewable options such as boreholes and a central ground source heat pump will depend upon the site. Any form of centralised cooling is expensive to retrofit and occupiers cannot be forced to use it retrospectively.

5.2 Limitations

The extent to which the passive options described here can be deployed on other buildings will depend upon their site and location. Limiting factors include the local climate. Brighton benefits from a coastal location and is therefore relatively cool compared to other cities. The sea breeze prevents air stagnation and provides an additional source of cooling. Developments in other cities may be deep within an urban heat island and experience much hotter temperatures, both during the day and at night. Noise and pollution are other issues, which may potentially hinder the use of natural ventilation.

As illustrated in this study, some options may be more expensive and difficult or not technically possible as a retrofit. For example, at One Brighton a bolt-on external blind would cover the intake/extract for the MVHR when closed. The alternative external blind system considered required replacement of the whole window frame. Where possible, it is better to consider all the options for adaptation at the initial design stage.

In an apartment development, it is also necessary to consider the terms of the lease. In One Brighton, the management company has control over the envelope of the building, including the windows, but not over the interior of each apartment. Therefore, they cannot force occupants to consent to internal measures, installing ceiling fans, for example. This would be typical of most such developments.

The services strategy is also usually part of the lease. It is essential to consider at design stage whether active cooling strategies may be needed in future and make provision for them. Occupiers cannot be forced to adopt them retrospectively and may instead buy portable air conditioning units, with all the potential disadvantages they bring.

5.3 Similar Buildings

Small, one or two bedroom apartments form a considerable proportion of new-build housing within the UK, particularly within urban areas. Figure 29 shows annual statistics for one and two-bedroom apartments as a percentage of all new-build permanent dwellings completed in England during the period 1991 to 2013. In London, the proportion of apartments is much higher; almost 25% of new-builds in this period are one-bedroom apartments.

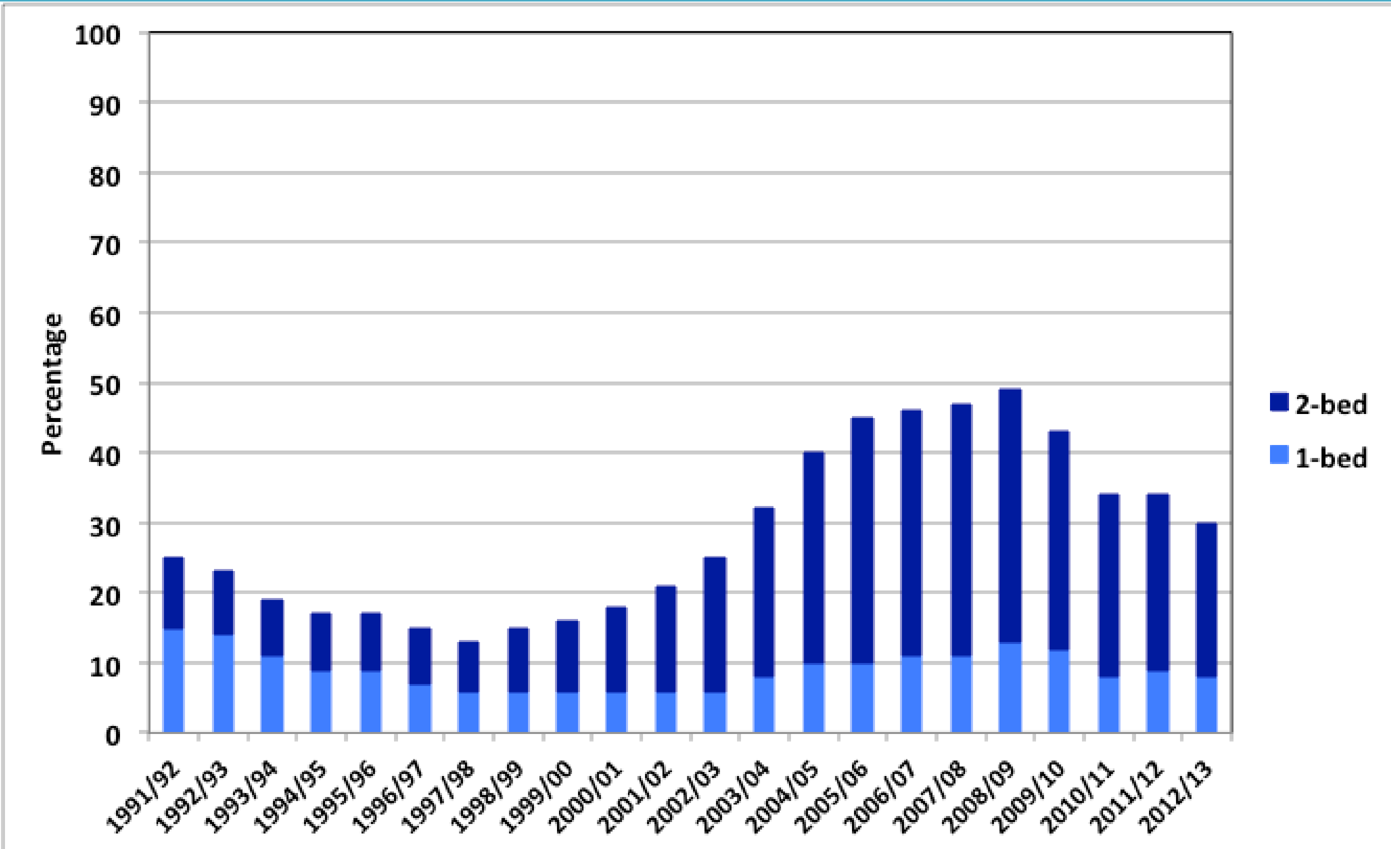


Figure 29 Newly completed one and two-bedroom apartments as percentage of all permanent dwellings completed in England (CLG Housing Statistics Table 254)

In addition to the evidence presented in this report, a recent survey undertaken by the Good Homes Alliance for the Department of Energy and Climate Change (GHA 2014) found that recently built urban apartments are extremely prone to overheating, more so than any other type of residential dwelling. This was due to a number of factors including many of those identified in this study: single-sided apartments backing onto a central corridor; heat coming from communal pipes running through corridors, glazed doors which are difficult to secure for ventilation and a reluctance to open windows due to noise and security concerns.

Recent years have also seen a growth in privately-owned purpose built student accommodation, particularly in London (GVA 2012). Many of the findings in this report are also readily applicable to such accommodation. Student study bedrooms may not contain the full range of appliances found in a one-bedroom apartment, but they still have lots of electronic devices contained within a very small footprint. They also often utilise the same configuration of single-sided dwellings backing onto a central corridor.

5.4 Resources and Dissemination

5.4.1 Overheating Bar Graph Visualisation

According to the CIBSE Guide A definition used here, overheating occurs if the internal temperature within a space exceeds the overheating threshold temperature of 28°C for living areas and 26°C for bedrooms for more than 1% of occupied hours during the year. Whilst this quantifies the duration of overheating, it does not provide any information on the intensity of overheating, i.e. by what margin the threshold temperatures are exceeded. Other quantitative metrics are sometimes used to examine the intensity of overheating, in particular the peak temperature and the number of Cooling Degree Hours above the threshold.

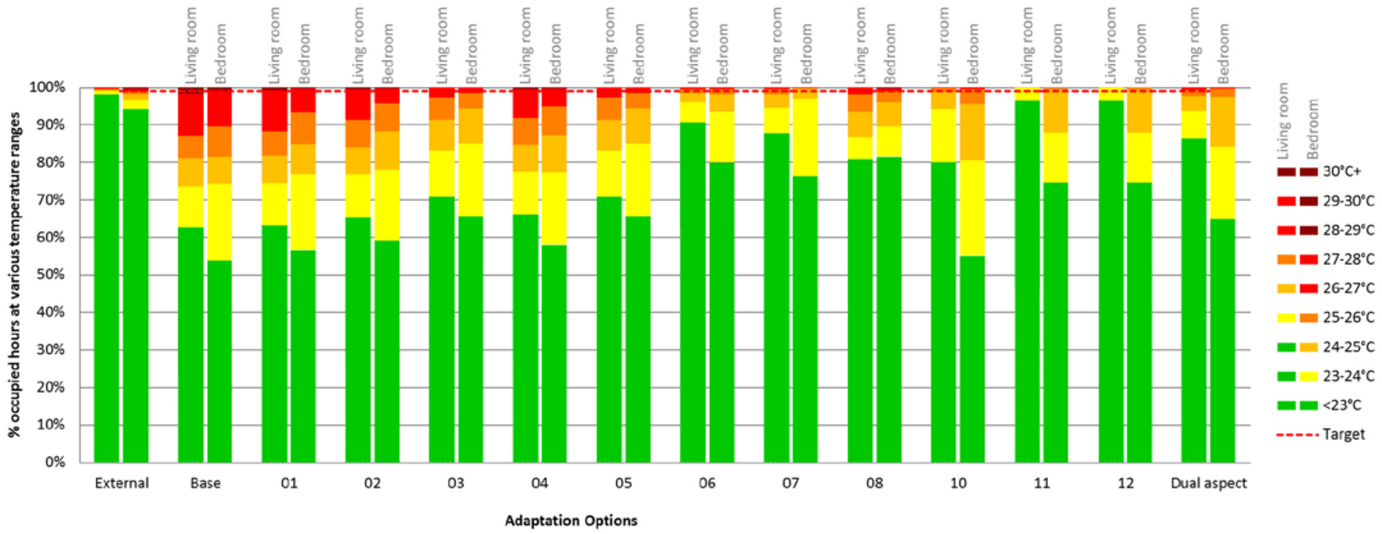


Figure 30 Visualisation of overheating risk, showing percentage of occupied hours over the CIBSE comfort thresholds in 1-degree temperature bands for shortlisted adaptation options for both living room and bedroom.

In this project, we visualised overheating risk by plotting a 100% stacked bar chart in Excel showing the percentage of occupied hours over the CIBSE comfort thresholds in 1-degree temperature bands (see 3.5 and Figure 30). Hours below the comfort threshold are shaded in green; for hours between the comfort and overheating thresholds the shading gradates from yellow through to orange; red shades indicate overheating. A dotted red line indicates the CIBSE target of overheating occurring for less than 1% of occupied hours.

We developed this new graphical representation in order to illustrate different aspects of overheating risk within one plot. From these graphs, we can immediately see both whether the CIBSE Guide A overheating criteria is satisfied and the severity and intensity of overheating. This is extremely useful when comparing different adaptation measures.

5.4.2 Guidance Document

The Good Homes Alliance is producing a guidance document on avoiding overheating in Urban Apartments. Aimed at key industry sectors, it shows how to apply the lessons learnt on this project, to the design and adaptation of similar contemporary, urban apartment developments. It will be available for download from

http://www.goodhomes.org.uk/research/

5.4.3 Supply Chain Conference

The Good Homes Alliance organized a conference entitled 'Climate Change and Overheating: Opportunities and Risks for Designers and the Supply chain', held at the Building Centre, London on 25 June 2013. Architects, engineers, consultants and manufacturers presented findings of their research and innovative supply chain products. The presentations are accessible from the Good Homes Alliance website.

http://www.goodhomes.org.uk/events/138

5.5 Further Needs for Future Provision of Adaptation Services

Further guidance is required for design teams, for example the need to use future climate scenarios for thermal modelling and which is an appropriate choice of scenarios.

However, unless clients are made aware of climate risks and the need for future resilience, they will be reluctant to embrace adaptation, not least because of the possible extra cost – both capital and for design.

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