Bermondsey Square

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

Innovate UK project number	450063
Project lead and author	Urbanism Environment Design (for igloo Regeneration Ltd)
Report date	2014
InnovateUK Evaluator	Robert Cohen (Contact via www.bpe-specialists.org.uk)

Building sector	Location	Form of contract	Opened
Mixed use	London	Various	2009
Floor area	**Storeys**	**EPC / DEC**	**BREEAM rating**
Various (mixed use)	N/A	N/A	N/A

Purpose of evaluation

The study focused on several key aspects of the scheme's energy performance, including the performance and use of the district heating system, the performance of the adiabatic cooling system, user satisfaction and comfort within the office spaces, the environmental control and management systems, the mixed use nature of the scheme, and the complications that arose.

Design energy assessment	In-use energy assessment	Electrical sub-meter breakdown
No	Yes	Partial

Lack of adequate metering prevented full understanding of where energy was being used in the development. While meters and sub-meters have been installed on almost all systems, these did not always tally with how the building was divided up and occupied, and thus were not able to give a detailed picture to be built up. In addition, some heat meters malfunctioned while others had been capped off. As the plant room was not adequately sub-metered, a meter was added to the AHUs. Energy consumption for the offices (2013): Electricity 137 kWh/m^2 per annum, gas 124 kWh/m^2 per annum. Hotel: heating energy 52 kWh/m^2 per annum (plus 44 kWh/m^2 per annum of electricity), electricity 207 kWh/m^2 per annum.

Occupant survey	Survey sample	Response rate
BUS, paper-based(x2)	Various	N/A

BUS surveys were conducted separately for the office and hotel. Some occupants of office areas maintained a thermal comfort diary in response to reports of overheating and general thermal discomfort. Temperature and humidity data were collected in both the office and hotel spaces, again primarily in response to reported problems with thermal comfort. A feedback session was conducted with office tenants based on initial findings in December 2012.

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About this document:

This report, together with any associated files and appendices, has been submitted by the lead organisation named on the cover page under contract from the Technology Strategy Board as part of the Building Performance Evaluation (BPE) competition. Any views or opinions expressed by the organisation or any individual within this report are the views and opinions of that organisation or individual and do not necessarily reflect the views or opinions of the Technology Strategy Board.

This report template has been used by BPE teams to draw together the findings of the entire BPE process and to record findings and conclusions, as specified in the Building Performance Evaluation - Guidance for Project Execution (for domestic buildings) and the Building Performance Evaluation - Technical Guidance (for non-domestic buildings). It was designed to assist in prompting the project team to cover certain minimum specific aspects of the reporting process. Where further details were recorded in other reports it was expected these would be referred to in this document and included as appendices.

The reader should note that to in order to avoid issues relating to privacy and commercial sensitivity, some appendix documents are excluded from this public report.

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1. INTRODUCTION

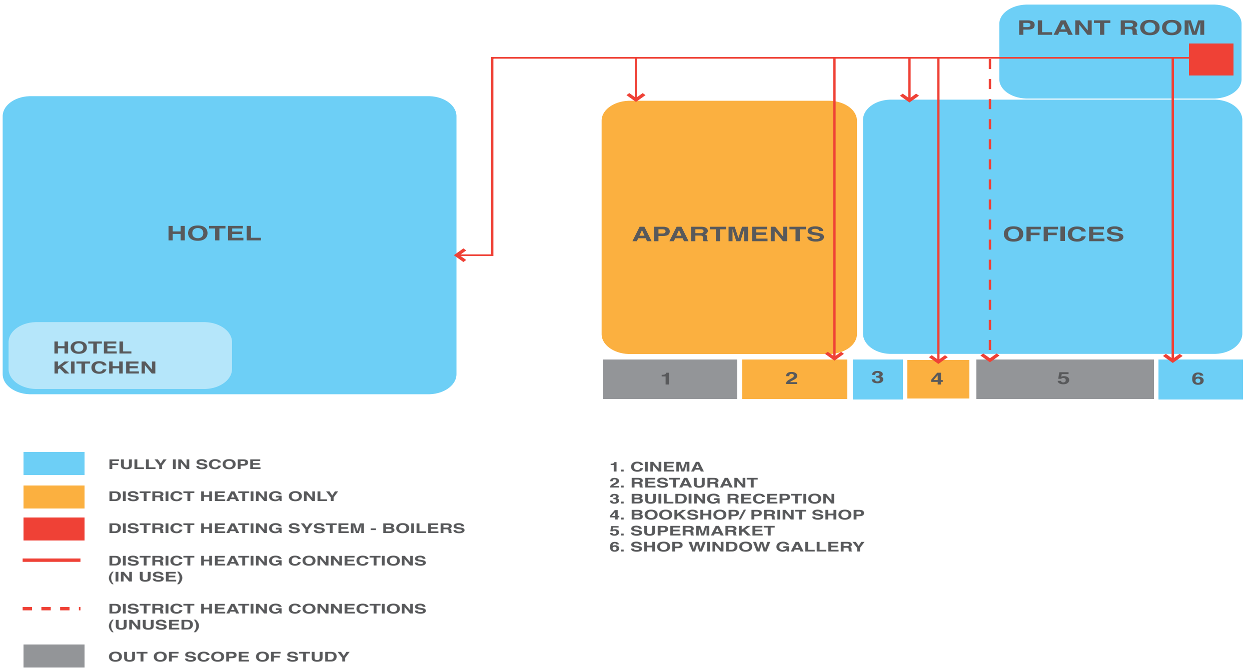
Bermondsey Square is a mixed use development in central London. It was developed by Igloo Regeneration Ltd for the Igloo Regeneration Fund, a specialist investor in urban regeneration - described by the UN as the 'world's first responsible real estate fund', with its own sustainable investment policy, 'footprint', motivated by a desire to 'do well by doing good'.

The scheme is made up of two blocks arranged around a public square. The northern most block, rectangular in plan and seven storeys tall, contains a 79 bed boutique hotel. The main southern most block forms an L-shape to enclose the square. This contains 76 apartments over nine floors in one side of the 'L', and 35,000 sq ft of offices for multi-lets to a variety of occupiers over five floors on the other. The ground floor comprises 12,636 sq ft of retail space including a 55 seat art-house cinema. It was built to Part L 2002, with a 15% uplift in U-values, and contains a district heating system, which supplies the whole development, and an adiabatic cooling system in the office spaces.

For the last two years the scheme has been the subject of a building performance evaluation study led by Igloo Regeneration Ltd in collaboration with URBED (Urbanism Environment Design Ltd) and Sheffield Hallam University. This study focused on the non-domestic aspects of the development - primarily the office spaces and hotel - and specifically excluded the residential apartments. In a relatively complex development with a number of different uses, and particularly a shared district heating scheme, drawing the boundaries of the study has been a challenge.

Since it covers such a large and complex development, the study focused on several key aspects of the scheme's energy performance and use to inform the management of the scheme itself, but also future design and investment decisions by Igloo:

- The performance and use of the district heating system
- The performance of the adiabatic cooling system
- User satisfaction and comfort within the office spaces.
- The environmental control and management systems
- The mixed use nature of the scheme, and the complications that may arise from this.



Above: Diagram showing scope of study and basic layout of district heating system.

Left: Aerial Photograph of development showing 'L' shaped residential and commercial block to west, and rectangular hotel block to east.

Bottom: Bermondsey Square showing reception entrance between apartment and office blocks, with bookshop and supermarket to right and restaurant and cinema to left.

2. DESIGN AND DELIVERY

2.1 Development Process

Bermondsey Square is a large scheme in central London, with many interested parties and a complex brownfield site. The development process for the scheme was not straightforward, taking the best part of a decade, two lead developers and two different design teams. It was also one of the first developments undertaken directly by Igloo Regeneration Ltd, so many of the procedures and roles within the development team had not yet been fully developed or were not applied to this scheme.

A scheme was originally developed for the site in the early 2000s but was rejected at planning stage, primarily due to concerns about the large scale of the scheme and its potential effects on what is still a mostly low-rise neighbourhood with several important heritage features, including a long-running antiques market on the site itself. Urban Catalyst acted as developers on a revised scheme, which achieved planning permission in early 2006.

Igloo had always been involved as funders, however once the scheme moved towards start on site there were problems, and Igloo Regeneration Ltd stepped in as developer in June 2006. There would have been a detailed analysis of the project - its finances and the projected construction programme - at this handover stage. However, many of the people involved in this have since moved on, so it has not been possible now to record and understand the full detail of this process. However there is enough to suggest that this was a complicated and sometimes trying development process, and that this may have affected outcomes for the development.

Development team:

Funder: Igloo
Developer: Urban Catalyst (to 2006)/ Igloo Regeneration Ltd (2006-completion)
Architect (Main Building): Munkenbeck+Marshall
Structural Engineer: Buro Happold
Services Engineer: Atelier Ten
Landscape Architect: East
Main Contractor: Galliford Try
Hotel Fit Out Contractor: E.E. Smith
Managing Agent: Living City (2008-2010)/ GVA Grimley (2010-2013)/ CBRE (2013-present).

2.2 Design

Context: The scheme is located on the end of Bermondsey Street in Southwark, London. It is approximately ten minutes walk from London Bridge station, for tube and national rail, and is located on several major bus routes. The triangular site is bounded by Bermondsey Street to the west, Abbey Street to the north, and the very busy Tower-Bridge Road to the south-east. It's an area that has changed a lot since the development was first proposed over ten years ago, and is now part of a regenerated neighbourhood featuring independent shops and cafes. It will continue to change as the nearby relatively recently built 'Shard' is populated and development around London Bridge is completed. Streets and public spaces in the area, especially to the Bermondsey Street side, are well used and well-populated day and night, with plenty of cycle parking and a dedicated secure cycle shed forming one of the features of the square. Tower Bridge Road is less pedestrian and cyclist friendly, with heavy traffic day and night.

Layout: The separate rectangular block of the hotel runs along the Bermondsey Street side, with its primary elevation facing south-east onto the square between it and the rest of the development, with seating from the downstairs bar and restaurant onto the square and a first floor terrace.

Residential accommodation is contained with one leg of the L-shaped block along the quieter Abbey Street, with single aspect apartments off a central spine corridor facing north and south, all with balconies and some with roof-terraces on top of the block.

Five floors of office space is contained within the other leg of the 'L' along Tower Bridge Road, with full width open plan spaces looking south-east onto the main road and north-west onto the square. A central reception point and building manager's office is located at the corner of the 'L', with separate stairs and lifts to the residential and commercial areas accessed from here. The ground floor is taken up with commercial and retail spaces - including an independent cinema, a restaurant and a supermarket - as well as some service spaces for the whole development, such as bin stores.

Building Fabric: The construction is steel frame with concrete floors. In the office spaces and communal areas the concrete at the ceiling has been left exposed to increase the available thermal mass - though this has not been maintained in all areas during the building's use. The fabric was constructed to Part L 2002, with a 15% improvement on the U-values required at the time. The external walls are made up of infill panels clad with either timber or aluminium. The office spaces feature less glazing than is often present in Grade A office space, with windows on the south-east side glazed from desk to ceiling level only.

Daylighting and Solar Control: The blocks that make up the development were kept relatively shallow, so that most lighting needs are served by natural daylighting. This is reasonably successful in the hotel - though the hotel management have to control the potential for over-heating in south-facing rooms by ensuring curtains and blinds are drawn whenever the rooms are not in use and between guests.

In the office spaces the intention was to minimise the need for artificial lighting by having significant amounts of glazing

Above: view of the square with antiques market in progress

MAIN BLOCK FLOOR PLAN - THIRD FLOOR

Residential Block

Office Spaces

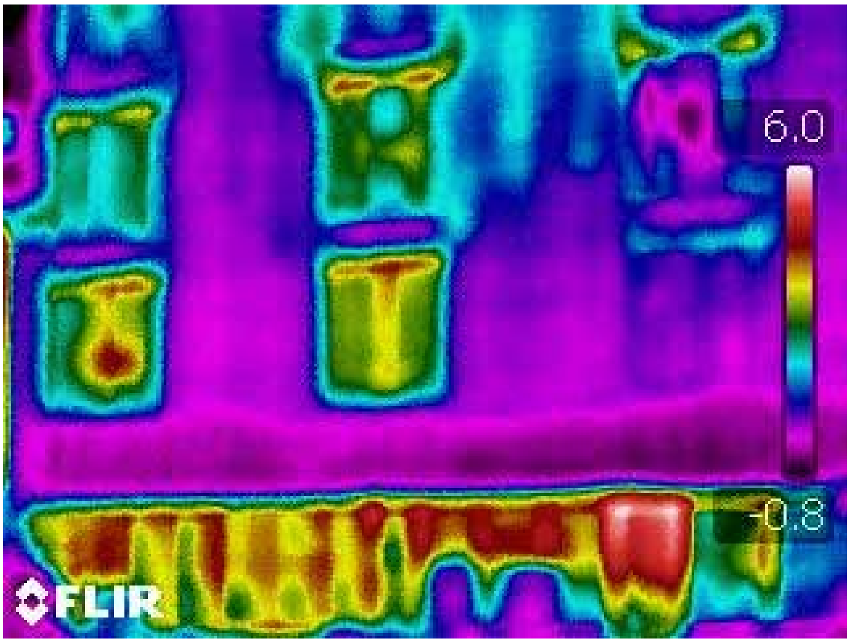
Shared/Core -
Lifts, Stairs, WC, Kitchens, Reception (atrium)

along the long sides of the block. However, as one elevation faces south-east, and another south-west, it was recognised that there would also be a need for some degree of solar control to avoid glare and over-heating. To address this a system of automatic retractable external blinds was installed.

2.3 Detailed Design and Construction Process

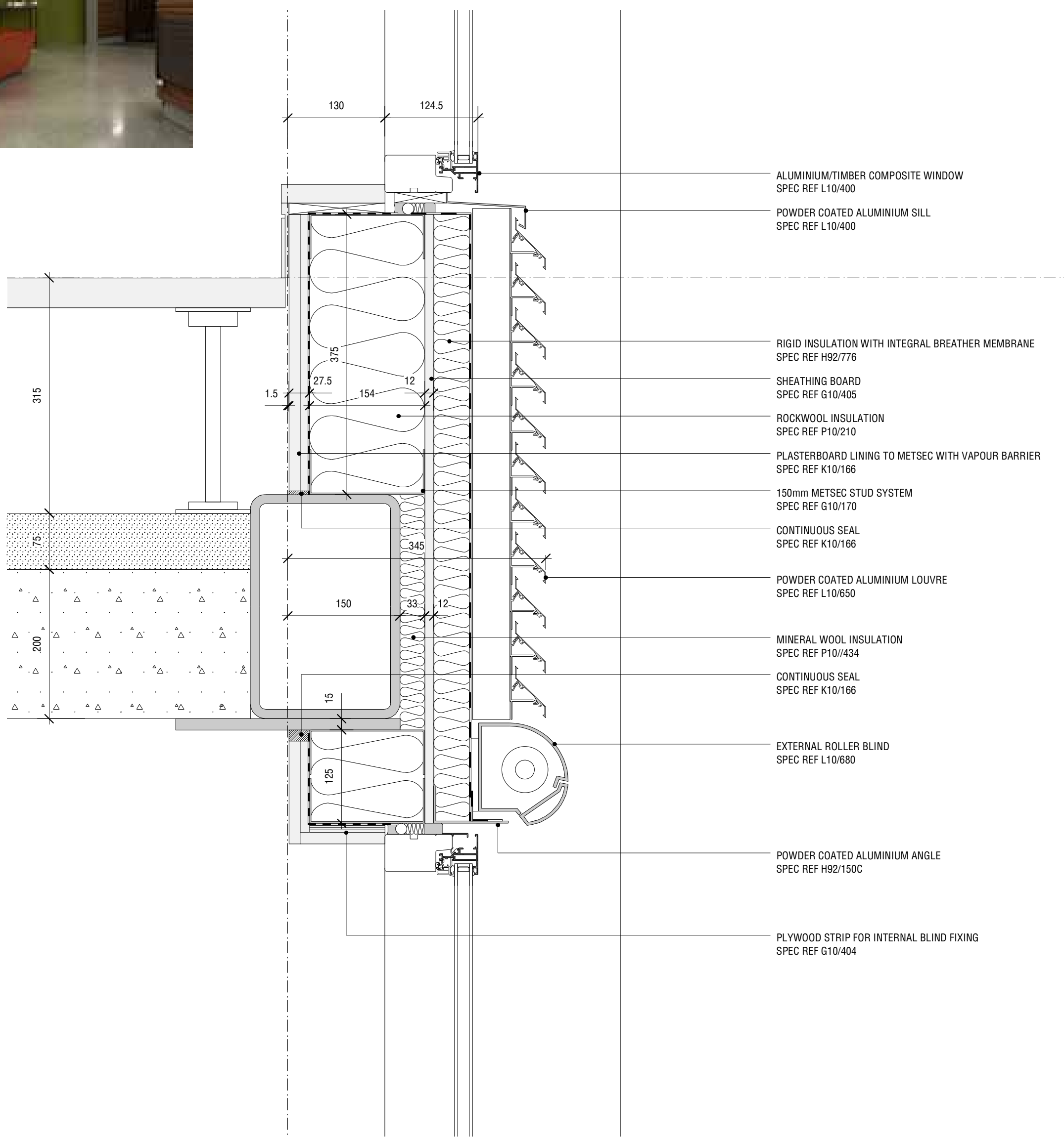
Work started on site in June 2006. There was a long period of enabling works and site investigation and preparation due to the sensitive nature of the archaeology on the site (remains of an early medieval abbey). Structural designs had to be developed and amended to fit around the existing structures found by the archaeologists, to avoid piling through historically significant elements as they were uncovered. This made designs very complicated, with no simple rows of structure, transfer slabs, and no ability to plan this out in full before starting on site. The construction programme was further complicated by the need to protect and provide space for the existing antiques market as the construction developed around the site.

A new development manager joined the team for Igloo Regeneration Limited (IRL) approximately six months after work started on site. A specification been produced as part of the detailed design process, and there had been a round of value engineering to try to bring costs down prior to start on site. When working through the details of the project, the



Though the fabric of the building was not a key focus of the study, a thermal imaging survey was undertaken to assess the performance of the buildings - to identify whether there are any particular problems with air-tightness or thermal bridging. While some potential issues were identified, particularly around areas of glazing or the steel structure of the building, these were not beyond what would have been expected given the designed performance and the post-completion air-tightness test results - which achieved a result of 9.52 m3/m2.hr @ 50pa. (See Q6 report for further details).

Above: Office spaces before and after occupation.
Left: Reception area, including building manager's office, shared between office spaces and residential block.
Below: Detail showing typical external wall construction at office block floor junction, with potential thermal bridge of steel structure.



development manager found that some items that had been removed during value engineering had to be included again. For example, the wiring, motors and controls to the external blinds on the offices had been removed, so there was no means of controlling them. This had to be added back in to the construction.

However, due to budgetary constraints, it was not possible to restore all value-engineering decisions. 5-core cabling had originally been specified to the corridors and communal areas. This was downgraded to 3-core to save money. However this now makes it much more difficult to fit PIRs - so in the past they have been on all the time contributing to heating load and energy use in the building, which many residents have complained about. This has now been resolved, with PIRS fitted on every residential corridor by November 2013.

As they were not the original developer, Igloo Regeneration Ltd (IRL) did not write the original briefing document for the development, and this caused something of a disconnect, especially throughout the detailed design process. On other igloo projects a full brief would be developed and regular “development in use” meetings would be held to iron out the details of the scheme. These would include the managing agent and project team, where scenarios are run to interrogate issues such as security and billing. However this did not happen on this project, and some of these matters, particularly billing for the district heating system, have caused problems for the development.

Sub-metering and billing for the district heating system were identified during development process as potential issues, and the development manager tried to resolve these. However the design and construction were well developed by this stage, already a long way down the track and some of the technology (for district heating system) was relatively new. SAV were identified as a specialist supplier who might be able to resolve this, and asked to develop an extension to the BMS for the district heating. They did so, but there were issues because it was a new system to them as well as igloo.

The main construction programme was completed in late 2008, with the hotel completed in early 2009, with hotel fit-out complete by late 2009.

2.4 Fit out, ownership and sub-divisions

The office spaces and residential units were completed in their entirety by Igloo as developer. The ground floor units were handed over as ‘shell and core’ to new tenants for fit out. The hotel was completed on a shell and core and then fit-out contract. The main contractor for the whole scheme completed the shell and core, with a full “turn key” fit out, down to the pictures on the wall, carried out by E.E. Smith.

The Igloo fund has retained ownership of the freehold on the development, and responsibility for its overall management. The leaseholds for the residential units have all been sold privately, and the hotel is on a 30 year lease from igloo. The commercial spaces - offices, retail and restaurant - are on lease from Igloo.

The development was completed as the 2008 banking crisis was starting to have a severe impact on house prices and the commercial property market. Though the development has performed well in these circumstances, it has not been without implication. Offices were designed to have an open floor-plate. However, on all floors this has been subdivided. The top two floors have a single tenant each, and these tenants have decided to divide up some of the space into separate kitchens, printer rooms and meeting rooms - in both cases predominantly on the North-Western side of the building. The remainder of these offices are open-plan, with desks arranged in row perpendicular to the windows. The lower floors have also been sub-divided so smaller areas can be rented out to different tenants. In most cases these tenants have then also chosen to sub-divide some of the floor to provide kitchens, meeting rooms and individual offices - again mostly on the north-western side - though the majority of the space remains open plan. This has had implications for the operation of the building, which will be discussed below.

3. BUILDING SERVICES AND ENERGY SYSTEMS

3.1 District Heating System

One of the key features of the scheme for this study is its district heating system. At the time the building was constructed this was being promoted by the local planning authority and the Greater London Authrity as a low-carbon 'future proofing' strategy. The intention was to provide a simpler to manage centralised plant, with higher efficiencies and better pollution control than providing individual systems to each area of the scheme. It also allowed for potential future connection to an area-wide district heating or combined heat and power scheme - SELCHP (South East London Combined Heat and Power) network.

Space heating and domestic hot water services (HWS) are provided by the Landlord's centralised low temperature hot water (LTHW) district heating system. This is located within the roof top plant room on top of the office block to the south-east of the scheme. The system is laid out as follows:

Boiler Specification

Manufacturer: Hamworthy Heating Ltd.

www.hamworthy-heating.com

Model: Wessex Modumax

Description: High efficiency fully modulating condensing pre-mix boilers

Seasonal Efficiency (BRegs): 93%

Total Duty: 2MW

Arrangement: 2 sets 250/750c, 1 set 250/550c (8 units total).

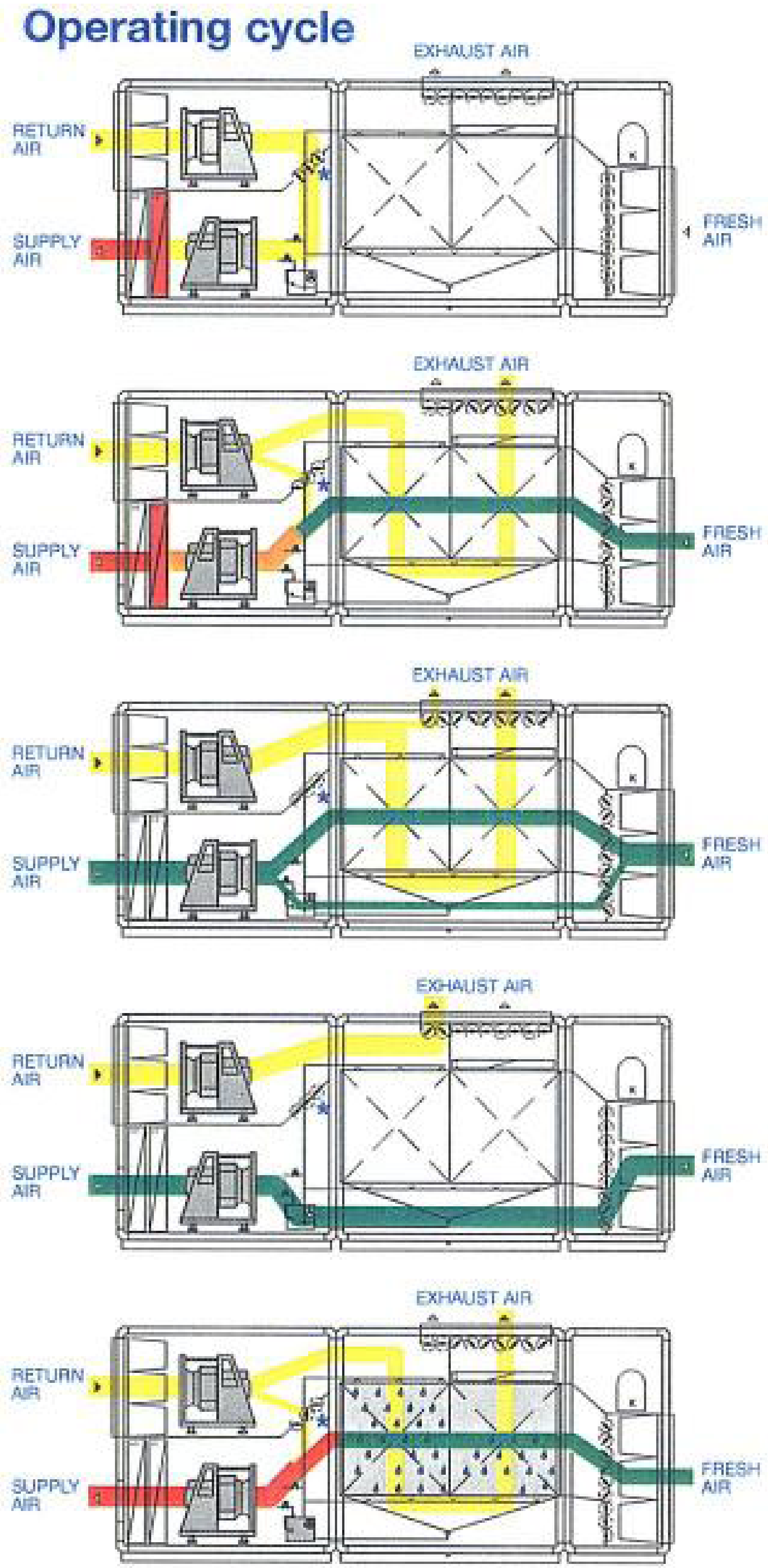
Above: Bank of condensing boilers to district heating system in rooftop plant room.

The Office areas are provided with metered constant temperature (CT) LTHW serving Office Air Handling equipment and 2 N° HWS calorifier's while a variable temperature (VT) LTHW circuit serves space heating via perimeter radiators with manually adjustable TRVs on each floor.

The 76 Residential units are served via a dedicated metered constant temperature (CT) LTHW circuit with branch connections to each residence connecting into a hydraulic interface unit (HIU). These HIU's are responsible for space heating and HWS generation within each flat. An air curtain to the main reception entrance is also served on the ground floor by this constant temperature LTHW supply.

The Hotel block is served via a dedicated metered constant temperature (CT) LTHW circuit, terminating within the Hotels basement plantroom. Though it appears this was originally intended to serve both hot water and space heating needs, it seems that in reality it provides only hot water, with space heating needs in the hotel instead being served by both a centralised and individual room electrically powered air-conditioning units.

Each retail unit is provided with a separate metered constant temperature (CT) LTHW circuit, terminating within each demise. This is not used by the supermarket.



AHU Specification

Manufacturer: Menerga Energy Systems - www.menerga.com

AHU01

Model: Type 56 Adsolair Solvent 563201

Total Power Consumption: 19.5kW

Heat Recovery Temperature Efficiency: 77%

Supply air temp after heat recovery: 16.0°C

Heater Rating: 104.8kW

Max supply air temp: 30°C

Adiabatic Cooling - mains water flow rate @ 2bar: 2340 l/h

AHU02

Model: Type 56 Adsolair Solvent 562501

Total Power Consumption: 19.0kW

Heat Recovery Temperature Efficiency: 73%

Supply air temp after heat recovery: 15.1°C

Heater Rating: 98.2kW

Max supply air temp: 30°C

Adiabatic Cooling - mains water flow rate @ 2bar: 1812 l/h

DESIGN STAGE PROJECTIONS

When compared with a conventional fan-coil refrigerant based air-conditioning system, it was claimed that the displacement ventilation and adiabatic cooling based system would:

- Reduce energy demand through use of displacement ventilation by 40-45%
- Eliminate need for mechanical cooling, reducing total building energy demand by 20%.
- Above two factors combined reduce carbon dioxide emissions by 60% vs conventionally cooled building.
- Reduce running costs by 50%

Left: Diagrams showing the air-handling unit in different modes of operation (from Atelier Ten design stage report, Dec 2008). From top to bottom:

- *Winter warm-up mode - air recirculated with no fresh air intake*
- *Winter day - full fresh air with heat recovery*
- *Winter day (warmer) - fresh air with reduced heat recovery*
- *Spring/Autumn day: full bypass (saving on fan energy)*
- *Summer day - evaporative cooling*

The system as installed was metered so that there was a record of the heat used by each end user. However, there were few other check-meters on the system, so it was difficult to determine either overall system losses or whether there were excessive losses in any particular part of the system. This has been addressed as part of this study.

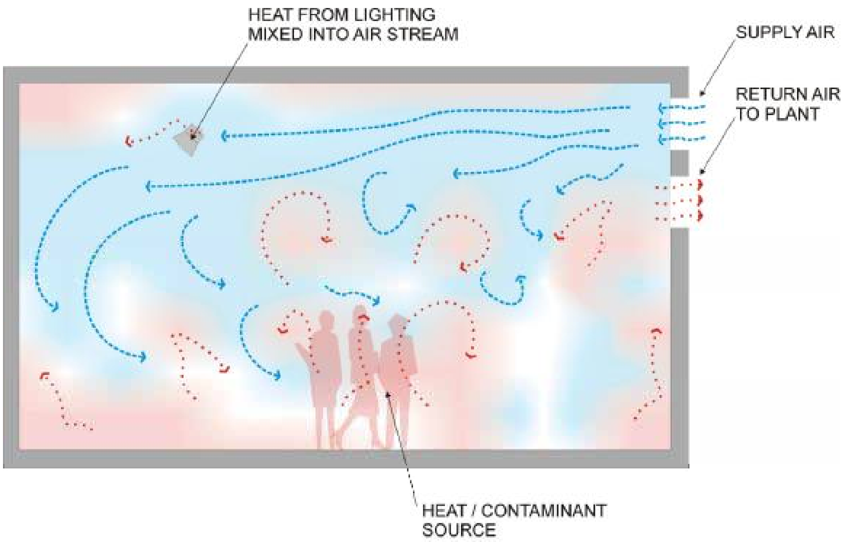
3.2 Ventilation and Conditioning to Office Spaces

The office spaces on the upper floors of the main block were designed to be entirely mechanically ventilated, rather than being naturally ventilated or mixed-mode operation being used. This decision was taken in part to deal with the noise and pollution presented by the adjacent very busy road.

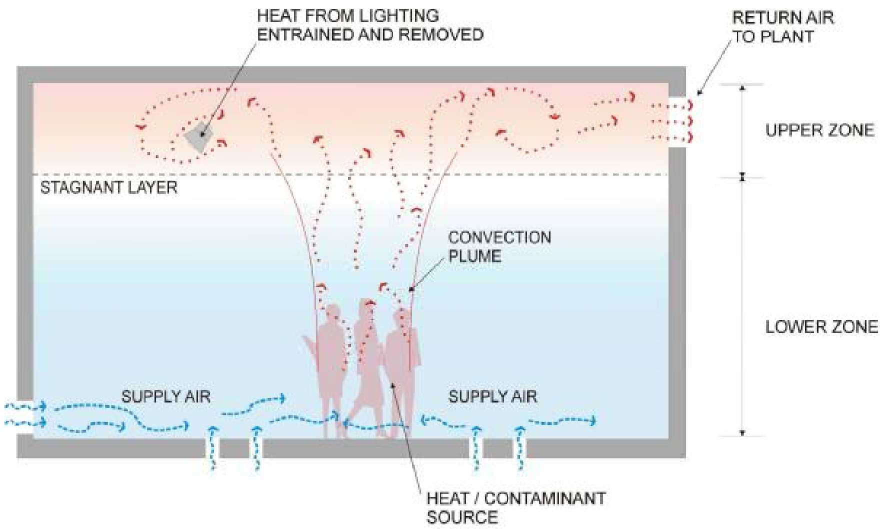
The developer and design team wished to avoid the use of an energy-intensive traditional air-conditioning system, which was the standard approach at the time in Grade A speculative office space. Instead, a displacement ventilation (DV) system was installed, with indirect evaporative (adiabatic) cooling. The expectation was that this would result in a 50% saving in energy use and up to 60% reduction in carbon emissions.

The air-handling units (AHUs) on this system act to either cool or warm the air supply to the offices - as shown in the diagrams on the previous page. The volume of air moved by the fans is likely to be similar to that for an air-conditioned building. The difference is that none of the air is re-circulated (other than when

Conventional air-conditioning air distribution by mixing. (Air is supplied at design condition at approx 12°C)

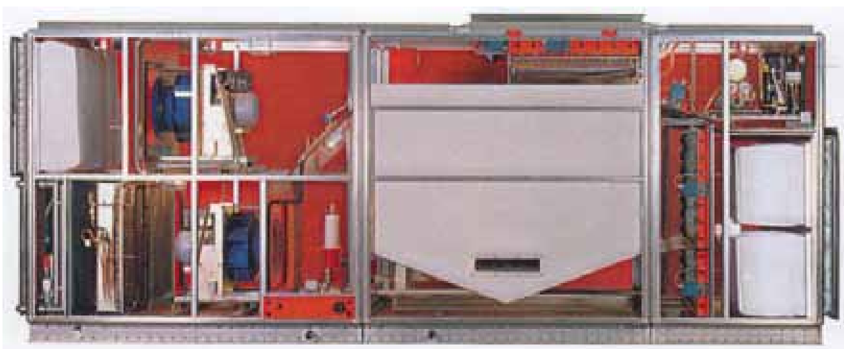


Displacement air-conditioning air distribution by displacement from floor level. Air is supplied at design condition at approx 19°C



Above: Diagrams comparing conventional air-conditioning distribution and displacement distribution (from Atelier Ten design stage report, Dec 2008).

Below: Photograph of inside of AHU (from Atelier Ten design stage report, Dec 2008).



the unit is in 'winter warm up' mode), with full fresh air instead being supplied. Air is supplied at low-velocity, to avoid mixing, whilst in contract air-conditioning supplies at high velocity, so that fresh and re-circulated air does mix. DV is therefore assumed to achieve better indoor air quality as pollutants are extracted, rather than being mixed or re-circulated.

For much of the year 'free' cooling is provided by the supply of outdoor air. In the predicted 15% of hours per year when the external air temperature exceeds the internal supply air temperature of 19°C, adiabatic cooling is used. Mains water is sprayed into the air extracted from the offices, cooling and humidifying it. This cooled air passes through a heat exchanger, cooling the incoming air. It was predicted that when the external air temperature was 29oC, this system would be capable of reducing the supply air temperature to 20oC - with the only energy expended being that required for the fans to move the air. In winter, a reverse process is used, with heat being extracted from the outgoing air via the heat exchanger.

Whilst these AHUs were metered for their use of heat from the district heating system on installation, their electricity use was not metered. This was addressed as part of this study, with electricity meters being fitted to each of the two units installed.

Incoming air is supplied to the offices via floor-level ducts mounted within a floor-level service zone. These can be moved and arranged to suit different floor layout. Each office

Above: External motorised blinds formed part of the integrated environmental design strategy.

Right: In room control panel for individual hotel room AHUs.

Below: Photograph of roof-mounted central air conditioning plant to hotel.

floor is fitted with six air volume control devices (VAV boxes) within the floor void. Floors are zoned - north, south and central - with the amount of air delivered varied to meet the air supply requirement of that zone.

This approach means that the ceiling within each office space can be left as exposed concrete, contributing to the usable thermal mass within the building, with the intention of helping to regulate internal temperatures. Air is extracted from the office spaces at ceiling level - taking the heat gains from lighting out of the space close to source.

A final part of the environmental design of the building is the installation of motorised external blinds on the south-facing facades of the office space. These were intended to both reduce solar gains - helping to reduce cooling load - and also help control glare and thereby improve visual comfort.

3.3 Ventilation and Conditioning to Hotel and Commercial Units

The shell and core approach to development in these areas meant that the coordination of services with the rest of the development - the office spaces and the residential units - was limited. For ventilation and conditioning purposes, the hotel and commercial spaces are completely separate to the offices. This is partly a function of use - the needs of a hotel restaurant, or a supermarket, are very different to those of an office space. In practice this has meant that each of these different units and uses has taken their own approach to ventilation and conditioning, with most opting for a standard air-conditioning installation, with additional high-powered extract to kitchen areas in the hotel and restaurant.

The system in the hotel contains two levels of air-conditioning. There is a roof-top mounted centralised air-conditioning system, which runs though ducts to each of the individual bedrooms and common areas within the hotel. This is controlled via the BMS unit in the main roof-level plant room of the hotel. This is complemented by individual air-conditioning units within each hotel bedroom, mounted to the facade and controlled using a small digital panel by the doorway in each room, giving hotel guests a good degree of control over their environment. This unit is designed to only be ‘on’ when a key-card is inserted in the slot, which also controls the circuits for the lights and appliances. Most of the hotel bedrooms, other than those with private balconies, do not have opening windows, so this is the users’ only means of controlling their environment. In addition to this there are large commercial extraction units in the kitchen/restaurant area, and additional independent air-conditioning units to the hotels central internet TV and server rooms.

3.4 Photo-Voltaic Panels

Photo-voltaic panels were installed on the roof of the office building in February 2012. The system has is 8.14 kWp with a declared net capacity of 7.36 kW. These feeds into the landlord’s supply to the office block.

3.5 Metering and Control

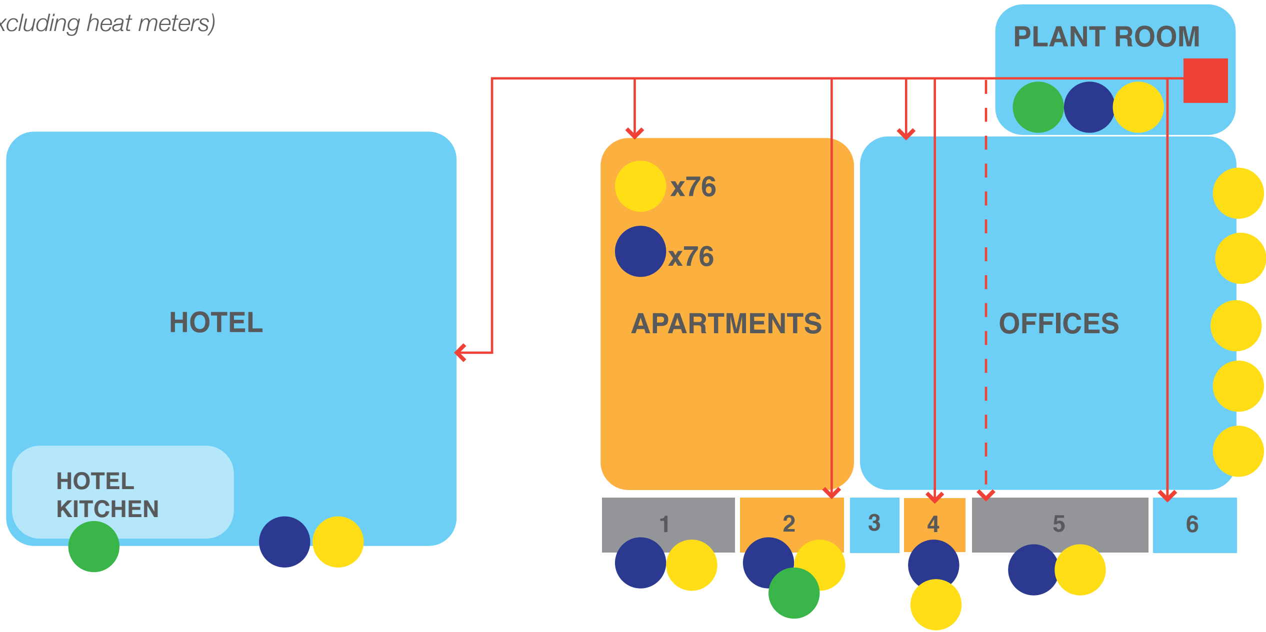
3.5.1 Metering Strategy

One of the main difficulties in this study has been the lack of existing adequate metering to be able to understand where energy is being used in the development. Whilst meters and sub-meters have been installed on almost all systems, these do not always tally with how the building is divided up and occupied, and especially are not fine grain enough to allow a detailed picture to be built up.

Heat meters: As the district heating is a key focus of this study, it was important that metering was in place that allowed us to understand which individual units were using heat energy, but also where the biggest losses were occurring in the system. Whilst the first element of this was nominally in place at the outset of the study - with each office floor, apartment, shop unit and the hotel being separately metered - we found that some of these meters were malfunctioning and some had been capped off. We also found that due to the sub-division of the office floors into smaller units, and some spaces remaining unoccupied, finding the exact locations of heat energy use was tricky. However, the bigger issue was the lack of ‘totalising’ meters on several legs of the system - in particular the office perimeter heating circuit and the residential circuit. This was addressed as part of this study.

Electricity Meters: Each individual office unit has its own metered electricity supply, separate from

METERING LAYOUT:
(excluding heat meters)



GAS METER

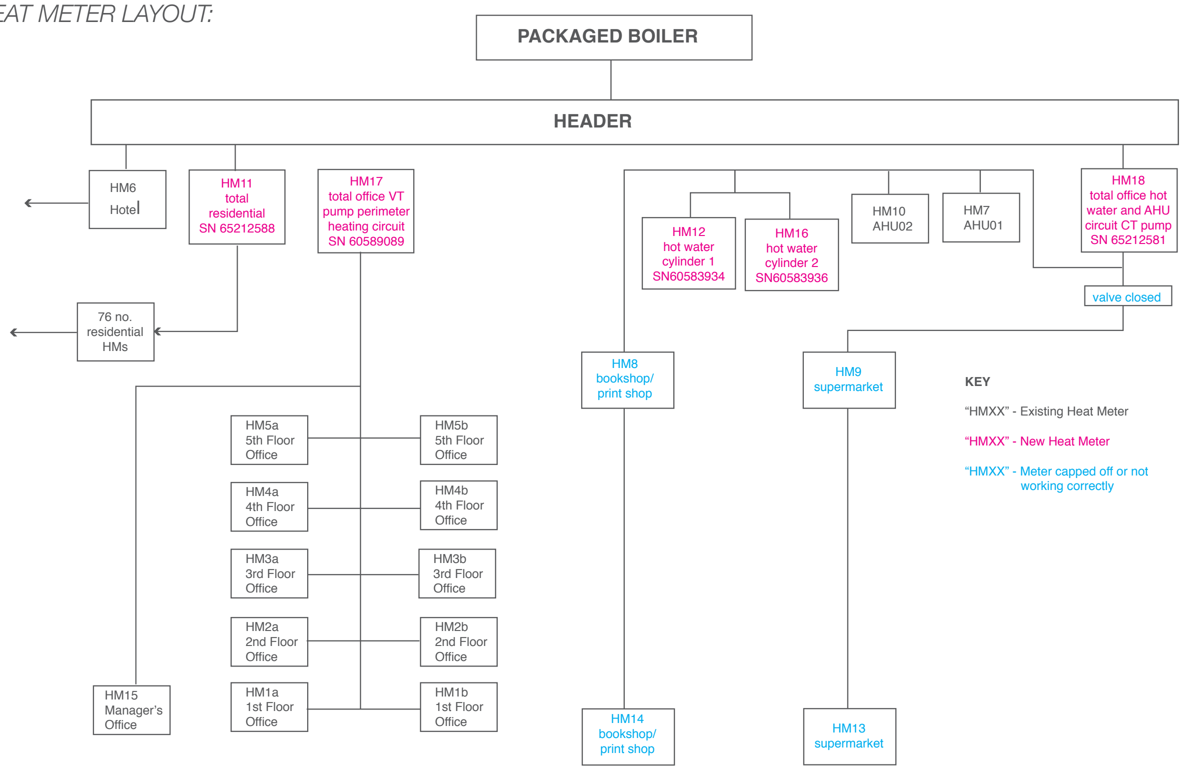
ELECTRICITY METER

WATER METER

(see separate diagram for heat meter layout

1. CINEMA (out of scope)
2. RESTAURANT
3. BUILDING RECEPTION
4. BOOKSHOP/ PRINT SHOP
5. SUPERMARKET (out of scope)
6. SHOP WINDOW GALLERY

HEAT METER LAYOUT:



that of the landlord's supply, as does each shop unit and the hotel. However, we found that the plant room was not adequately sub-metered, and so as part of the study added a meter to the AHUs to identify their energy use. Unfortunately, the only existing half-hourly electricity meter is in the hotel - data has been obtained for this. Sub-meters do exist in the hotel as part of its BMS system - though as this has no PC front end and much of the associated handover information is missing, it is difficult to find out what these sub-meters tally to.

Gas: Due to the presence of the district heating system there are a limited number of gas meters in the development - covering only gas use for the central boiler plant and the kitchens in the hotel and restaurant.

Water: The hotel, apartments and commercial/shop units all have individual water meters. The kitchens and WCs on each floor of the offices are fed from the landlord's supply, and this is covered as part of the service charge. Heat meters were also added as part of the study to monitor usage from calorifier 1 and 2, which supply the office WCs and kitchens.

3.5.2 Building Management Systems

Both the offices and the hotel have building management systems installed. The system has a PC front end control unit located in the building manager's office, to enable the operator to access the control system for logging, control and monitoring purposes. It was supplied by Berkeley Environmental Systems (Midlands) Ltd, and is a 'Trend' system.

This system controls the air-handling units (AHUs) and district heating system, as well as various other electrical and fire related services.

Within the AHUs temperature sensors monitor the supply, return and outside air temperatures. The AHU controller then determines the lowest energy circulation path (the different operating modes described above) to meet the temperature set-point. The supply air temperature set-point, hours of operation, the enabling of primary operation modes (recirculation, normal day operations) are programmable from the BMS. If night-time cooling of the building is required, the BMS was intended to start the unit and changes the required air supply temperature set-point.

Direct Digital Controllers (DDC) are also installed in the variable air volume control units, and linked together and back to the BMS.

The office heating system is controlled via an optimiser control loop within the DDC controller. Under the dictates of internal and external temperature sensors, the controller activates the plant at the latest possible time to achieve the required internal temperature at occupation.

The office district heating circuit runs on variable temperature and variable speed. The district heating circuits for the hotel and the residential areas run at a constant temperature but variable speed.

A 'Trend' BMS system was installed in the hotel, though this has no PC front end, so is only controllable from the small digital access panel in the hotel plant room, and as documentation is

Above: In room individual air-handling units, vented to building facade and directly controllable by hotel guests.

4. OCCUPANT SURVEYS

4.1 Summary

This is a large and complex development with a number of different user groups and differing uses. A decision was taken early in the study that rather than try to gather detailed information on the whole range of user experience, tools and methods would be tailored to focus on those areas of greatest concern to users, especially where they affected comfort and energy use. This was informed at the outset by the more limited post-occupancy survey already undertaken by URBED as part of Igloo's 'footprint' policy requirements, and by informal discussions with building management and users throughout the process. These tools included:

- A 'Building User Study' questionnaire and analysis, conducted separately for the office and hotel.
- A walkthrough survey of both hotel and office spaces.
- A limited thermal comfort diary in some office spaces, undertaken in response to reports of overheating and general thermal discomfort.
- Collection of temperature and humidity data in both the office and hotel spaces, again primarily in response to reported problems with thermal comfort.
- A feedback session with office tenants based on initial findings from the study in December 2012.
- A review of all of the above alongside more technical understandings developed throughout the study with those responsible for facilities management in both the hotel and the office spaces.

In carrying out the above investigations, a number of key factors in the operation of the building and users' responses to it were uncovered. Each of these key findings is outlined below, and discussed in greater in the remainder of this chapter:

- Significant problems with thermal comfort in the office spaces, and the systems intended to help users achieve comfort, with overheating a concern for many of those working in the offices, but also issues with draughts, stuffiness and perceived impacts on occupant health of these. Occupants attempts to address these issues have had an impact on the overall energy use of the building, contradicting some of the original design aims.

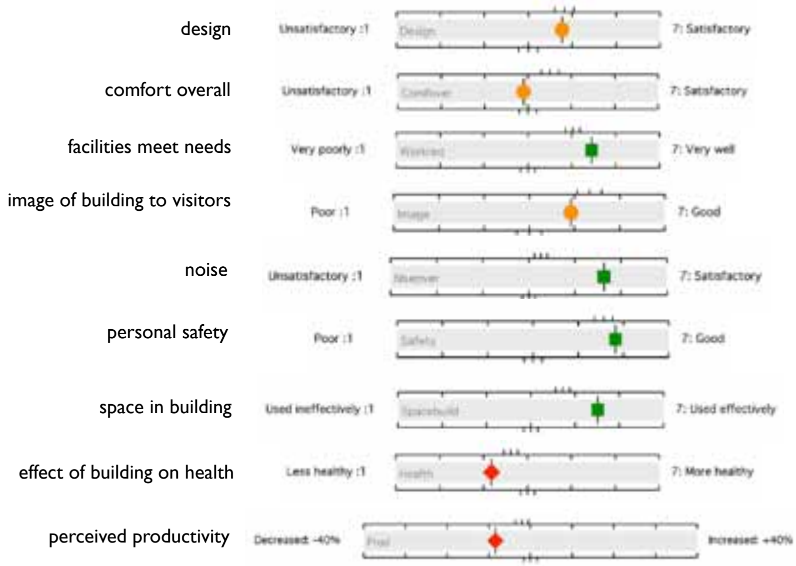
- Poor visual comfort in office spaces - mainly due to the malfunctioning of external blinds originally intended to provide solar control (which also may have exacerbated the over-heating problems) - resulting in a 'lights on, blinds down' condition in many of the office spaces.

- Problems with control and maintenance. Users and facilities management did not at the outset appear to have a good understanding of how the systems were meant to operate, and in some cases unoccupied areas were being heated unnecessarily. This was exacerbated by the sub-division of floors that were originally intended to be in the use of a single tenant. This also raises questions over the newly installed PV system on the building, and how this is to be monitored and maintained in future.

- Good levels of comfort in the hotel achieved through use of extensive conventional air-conditioning systems with limited understanding, monitoring or control of these systems, potentially contributing to the high level of electricity use here. This raises questions of how this approach to servicing fits with the stated design aims of the development, and how Igloo might address this in future developments where they relinquish control once a building is complete rather than being involved in its ongoing management.

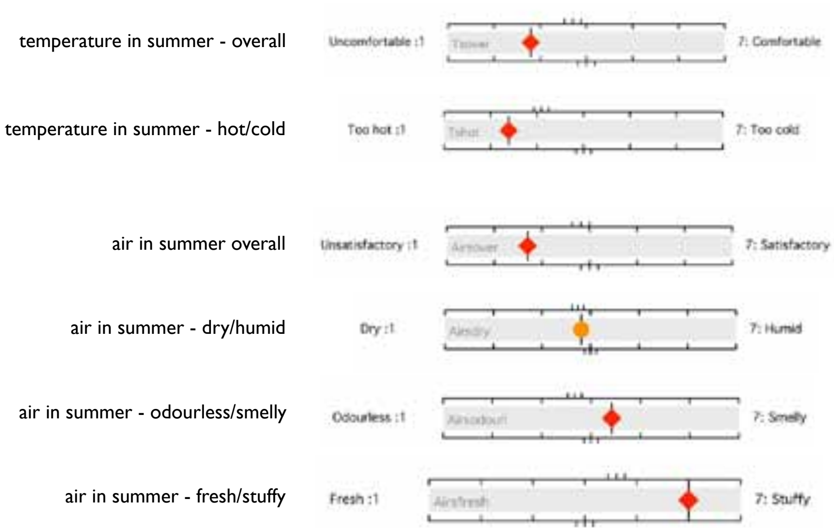
However, despite these problems, it should be noted that the building is generally well liked and well used. Despite the hard economic times, almost all of the office space is now let, the residential units have all been sold, and the hotel reports very high levels of occupancy. Whilst some of this is no doubt down to the pick-up in the economy in London over the last couple of years, the general levels of satisfaction with the building should not be discounted as a contributing factor.

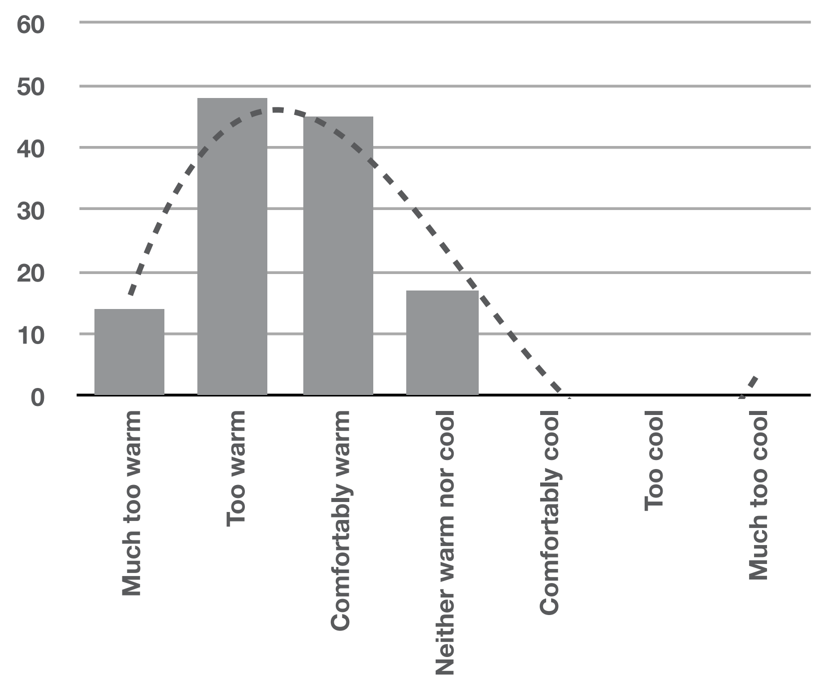
GENERAL COMMENTS



Above: General comments on the office spaces from users. Note the building is at or above average for most indicators - except for the last two, which are perhaps best explained by the problems experienced with the environment within the office spaces.
Below: Results from office BUS survey on response to summer conditions in the office spaces. The questionnaire had a response rate of 32.5%, which whilst lower than hoped, possibly due to the disaffection of some building users at this time and their distance from the building management, provides a strong indication of the user response on thermal comfort.

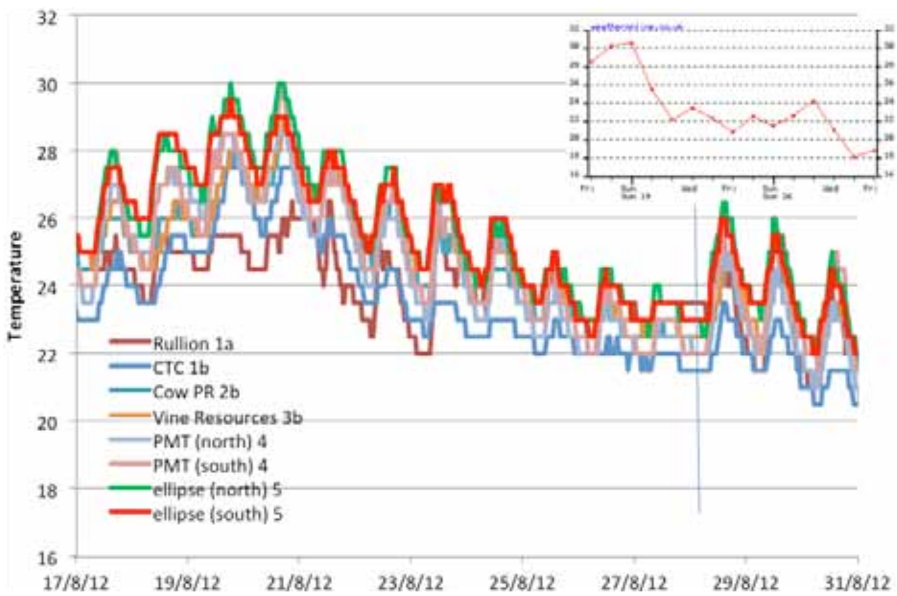
SUMMER CONDITIONS





Above: Results from a small-scale thermal comfort diary, conducted in June 2012 with 6 building users, all desk based relatively sedentary workers on the 5th and 1st Floors showing the skewing of comfort votes caused by perceived over-heating.

Below: Graph showing internal temperatures in the office spaces in August 2012. The green and red lines are the 5th floor office space (elipse). The pink and blue lines are the 4th floor offices (PMT).



4.2 Offices: Thermal comfort

4.2.1 Overheating in 2012

Both the BUS analysis and the thermal comfort diaries highlighted that overheating in the office spaces was a significant issue, with the majority of users reporting that summer conditions within the building were very uncomfortable. This is supported by evidence from dataloggers which showed that during July and August 2012, the average temperature across all the office spaces was around 24°C, with a minimum temperature of 20°C (even when offices were unoccupied), and a maximum temperature of 30°C, which was reached on the 4th and 5th Floors - well above the average external temperatures here.

Further investigations revealed a number of potential contributing factors to both the over-heating itself, and the very negative perceptions of the building users on this issue:

- Malfunctioning of AHUs: In summer 2012 one of the two AHUs designed to condition the air in the office spaces had been out of operation for over 12 months. This was discovered during routine maintenance in May 2012, and rectified at the end of August 2012. This adversely affected temperature control in the offices.
- Malfunctioning external blinds: The external motorised blinds designed to reduce solar gain and thereby over-heating were out of use at the time of this

study. Building users reported that even when they were working, they didn't respond quickly enough, and could not operate in sunny but windy conditions, since they had retract to avoid damage.

- Heating monitoring and control: In some cases unoccupied floors, or some office spaces in summer, were unnecessarily drawing heat from the district heating system when not required, so inadequate control here contributed to overheating problems.

- Occupant control and building management responsiveness: Some of the dissatisfaction of occupants was to do with feelings of lack of control. Occupants had to phone the central building reception to report problems, with the building manager then manually adjusting the set-point temperatures through the BMS. This is despite the system originally being designed to run automatically, with the intention of avoiding the need for this kind of intervention. In summer 2012 the building manager appeared to have quite a poor understanding of the overall system. The zoning of controls, despite being present as part of the design, is also unclear to users, leading to confusion.

- Lack of openable windows: A majority of BUS survey respondents in the offices complained about the lack of openable windows, which they felt would have given them more control over ventilation and cooling. The decision at design stage to not have opening windows was informed by advice from the acoustic consultant due to the building's location, but was also a cost-saving measure. As a consequence, disturbance from external noise is not a problem in the building. However, it could be argued that this is a case where it would have been better to allow people to choose their own 'trade-offs' with users opening windows when their priority was fresh air or cooling, and closing them when noise was a major concern. Frustration at the lack of openable windows is symptomatic of a lack of feelings of control over their environment as a whole for building occupants, particularly with regards to heating and ventilation, with limited opportunities for users to adapt their environment to suit their needs, limiting their capacity to achieve adaptive comfort and potential making them less tolerant of more minor changes in their environment (according to theories of adaptive comfort).

- Design and distribution of windows and shading: Excess solar radiation may be contributing to over-heating, with over 50% of the south-eastern and south-western facades glazed. The fact that external blinds are not working, and building occupants have had to install internal blinds in many cases, simply exacerbates this, as internal blinds have a limited effect on over-heating.

- Tenant fit-out and sub-division of offices: Every floor of the office space has undergone some form of sub-division. It is not clear whether this was allowed for in design assumptions, and this may have an affect on the functioning of the ventilation system.

- Tenant fit-out, light-fittings: One of the tenants had installed a number of large halogen lights as part of their own office fit out. These lights generate a significant amount of heat, and may have made some contribution to over-heating - especially as lights tend to be on all day in this office, as blinds are drawn to prevent glare. These have since been replaced with LED fittings.

This over-heating was worse on the 5th floor than anywhere else. This is particularly difficult as the 5th floor office tenant, a prestigious insurance company, had originally wanted to install a full air-conditioning system, as this was standard for their offices. However the project director at Igloo agreed a compromise position, with the insurance company agreeing to carry out a cost/benefit analysis of installing additional air-conditioning in the building, but set so that it would only kick-in once the internal temperature exceeded 25°C. On examination the directors of the insurance company decided that this would not be worth the investment, as it would be needed so infrequently. However this was on the assumption

Top to bottom:
- Halogen lights installed by tenant in 5th floor office, since replaced with LEDs.
- Floor duct uncovered in 1st floor office by user in an attempt to increase air-flow and cooling.
- Floor duct taped over by user in 2nd floor office, due to discomfort from ankle-level draughts.
- Small air-conditioning unit installed to server/ printer room in 4th floor office.

that the AHUs installed would perform as designed - which appears to have not been the case. Given the tenant here was not fully committed to this system in the first place, this has probably increased their levels of dissatisfaction.

4.2.2 Building User response to overheating

Perhaps understandably, office users took steps to alleviate these conditions, many of which will have affected the building's energy use and in some cases directly contradict the building's original design intentions. These have included:

- Installation of independent air-conditioning - no.1: One of the first floor office tenants has installed a full conventional air conditioning system. This was a direct response to their experience of over-heating. This is perhaps surprising given that this unit has only a relatively small area of external wall facing southwards, with the remainder facing the shadier square side of the development. However the density of occupation here was higher than assumed at design stage, as it is a call-centre operation rather than a standard open-plan office. There is also a lack of clarity on the part of building management as to the implications of this for the central conditioning system for the office spaces, provided through the roof-top mounted AHUs.
- Installation of independent air-conditioning - no.2: No other unit so far has installed a full air-conditioning system. However, on both the 4th and 5th floors some of the smaller cellular spaces within the floor plan of each office, created during their fit-out to accommodate private meeting spaces or offices, or to house plotters and servers, do contain individual small-scale air-conditioning units. It is unclear where this was accounted for in the original designs, and this will again be increasing the building's electrical energy use.
- Desk fans: Those offices or areas of offices that have not had air-conditioning installed have a large number of desk fans, adding to the electrical energy use within the building.
- Installation of internal blinds: Internal blinds have been installed by tenants in most of the office spaces along the south-east and south-west facades to combat over-heating and glare (see below). As the main facades for the offices face south-east and south-west and are almost wholly glazed to the offices from above desk level to the ceiling this is perhaps unsurprising. However, internal blinds are of limited effectiveness in reducing over-heating, and this will mean that more energy is being used for lighting that assumed at design stage, resulting in higher carbon emissions.
- Tampering with floor ducts: Some building occupants have tampered with or

adjusted floor ducts in an attempt to improve comfort. In summer some floor duct covers have been completely removed, in an attempt to increase air-flow and reduce over-heating and stuffiness.

4.2.3 Ventilation and air quality - perception and control

Whilst over-heating was the most commonly reported problem by building occupants, related factors were an area of concern for many, especially where they related to health, productivity and air quality. The quotes below from the BUS questionnaires give a flavour of user's perceptions:

"Closed system vent, is too still/dry/ artificial, temperature control is poor"

"The building atmosphere has a general subduing effect on everyone".

"Stuffy and airless with no means of control"

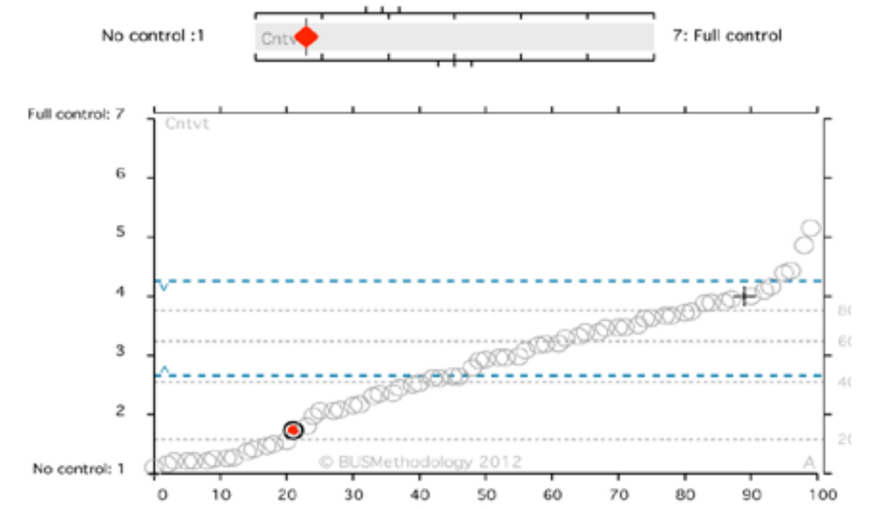
"Airless environment creates stress"

"Dusty, no windows, no natural air flow, allergies are bad in building"

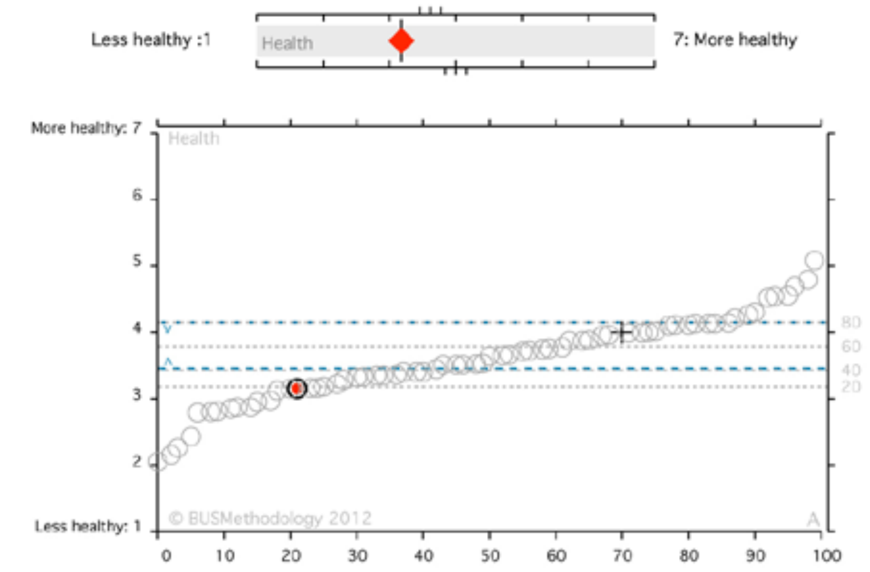
"We seem to have common bugs going round the office all the time"

These comments are supported by the results of the BUS analysis, which show the building to be among the worst performing in the data-set on control of ventilation, perceived effects on health, and stuffiness of the air in summer.

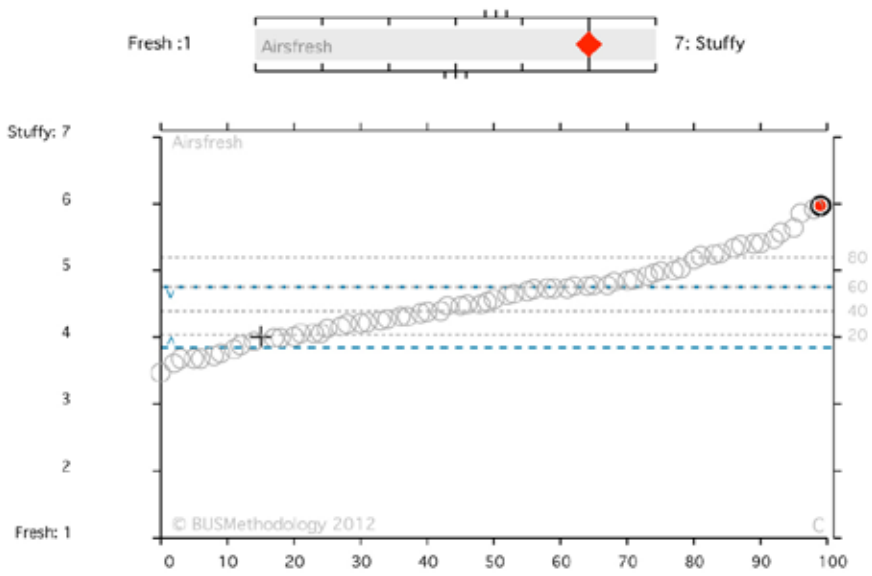
A smaller number of users also reported coldness and draughtiness, especially in winter,



Office users' reported feelings of control over ventilation



Office users' reported perceptions of the effect of the building on their health



Office users' reported perceptions of freshness/stuffiness of the air in the offices as a problem. This seems to mostly be related to functioning of the floor mounted ducts, which in many cases are positioned right beneath where people sit to work. As most of those within the building are in fairly sedentary occupations, sat at a desk looking at a computer for most of the day, even small draughts may cause significant discomfort. For such a small data-set it is difficult to say for definite, but these problems also seemed most apparent at the centre of the floor-plate in each office - at the furthest point from the perimeter radiators over which those in the offices have some control through the use of TRVs.

4.2.4 Building management actions and improvements

One of the advantages of conducting a study over a longer time-period such as this is the ability to track the responses to the issues raised in it by building management. Since the evidence above was presented to Igloo and the facilities management team, a number of actions have been taken to try and address the complaints of overheating and poor ventilation and air quality from building users. These include:

The malfunctioning AHU was repaired in August 2012, resulting in a slight drop in average internal temperatures.
Later in 2012, following renewed complaints from building occupants about overheating and stuffiness, it was discovered one of intake vents had a malfunctioning actuator and was therefore permanently closed, leading to air being recycled, and increasing temperatures - in effect the unit had been stuck in the 'winter warm-up' mode on a permanent basis. Initially this was controlled manually by the building manager, opening the vent as required. This has now been resolved, and the actuator has been fixed.

It was discovered that some of the complaints about draughts were due to the floor ducts on some of the office floors providing air at different temperatures - for example on the 5th floor at one side of the building air was provided at 21°C, and on the other at 25°C. The building manager at the time was able to deduce this, but was unable to resolve it. Since then the new building management team have been trained in how to control the temperatures from the VAVs at each end of the building, and are able to do this from the centralised BMS control.

It was discovered in later investigations that the 'night-time' mode for the ventilation system in the offices had never been put into operation. The AHUs installed are capable of 'free' night cooling, which may be appropriate on summer nights in London when the external temperature drops low enough. However it seems that whilst this may have been part of the original environmental design strategy, the manufacturer's literature suggests that this function is deactivated on delivery as standard. It therefore needs to be reactivated during the commissioning phase. It's apparent that this did not happen here (ref p.19, 21 of Manufacturer's operating instructions in O+M pack). Instead it seems the units were left to run in 'daytime' mode, as if the offices were occupied 24 hrs/day. This will have contributed to both overheating and energy use within the building. This has now been resolved by the facilities management team, with AHUs simply switched off from 8pm to 6am - reducing energy use. However, this action obviously means that the opportunity for 'free' night cooling has been negated.

The external blinds on the building have now been repaired, and are being operated by the automatically controlled systems as originally designed.
In later 2013 a new facilities management team and building manager were appointed. It appears they have taken a more pro-active approach to facilities maintenance and management, with most of the originally designed building systems now being fully operational.

Unfortunately, it has not been possible to repeat the BUS survey, to be able to chart what effect these changes may have had on the user's experience and perceptions of the building. Anecdotally the building management and Igloo staff report that building users are generally more satisfied - and that the building management are now much more responsive. However, the real test of this will be summer 2014 - particularly if the weather is warm. Continued monitoring of temperature and humidity within the office spaces throughout 2013 shows that while the situation has improved, the offices can still often be at the higher end of the normally acceptable temperature range.

However none of these actions can address the users' fundamental concerns over the lack of control they feel they have over temperature within the building and ventilation - it is not possible at this stage, without major disruption, to introduce opening windows to the office spaces or to completely re-configure the controls.
So whilst the actions of the building management are to be commended, and appear to have made a positive difference to users experience of the building, there are some key lessons for future developments.

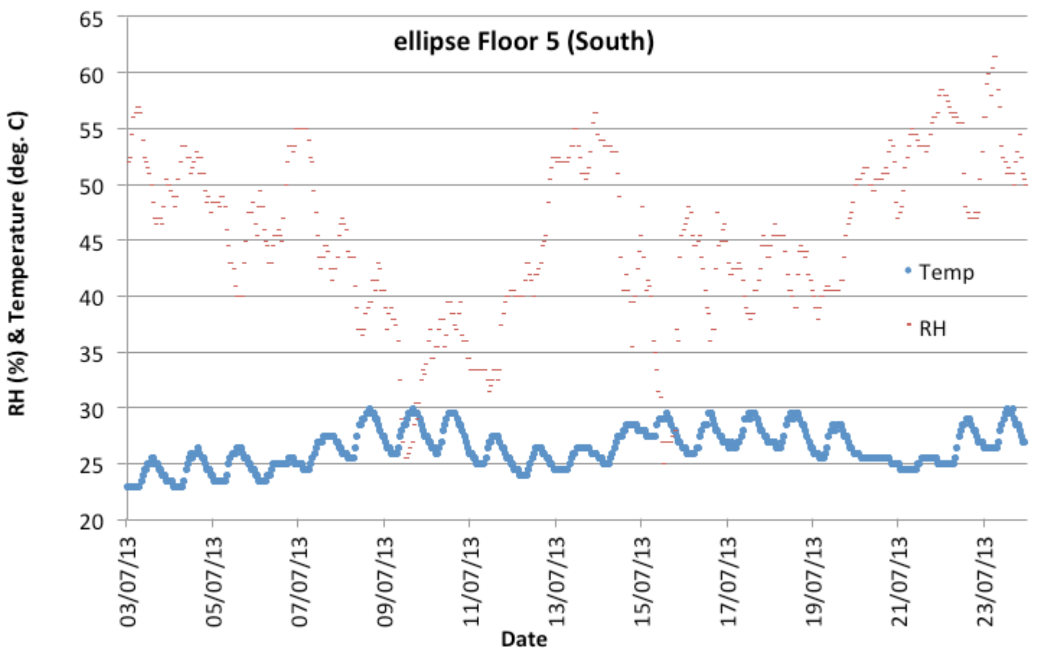
4.3 Offices: Visual comfort

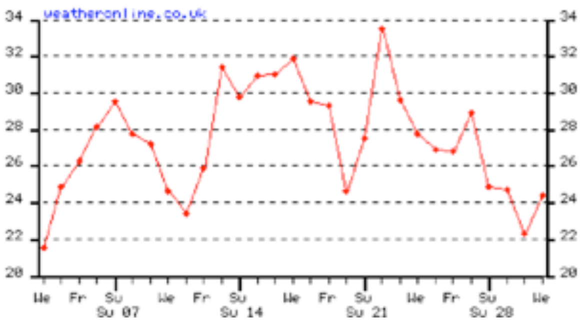
In the initial walk-throughs of the building undertaken by the study team, it was noted that a 'lights on blinds down' condition was present in many of the office spaces. Problems with glare from the sun and sky were also identified in the BUS survey. Whilst this is unfortunately a common issue in office buildings, it is disappointing to see it in a recently completed purpose-designed office building with decent environmental aspirations. The external blinds designed as part of the buildings systems to combat glare in the office spaces were not working in 2012. The blinds cannot be used on days when it is both sunny and windy, and it is not clear how closely this was considered at design stage. Though designed to be automatically controlled, via a light sensor and an anemometer, the controls had been manually overridden, leading to the blinds becoming damaged in high winds.

Two suggestions have been made as to why this might have happened. The first is that the trees planted alongside the building on Tower Bridge Road had grown enough to begin to interfere with the operation of the blinds, so the building management at the time switched off the automatic controls to prevent the blinds from descending. The alternative suggestion was that during sunny but windy conditions, following complaints from people in the offices about glare and over-heating, the automatic controls were overridden and the blinds were extended, leading to them becoming permanently damaged. The people responsible have all since moved on, so it is not possible to find out for sure which scenario is correct, though both seem plausible, and both perhaps bring into question the robustness of the original designs. The local authority are responsible for pruning the trees along Tower Bridge Road, and they have been pruned back significantly - though they are still quite close to the fully extended blinds.

Again, the length of time during which this study is undertaken has allowed us to see what response the building management have made to these issues over a 12-18 month period. The external blinds on the building have now been repaired and are back in working order.

Above left: Solar blinds in operation on Tower Bridge Road
Left: User's adapted solar shading in first floor office.
Below: Blinds down lights on condition in 4th floor offices, summer 2012.





Above and left: Grpahs showing the internal temperatures in the 5th floor office space and external temperatures during the same period.

Below: Table showing average, maximum and minimum temperatures across all office spaces during the study (from available data - see Sheffield Hallam University quarterly reports for detail).

Floor	Occupier	Location	Average Temp (°C)	Average RH (%)	Max Temp (°C)	Min Temp (°C)	Max RH (%)	Min RH (%)
5	ellipse	South	24.0	40.0	30.0	18.5	70.5	13.5
		North	24.0	43.3	29.5	19.0	71.0	13.5
		East Wall S	23.2	42.4	30.0	20.0	70.5	20.5
		East Wall N	23.6	40.3	29.5	21.0	68.0	18.5
4	PMT	South	23.4	44.4	30.0	19.0	72.5	13.5
		North	22.9	45.4	28.5	19.0	73.5	14.0
3	Vine		23.4	44.7	29.0	19.0	69.5	16.0
2	Cow PR		23.2	49.3	28.5	19.0	76.0	13.5
1	CTC		22.2	47.1	28.0	19.0	74.0	14.5
1	Rullion		23.1	44.4	27.0	19.0	67.5	16.0
		Average	23.3	44.1				

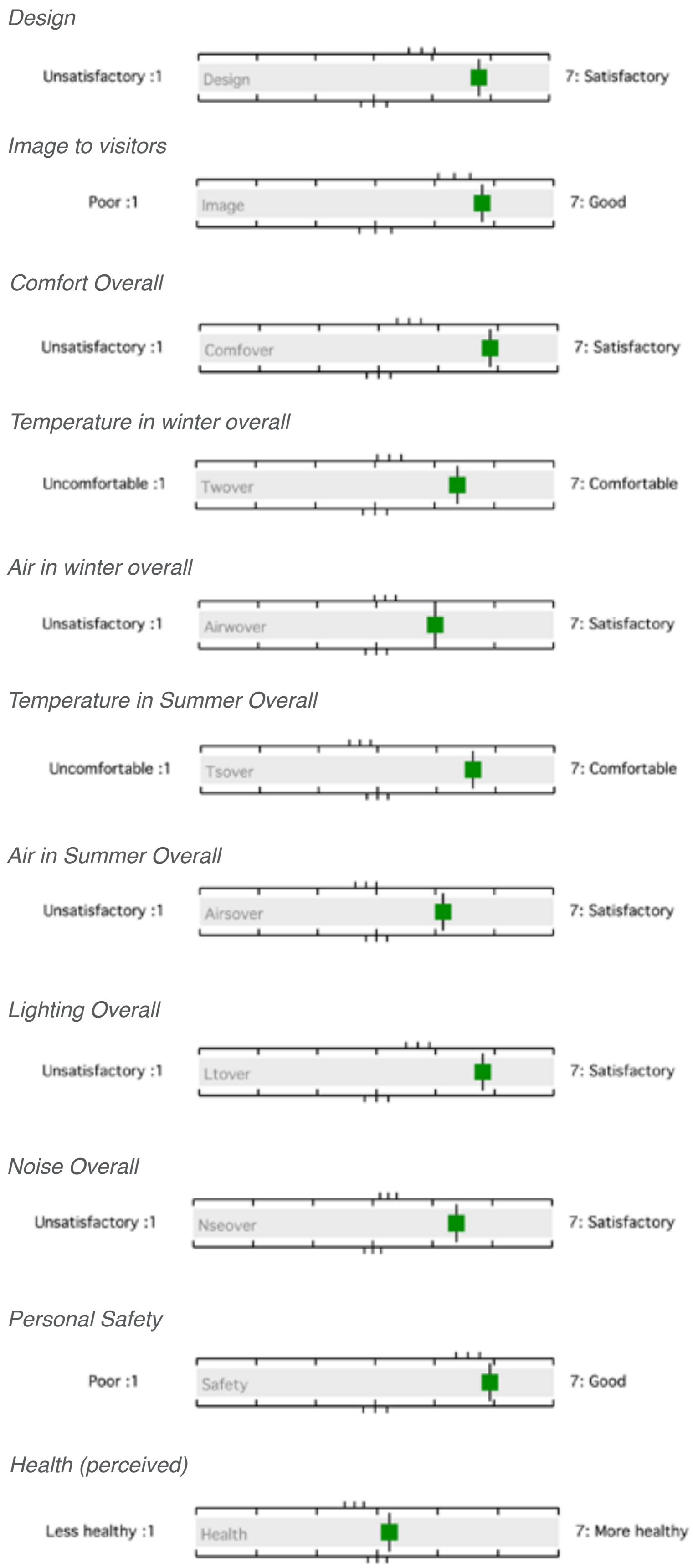
4.4 Hotel

4.4.1 Comfort and perceptions

In contrast to the offices, the hotel is highly rated across almost all criteria in the BUS questionnaire by staff. A shorter questionnaire was devised for use by guests, which was also complemented with a review of ratings on websites such as 'trip advisor' - with results again being mostly positive. There have however been fewer informal interactions with staff and guests at the hotel than in the offices, and with a more transient body of people, both staff and guests, it has proved harder to corroborate results (see note below on hotel context and methodology).

In the reception and bar areas there are some concerns about comfort - where staff complain of both draughts from the doors and glare on screens. They are also expected to stand at reception, with no seating provided, which may also affect their view of comfort. These could be relatively easily addressed by providing seating and screen-level glare control.

The context of a hotel, and the expectations of users, are likely to be very different to those of an office space. The hotel is used by a mix of leisure and business users, and both they and the staff move around the hotel using a range of different environments - from the bar to individual rooms, function rooms and the reception. The different activities inherent in this movement between spaces will affect expectations of both thermal comfort and lighting levels - which the BUS survey



Above: summary results for hotel BUS questionnaire and other follow-up reviews have not been able to cover in any great depth other than to say that its likely that they exist.

The follow-up semi-structured review with the hotel management and care-taker confirmed the generally positive view of the environment within the hotel, though also confirmed the high electrical energy use in the hotel. The use of a full conventional air-conditioning system in the hotel is providing high levels of comfort, but this is likely to be at the cost of much higher electrical energy use and thereby carbon emissions (see section 6).

4.5 Understanding of building systems

One of the biggest struggles throughout this study has been our attempts to gain an understanding of how the building's systems were designed to operate, how they are being monitored and maintained, and whether they were operating as designed or not. This has been made more difficult by the fact that often the building management have had a limited understanding of these systems themselves, and records provided at handover have proved to be incomplete and in some cases inaccurate. In the case of the offices the facilities manager felt like they'd had to 'learn as they'd gone along', and the fact that this was the third facilities manager since the building was complete will not have helped this process.

Likewise in the hotel, the management team had only a limited understanding of how building systems were meant to operate. The lack of a front-end PC unit to operate the BMS perhaps exacerbated this - meaning that the only point of interaction for the building manager with the central systems was a small and difficult to navigate control panel located in the very warm roof-top plant room.

4.6 Conclusions

The office building was well liked by users in some respects - noise and space for example. However, there were significant issues with thermal and visual comfort, namely with overheating, poor perceived air-quality and glare. These caused a great degree of dissatisfaction with the building, and they have affected the perceived health and productivity of workers. Some of these problems have since been addressed by fixing malfunctioning equipment, such as the external blinds and the AHUs. However some problems reported by users appear to be related to more fundamental design decisions such as the location of windows and the fact they don't open, or the design of control systems.

The hotel performs much better on the key indicators for comfort and well-being of building occupants. It is also well liked and has a high degree of aesthetic appeal for visitors. Indeed, the contemporary stylings of the hotel led to it being used as a filming location by the Channel 4 TV programme, 'Hotel GB' in autumn 2012 - http://www.channel4.com/programmes/hotel-gb/4od (We've assumed this 2 week change of use has not had a significant impact on energy use and benchmarking).

However, there are indications from energy use data that the good comfort performance in this fully air-conditioned building may be linked to high energy use.

In both the office spaces and the hotel there was a limited understanding, within both the facilities management teams and the users, of the building systems and how they are meant to operate. In the offices this has been addressed during the study, though this has taken a lot of hard work and effort on the part of both the facilities management teams and Igloo.

5. OPERATION, MAINTENANCE AND MANAGEMENT

5.1 Design intention and use

There are several respects in which the building is currently used or serviced which are not in accordance with original design intentions, and this may be affecting energy use:

The lower 3 office floors have all been subdivided to provide smaller units. The original intention was to let them as whole floors. There are concerns that this has affected the operation of the ventilation system.
Air-conditioning has been added by some of the office tenants. It is not clear what impact this has on the operation of the central ventilation and conditioning system, and whether any conflicts have been set up by this.
Some of the office spaces are more densely occupied than had been assumed at design stage (e.g. first floor 'call centre').
The existing building services systems in the hotel appear to not match the original design intentions. Earlier design stage documents appear to assume that the hotel would draw both heating and hot water from the central district heating system. In fact it only uses the heat provided by the central system to provide hot water, with heating provided through the electrically fuelled central air-conditioning units. This will affect both the assumptions of system losses in the district heating system, and the electrical energy use of the hotel.

5.2 Managing Agents and Handover

The role of the managing agent, and the thoroughness of handover and commissioning when the building was first completed, have had repercussions throughout the life of the building, in particular for the main office and residential block. The original managing agent were given the O+M documentation at handover, but then later claimed to not have any of it. It was later discovered in disorganised boxes in a second floor store room, and a digital copy provided by the developer to the agent was also lost.

At handover the developer arranged for training for the managing agent on the building systems, including from the manufacturer of the AHUs. The manufacturer reported that the building management team 'didn't seem interested' in the training provided, and were not engaging with it. The developer now feels that this should have set off alarm bells - however they decided to persevere with the agent, and trusted that they were setting up all the appropriate maintenance contracts for the ventilation, heating and lighting systems as reported and expected.

It was only when problems came to light approximately 18 months after completion that it was discovered that these contracts had not been set up. The developer found that one of the AHUs was not working at all and the other had blocked filters. No filters had been changed and annual maintenance checks had not been carried out.

The blinds have been another area of concern. At building commissioning the blinds were working. However, at some point these had been manually overridden (it is suggested by the building manager to allow window cleaners onto the building among other possible reasons) and never properly re-set. Left in manual mode, blinds were damaged when extended when wind was too strong. In addition, one of the trees on Tower Bridge Road had grown and was obstructing one of the blinds. So the managing agent turned off this blind separately.

Similar problems have occurred

with the BMS. This had worked at commissioning, but was somehow corrupted and then never re-booted. This meant that all of the automatic systems in the building - and in particular the AHUs to the offices - were not monitorable or controllable - making problems more difficult to identify and address.

Overall, the response of the initial building management team to commissioning and handover was poor. Rather than attempting to address problems properly, and in accordance with manufacturer's requirements they went round them with temporary fixes. As systems were not maintained properly in the first year, this has caused significant ongoing problems. (However should be noted that current caretaker, Mike, has been there all along and is very knowledgeable about the building and has helped solve quite a few of the problems).

The next building management company therefore came in to a building that had not undergone a proper commissioning and bedding in process - resulting in a failure to achieve a 'soft landing'. They struggled to understand the systems in the building, and to diagnose and resolve problems quickly. This has a knock on effect on building user satisfaction and probably also energy use. For example, they were unaware of the 'night-time' settling for the conditioning system in the office building, resulting in it being left in full daytime mode at all times, using more energy and contributing to over-heating.

The building is now on its 4th building manager, and 3rd managing agent company. This lack of continuity has not helped the operation of the building, as the building manager has to work hard each time to understand how the building is meant to work. The fact that some of the handover information is incomplete, contradictory and in some instances incorrect has not helped.

In a simpler building, this might have been less of an issue. However as described above the building's environmental systems rely on a series of interconnected automatic controls. Whilst if they were all working correctly they should require minimal input from building management, if any one of these systems develops a fault, it is vital that it is diagnosed and addressed quickly to prevent the operation of the building being very adversely affected. As the systems are quite complex, this requires a thorough understanding of how they are meant to work - something which the first two building managers at least did not have.

The igloo asset management team have worked hard to try to rectify a lot of the issues during the period of this study. It seems like the building is coming right now - but this has taken a lot of time and effort. This is a demonstration of the fact that the more complex a buildings systems and services, the more management input is required to ensure they are working properly and efficiently. Whilst it may have saved a lot of time and effort if the first building manager had adopted a more thorough-going approach to commissioning and maintenance, resulting in a reduced requirement for management input later on, it is unlikely to have negated the need for management completely.

5.3 Metering

As described above, metering in the building at completion and at the outset of this study was insufficient to understand exactly where all energy was being used, and in particular to understand the rate of system losses.

In addition to this there have been questions about the reliability of some of the meters installed. Indeed, there are still some questions about whether the heat meter to the hotel is functioning correctly. There have also been difficulties in understanding exactly what is being monitored. Alongside this study a survey was commissioned of all the existing meters in the office/commercial areas - this has informed the detailed work undertaken as part of the TM22 energy assessment of the building - but it was also required so that the developer landlord could more accurately bill their tenants for the heat energy used (something that had also caused problems for management throughout the life of the building.

6. ENERGY USE

As a mixed use building with different ownerships and tenants and a complex and partial metering arrangement at completion (see discussion above), it has proved to be quite a challenge to identify where in the development energy is being used and to break this down sufficiently to develop an understanding of how the current situation might be improved. A number of additional energy meters, both heat and electrical, were introduced as part of this study to create a clearer picture. Whilst it hasn't been possible to obtain a very fine grain of information everywhere, the data collected supports a number of key findings which are set out below.

6.1 District Heating System

One of the key aims of this study was to understand the performance of the district heating system at Bermondsey Square. It should be noted that whilst this study, as a non-domestic BPE project, does not include the residential element of the scheme, it has been necessary to gather data on the residential energy use from the district heating system, to understand the system as a whole. Understanding the system is seen as particularly important as district heating is seen by many as a means of reducing carbon emissions from new-build developments (for example in the London Plan), and igloo have a number of schemes in development for which district heating is being considered.

6.1.3 Overall system efficiency

The district heating system is fed by a bank of condensing gas boilers, for which the total amount of gas used in 2012 and 2013 is known. At each of the points where heat from the system enters a domain for use, a heat meter is installed. This means it is possible to compare the total amount of energy entering the system with the useful heat energy arriving at each of the different uses and units within the development. This has revealed a significant gap between energy input and useful heat energy supplied. The overall system efficiency stood at 40% for 2012, and 46% for 2013 - i.e. of the energy put into the system in the form of gas, only 40%/46% reached the building occupants as usable heat. For a relatively new development, with ambitions towards low energy design, this is obviously disappointing. With the ratios reversed, in effect looking at the 'primary energy' multiplier equivalent, a multiplier of 2.53 was achieved for 2012, and 2.17 for 2013. With the primary energy multiplier for grid electricity usually assumed to be approximately 2.7, this means that in effect the system has performed only marginally better than direct electrical heating.

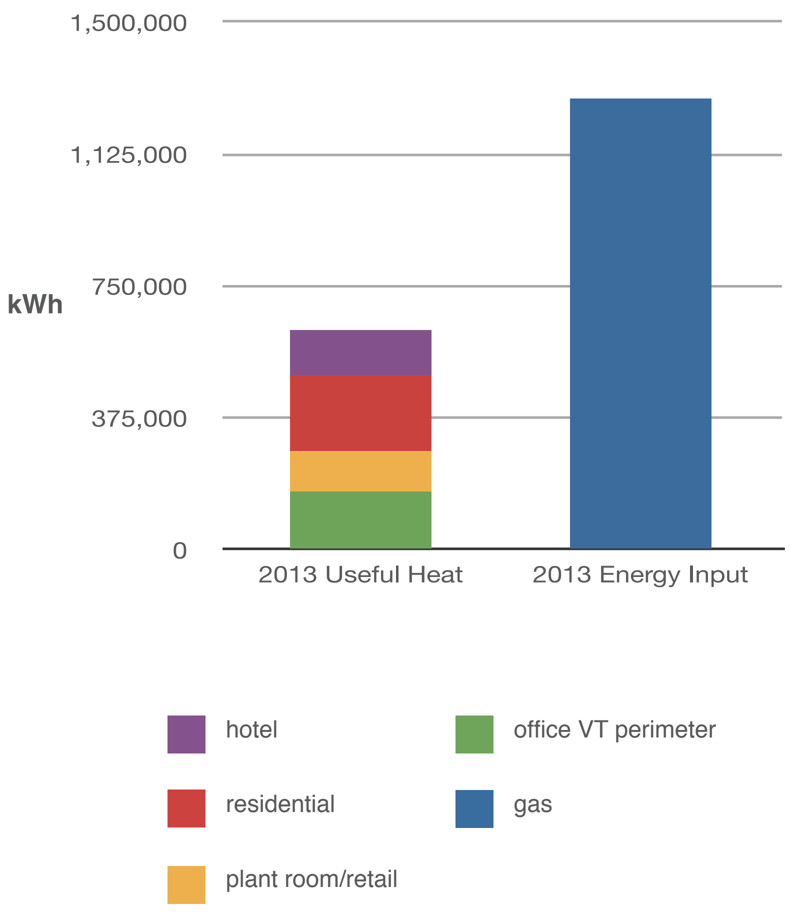
6.1.2 Distribution losses

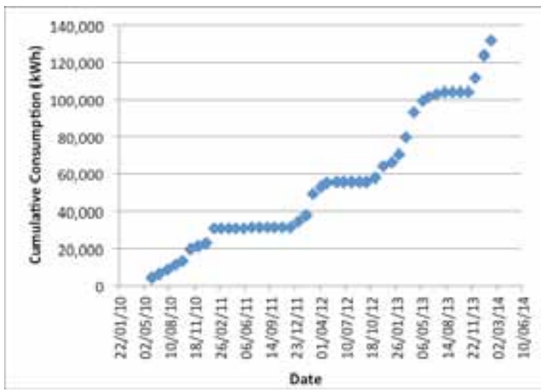
Given the boilers installed with the system are new, with a stated seasonal efficiency of 93%, the mostly likely cause of this poor overall system efficiency is large distribution losses. If a boiler efficiency of 90% is assumed, the efficiency of the system distribution is calculated to be approximately 51% (using 2013 figures, overall system efficiency/ boiler efficiency). This means approximately half the energy entering the system is lost before it reaches the users. Even if the boilers are operating less efficiently - say at 80% - this still suggests a distribution efficiency of only around 56%.

Adding a number of meters to the network, including 'totalising' meters for the different legs of the system, allowed us to find where the most significant losses are occurring. The highest losses by some margin, at 73%, are on the office perimeter heating circuit. This second highest, at 47%, were on the residential circuit. With the available data it has not been possible to ascertain exactly what is causing these very high distribution losses.

Lower than expected heat demand may be one cause. It is not clear from the information available what assumptions were made about space heating and hot water demand at design stage. If these demands were significantly overestimated, this will act to increase the proportion of losses vs overall energy use - as losses have a tendency to remain fixed for a particular system no matter what the

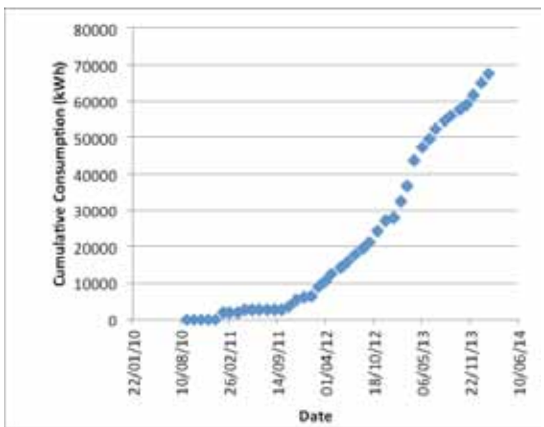
Useful heat energy vs energy input to district heating system.





Left: Graph showing cumulative energy consumption for AHU1

Below left: Cumulative energy consumption for AHU2



end use demand. No dynamic modelling was undertaken on the scheme to determine space heating demand, though the building fabric is of a greater thermal efficiency than was demanded at the time and there are significant areas of potential solar gain. It's not clear whether this was taken into account in the sizing of the district heating system.

However it should also be noted that there are, despite the efforts of this study, still some question marks over the reliability of the heat meters on this system. In particular, the heat meter for the hotel seems to be giving an improbably low reading. If this reading is true, then it suggests energy use for the provision of hot water in the hotel stands at 18 kWh/m^2.a. The good practice benchmark for this type of hotel stands at 48 kWh/m^2.a, the typical at 72 kWh/m^2. . Whilst the hotel does have some low-water fittings, it also has hot tubs and power showers and a generally high level of occupancy (>80% on average), making the reading given by the meter questionable if not improbable. Therefore all related benchmarks should also be considered with caution, and if this meter is in fact at fault, the system losses discussed above may not be as great as assumed (though it seems unlikely that this would negate all these losses). This can only be known for sure once the meter here has been re-checked and re-calibrated - something that has not happened in time to inform this study.

It is also not clear what assumptions were made on the occupancy of the building, which will also have affected space heating demand. The stage 4 footprint assessment, undertaken for igloo, found that many of the residential units are used as city 'crash pads', so occupied only on a part-time basis. Similarly, the office units were not fully occupied on completion, again potentially reducing demand for this period, whilst the design of the system still required heat to be circulated, resulting in proportionally increased distribution losses.

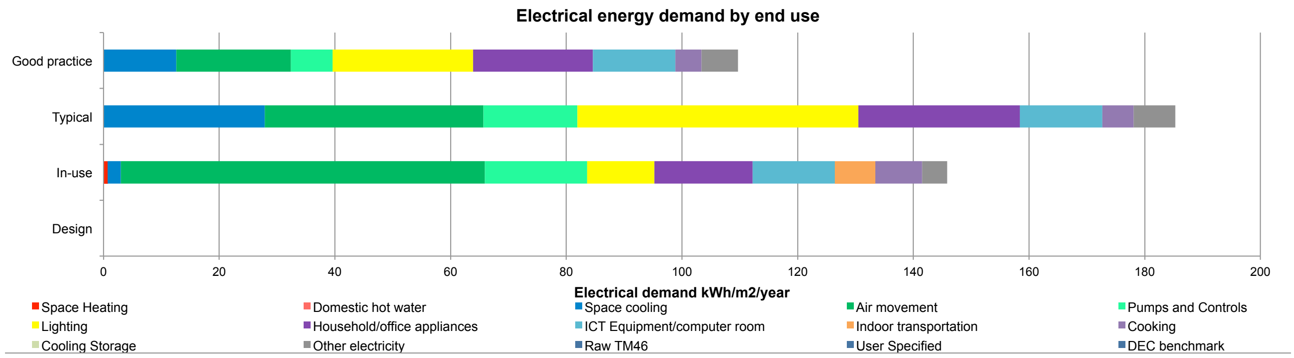
All of the above may also have acted to increase the return temperatures on the system, as less heat was drawn from it - reducing the difference between the flow and return temperatures and thereby reduce the efficiency of the boilers. This would reduce the potential for the boilers to be able to run in condensing mode.

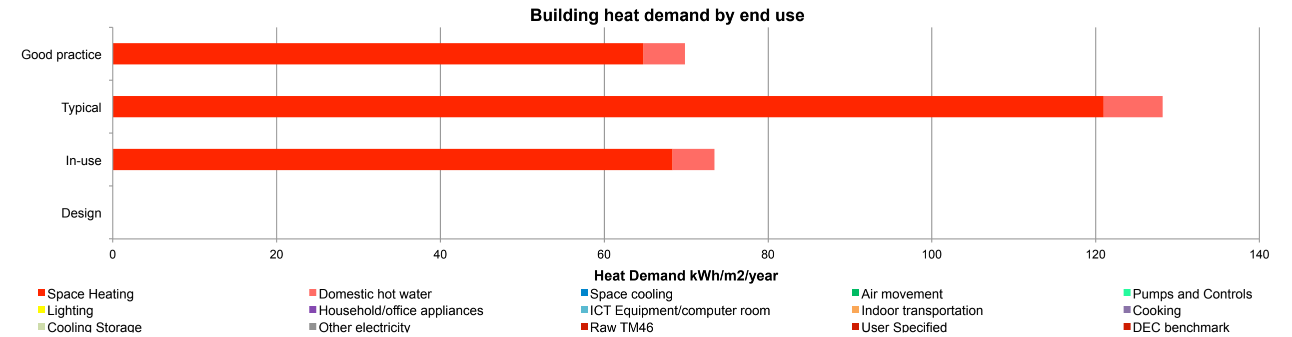
Controls may be another issue. Further analysis has shown that contrary to expectations, both the residential and office heating circuits showed a linear distribution of energy use across the year for 2013 - meaning that approximately the same amount of heat was being consumed in the middle of the summer as in the middle of winter. A similar pattern was uncovered in one of the central air-handling units to the offices, with AHU2 consuming 2,330kWh of heat in July 2013, during a period of higher than average external temperatures. This is obviously wasteful, and suggests the possibility of the heating and cooling systems operating at the same time and being in conflict.

The installation of new heat meters identified wasted energy, which could then be addressed. For example a valve on one of the retail circuits was closed when it was discovered that energy was still being consumed while the unit was unoccupied (in the time between the change over between tenants).

It was later discovered that the 'night-time' settings for the BMS controlling the district heating and AHU systems had been disabled, meaning the system was operating in daytime mode, and circulating heat, when the occupancy pattern of the building did not call for this. This will have increased overall energy use and increased losses, whilst also in all likelihood contributing to the overheating experienced in many if the office spaces, as there was limited opportunity for the office spaces to cool down overnight. Despite the AHUs being capable of it, the potential night-time 'free-cooling' mode was never commissioned - again contributing to excessive energy use and overheating.

This all suggests that within the office spaces at least, there are serious questions over the appropriateness, performance and commissioning of the installed control systems. Whilst we understand that the AHUs have undergone some maintenance and repair during the period of this study, we would strongly recommend that a thorough review is undertaken of the controls on both the district heating system and the AHU cooling system to ensure that they are configured so they cannot both be in operation at the same time, and that an appropriate





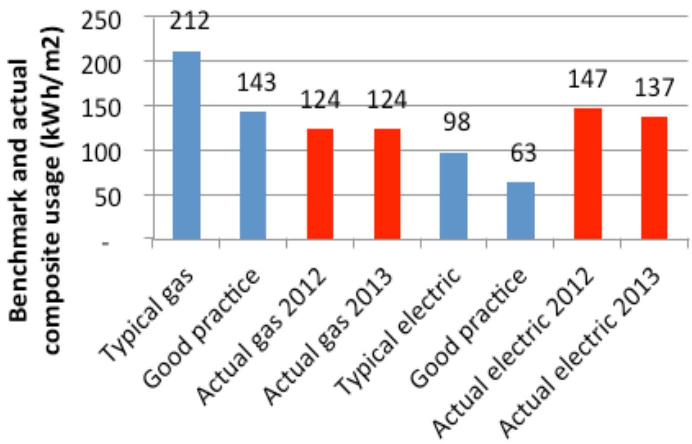
'deadzone' between heating and cooling set points is configured. We'd also suggest that if possible, the night-time 'free cooling' mode is commissioned to help cool the office spaces in summer - rather than the units simply being 'shut down' at night as at present.

6.1.4 Conclusion

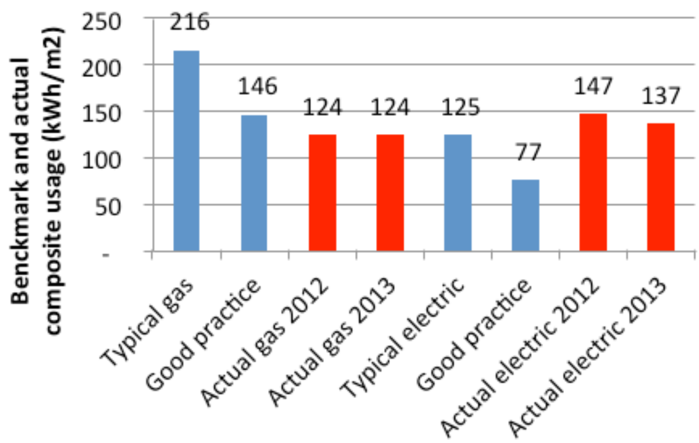
The above findings raise serious concerns about the district heating system at Bermondsey Square, and district heating systems in general. If these figures for actual distribution losses are the norm, it suggests that many of the savings from district heating systems are not being achieved in reality, bringing into question their usefulness as carbon emissions reducing technology. It also shows the importance of effective monitoring and controls on such systems, to minimise any avoidable energy waste.

Above: Graphs showing ECON19 benchmarking from TM22 tool for the office spaces only, using 'Type 3' conventional air-conditioned offices as benchmark. Below: Graphs showing area-weighted whole site benchmarking - for air-conditioned (ECON 19 Type 2) and naturally ventilated (ECON 19 Type 3) for offices. Hotel benchmarks from ECG36 Type 2 for both.

Composite whole site benchmark (type 2 office):



Composite whole site benchmark (type 3 office):



6.2 AHU Energy Performance

A second key aim of this study was to understand the performance of the adiabatic cooling system in the office spaces as compared with a more standard air-conditioning system. The assumption at design stage, repeated in the tenant handbook, was that this would result in energy savings of approximately 50% and carbon emissions reductions of up to 60% vs a standard chiller-based system. It was also expected that it would do this whilst still providing an acceptable internal environment. As can be seen from the findings of the occupant surveys outlined above a comfortable environment was not achieved for many users - though this appears to have been at least partly due to the malfunctioning of the system and in particular its controls, rather than something inherent in its design and specification.

The TM22 analysis undertaken as part of the study breaks down energy by use and benchmarks it against a variety of industry standards. This is useful when trying to understand whether the claims made for the ventilation and conditioning system at Bermondsey Square have any relation to what has happened in actual use.

When comparing the electrical energy use at Bermondsey Square with the ECON19 benchmark, it can be seen that whilst the calculated energy use for cooling is much lower than both the 'good practice' and 'typical' benchmarks, the energy use for fans is much higher. When these two elements, both necessary for the ventilation and conditioning of the office spaces, are combined, the resulting total energy use associated with the AHUs at Bermondsey Square is similar to that for the 'Typical' benchmark. This is obviously disappointing given the claims made for this system at design stage. However it should be noted that this performance may be due to the problems that have occurred with the control and maintenance of the system, rather than being inherent in the design of the system itself - though obviously the outcome is the same.

6.3 PV contribution

The PV system installed on the roof of the office block was calculated to have contributed 8,240 kWh in 2013. This stands against a total electrical energy use for the office block of 531,606kWh. So the PVs are thought to have supplied approximately 1.5% of the building's total electricity demand.

6.4 Overall energy use and benchmarking

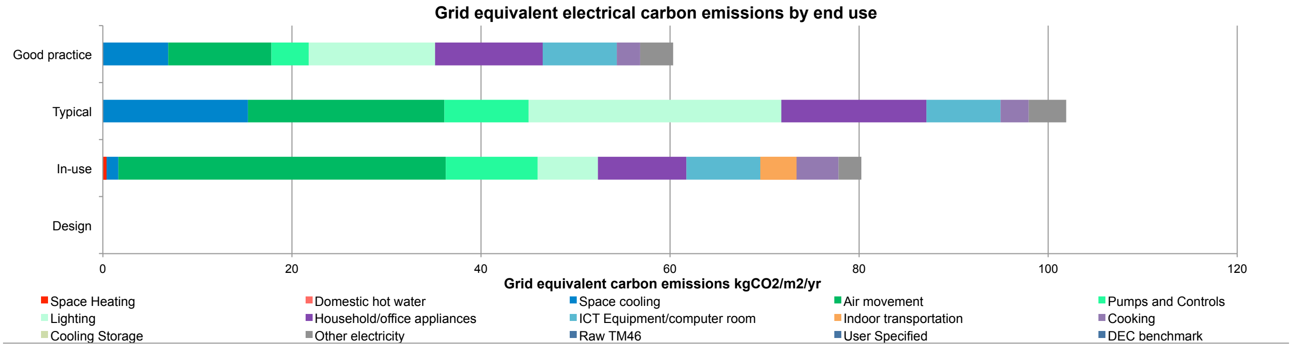
6.4.1 Whole site benchmarking

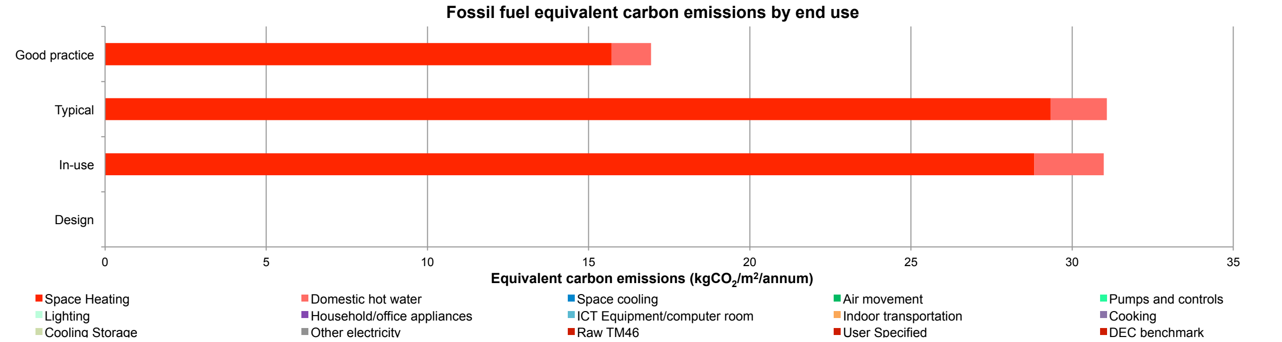
The mixed use nature of the development makes the construction of reliable energy benchmarks more complex than in a single-use, single-occupier building. A composite benchmark has been developed, to cover the entire development (see B2 Interim Energy Assessment Q9, r1).

The office space at Bermondsey Square, with its fully mechanical but non-standard air-conditioning system, does not fit neatly into the industry standard benchmarks for offices. So here we have shown both benchmarks - both for 'Type 2' open plan naturally ventilated offices, and 'Type 3' purpose-built air-conditioned speculative office development.

As can be seen from the resulting graphs, the overall development performs better than both 'Typical' benchmarks, but worse than both 'Good practice' benchmarks. As a relatively new building, it should be expected to perform better than the 'Typical' benchmarks, which include many much older and presumably more inefficient buildings. However, as a development with aspirations for a good environmental performance, it is disappointing that it does not more closely approach the 'Good Practice' benchmark in both cases.

Looking separately at the heating and electrical energy use for the development provides a slightly different picture. Heating use appears to be lower than both the typical and good practice benchmarks provided. It appears this may be explained at least in part by a much lower than expected heating energy use in the hotel. This may be partly explained by the fact that some space heating in the hotel is provided by in-room conventional electrical AHUs, with heat from the district system being supplied only to the central AHUs - thereby reducing 'heating' energy use and increasing electrical energy use. It also raises questions about the accuracy of the heat meter for the hotel - as usage is so far below the expected benchmarks. It seems possible that some



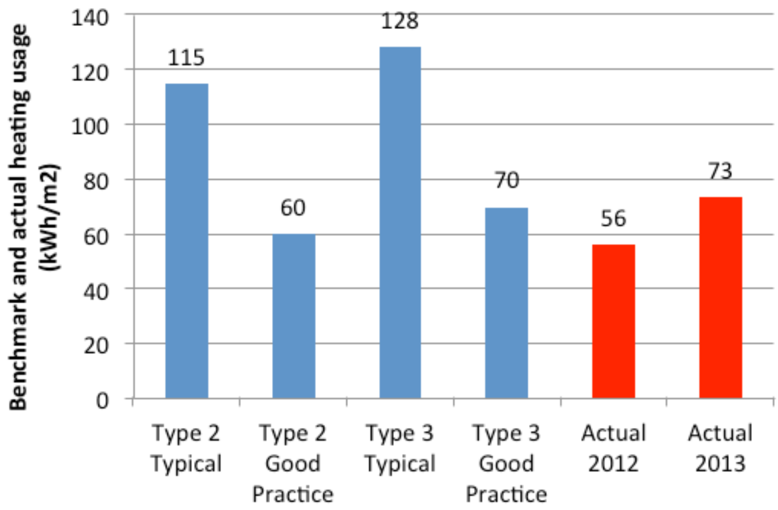


Above: Graphs showing ECON19 carbon benchmarking from TM22 tool for the office spaces only, using 'Type 3' conventional air-conditioned offices as benchmark.

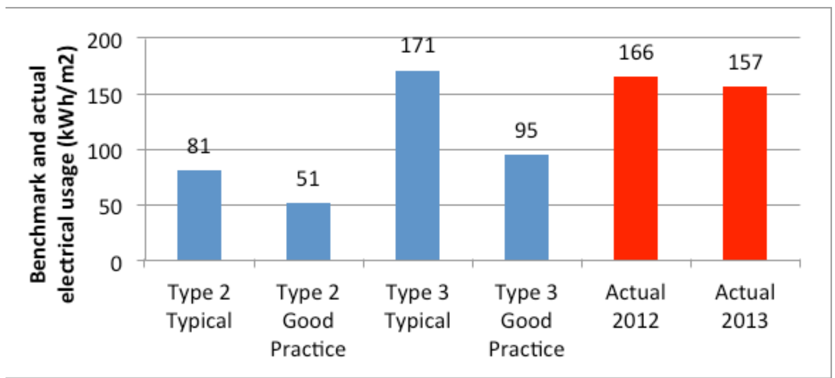
of the 'missing' heat from the district heating system is actually being used in the hotel, but being metered inaccurately. This meter should be checked as a priority. Though outside the scope of this study, it also seems likely that the residential areas use less heat than predicted at design stage or by benchmarks. (see stage 4 'footprint' assessment - comment from residents that over-heating central circulation corridors mean they don't need their own heating to be on very much at all - as heat comes in from the corridor).

The heating energy use in the office spaces sits at around the 'good practice' benchmark. Again, this may be surprising given the findings above relating to controls and the district heating system. However, given the other information available on overheating and the mal-functioning of the ventilation

Offices benchmark and actual heating energy use:



Offices benchmark and actual electrical energy use:



system to the offices, this is perhaps less surprising - with overheating being much more of a problem than under-heating.

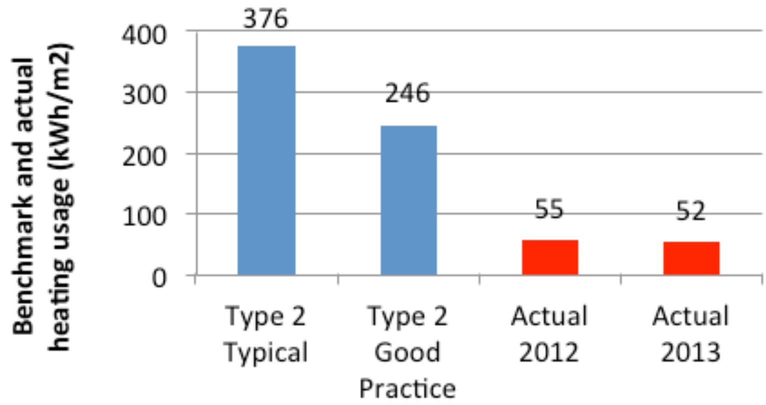
Electrical energy use across the development is higher than the ‘good practice’ benchmarks for the offices, and in the composite benchmark and for the hotel is higher than both the typical and good practice benchmarks.

There are a number of reasons why this might be the case in both the hotel and the offices. In the offices this includes:

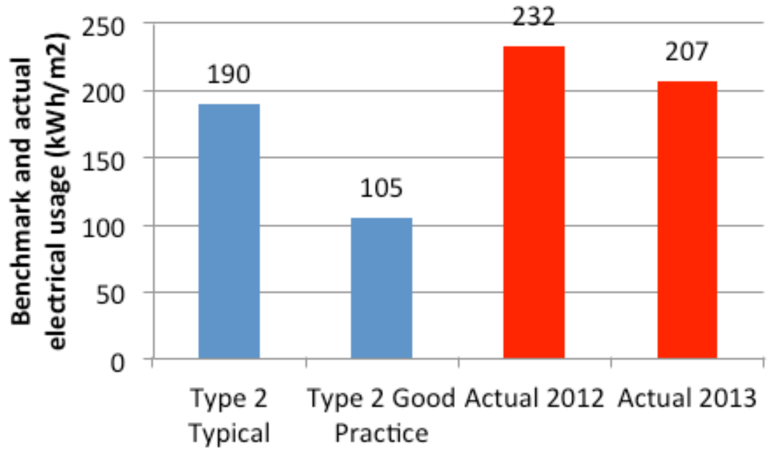
- The installation of additional air-conditioning units by several of the tenants.
- The use in many of the offices of desk fans to combat the uncomfortable internal environment.
- The higher than expected energy use for ‘air movement’ associated with the conditioning system and AHUS.
- Energy use for pumps and controls - associated with both the district heating systems and AHUs is higher than the ‘typical’ benchmark.

In the offices it should be noted that lighting energy use is calculated as well below the benchmarks - whilst ICT and appliance use is in line with the benchmarks. However again, these findings should be treated with some caution as they are reconciled rather than directly metered figures. Directly metering each separate use was not possible. Instead at Bermondsey Square each separately tenanted unit was sub-metered, with the lighting and appliance use etc for each contained within this

Hotel benchmark and actual heating energy use:



Hotel benchmark and actual electrical energy use:

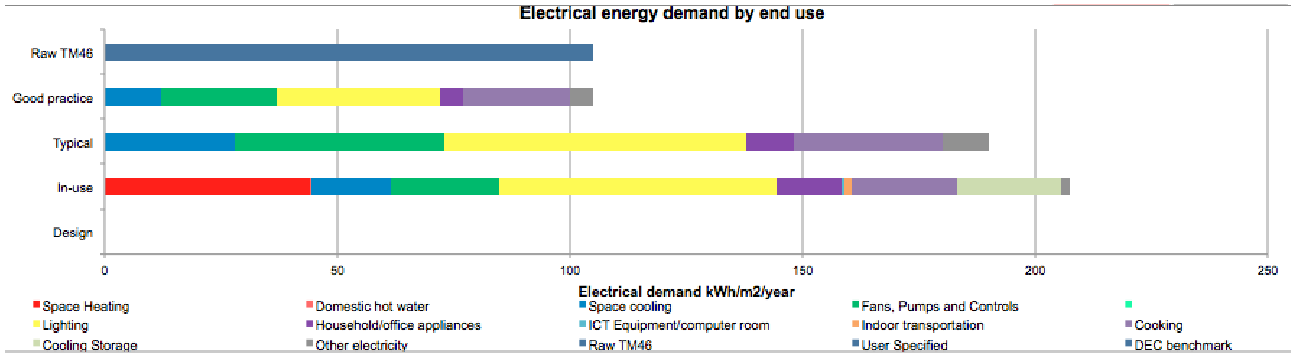


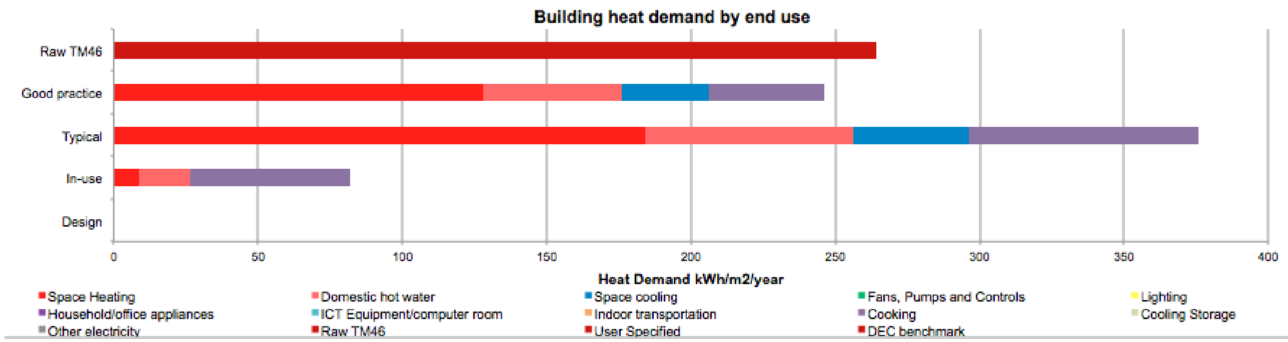
N.B. The benchmarks expect space heating to be by gas, not electricity, but the hotel uses 44 kWh/m2/yr of electricity for space heating (equivalent in CO_2 terms to 125 kWh/m² of gas and 100 kWh/m² of heat). This electricity use for space heating makes actual electricity use higher than expected at same time as actual heat is less than expected, although it still does not fully explain the gap between the actual heat and the heat benchmarks. These impacts are evened out when the benchmarking is based on CO_2 emissions

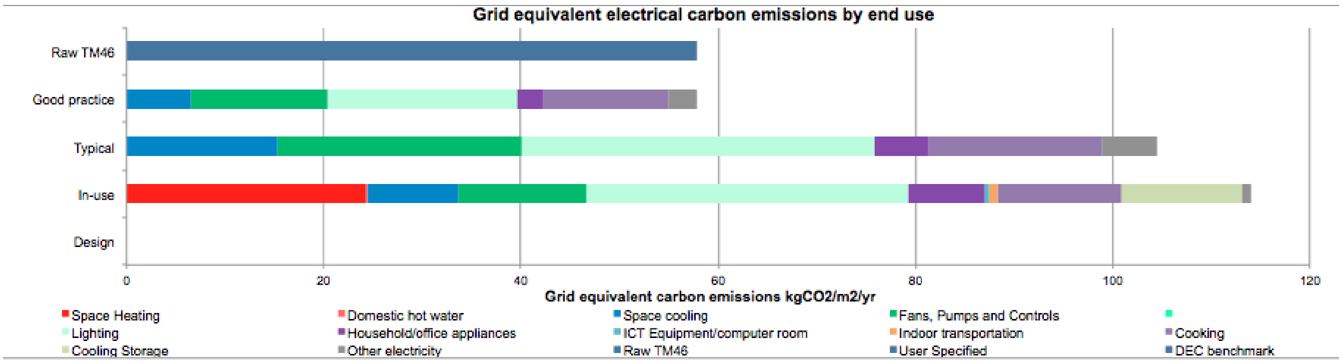
figure in the TM22 and tallied by surveying against equipment present and assumed operating hours.

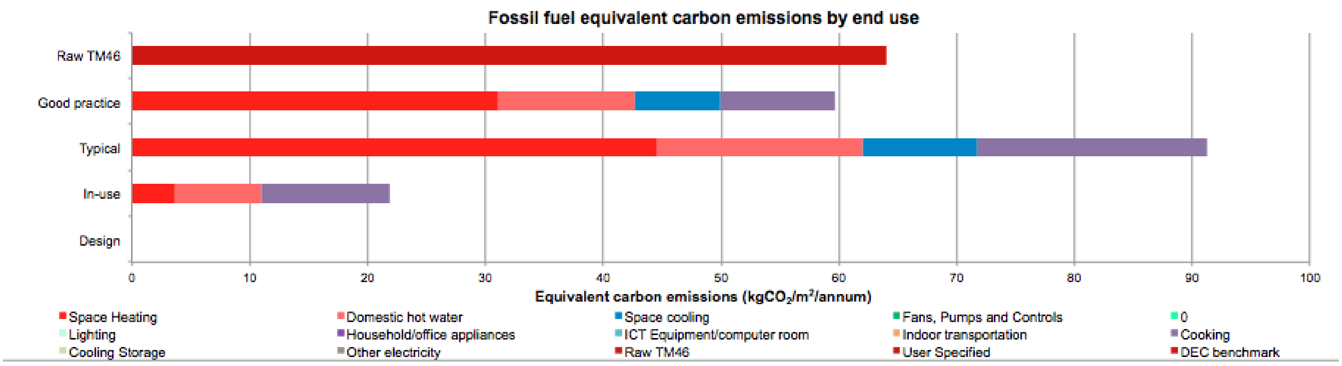
In the hotel the higher than expected electrical energy use may be the product of several factors including:

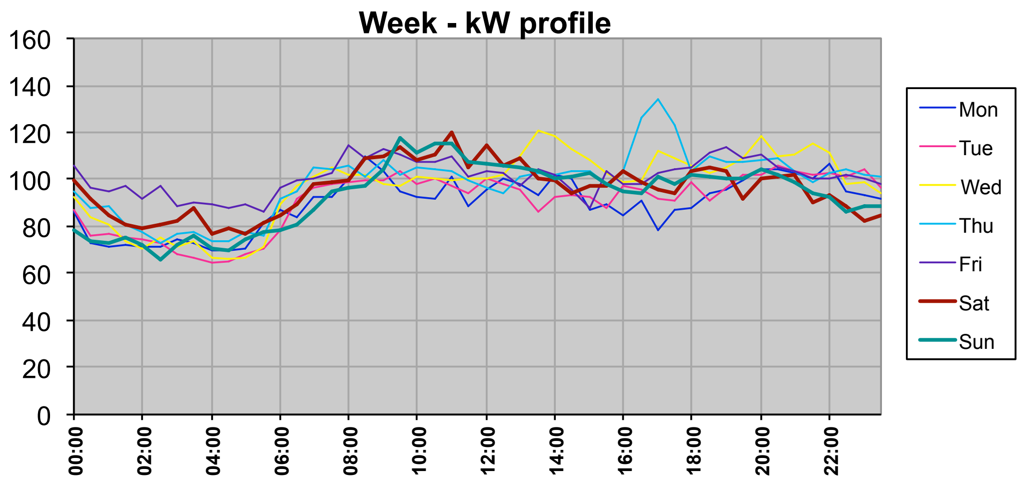
- The intensively air-conditioned nature of the building, with the use of both central and individual room traditional air-conditioning units. Whilst the individual room units can only be operated whilst a key-card is within the slot in each room which also operates the lights, providing some efficiencies. The fact that some space heating appears to be provided by the in-room units using electricity, rather than all space heating being provided from the district heating system, will act to increase electrical energy use vs the benchmarks. The higher energy use for fans, pumps and controls adds to electrical energy use for conditioning of the









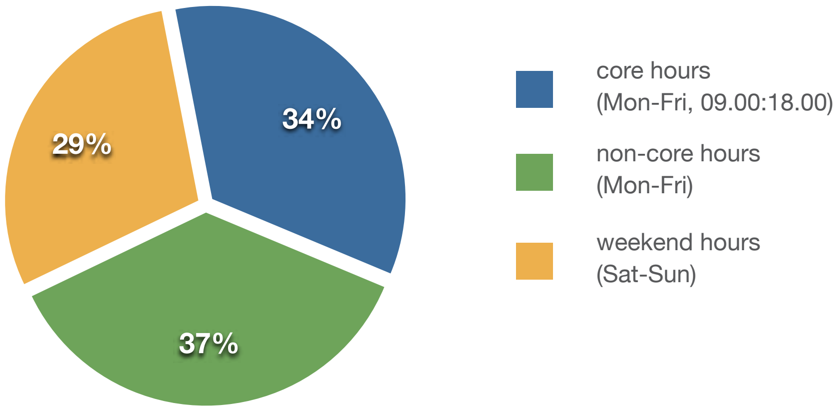


Above: Graphs showing TM22 analysis of energy and carbon emissions by use for the Hotel against ECG 36 benchmarks.

Left: Graph using half-hourly data from December 2011 to analyse electrical energy use across the week in the hotel.

hotel - possibly unavoidable in a building which is almost entirely mechanically ventilated and cooled, as so many of the rooms and spaces do not have opening windows. A commissioning check on the air-conditioning system may be advisable, to ensure it is operating as efficiently as possible.

Chart: Hotel Energy Use Pattern



- Each hotel room has a number of electrical appliances, including large TVs and iMAC computers, which often seem to be left on standby. Whilst individually energy use might be relatively small, over 70+ rooms, this will have an impact. Likewise monitors and televisions used as part of the interior design of the hotel in communal areas such as the reception and bar are left on permanently. In the TM22 analysis, based on reconciliation of metered data and a survey of appliances, shows that appliance energy use is 14.0kWh/m2.a, vs 10.0kWh/m2.a for the 'typical' benchmark and 5.0kWh/m2.a for the 'good practice' benchmark. This is something that it would be possible for the hotel management to address in their approach to interior design and controls.

- Lighting use in the hotel is just slightly below the 'Typical' usage benchmark. This may be partly a result of the design and layout of the building - with central access corridors with little natural daylight, and no daylight in key areas such as hotel room bathrooms and the central kitchen. The hotel management can however address this at least in part by the use of more efficient light fittings - particularly in the hotel rooms, where in some areas incandescent and halogen bulbs are still in use. The development of LEDs may make this more possible - as these can provide a quality of light more acceptable to guests (and interior designers) than compact fluorescent fittings. In some areas the hotel management is in the process of fitting daylight and motion sensors on lighting.
- Cooling storage: This is a significant use in the hotel, but completely absent from the ECON19 benchmarking. It includes both the large refrigerated storage associated with the kitchen and bar areas, and also the small fridge unit for chilled drinks present in each hotel room. This is clearly an area where improved efficiency could have a large impact on costs for the hotel - and something the hotel management have a good degree of control over.
- ICT and Vertical Transport: Though only a small contribution, both of these elements appear in the energy use profile of the hotel here, but do not appear in the benchmarks. This perhaps says more about the benchmarks than it does about the hotel at Bermondsey.

Whatever the cause of higher electrical energy use across the whole development, the result is significant for the environmental impact of the development as a whole. Per kWh consumed, grid electricity results in a higher rate of carbon dioxide emissions than gas, So whilst for energy use, the development may sit between the 'typical' and 'good practice' benchmarks, for carbon emissions the development actually performs worse than both these benchmarks at 105 $kgCO_2/m^2.a$ in 2012 and 99 $kgCO_2/m^2.a$ in 2013. This is disappointing given the original ambitions of the development.

6.4.2. Hotel HH Analysis

Some half-hourly (HH) data was available for the hotel electricity meter. This allowed us to carry out an analysis of when electricity was being used - in an attempt to establish a 'baseload' demand. This showed very little difference between daytime and night-time energy demand - at approximately 100kW and 80kW respectively. This is very different to what would be expected in an office - where these numbers would usually vary by a factor of two to five (i.e. the night-time load would be as little as a fifth of daytime load). However, in comparison with a typical office, a hotel may be argued to have no definite 'out of hours' periods, and instead be in use 24hrs/day. Though you might expect a greater spike than is currently evident in demand in mornings and evenings. This suggests that there are a number of energy uses which are permantly running - which may include the central air-conditioning plant, any refrigeration, server rooms and ICT aquipment as well as lighting and any appliances left on standby.

The energy use of the hotel appears to be roughly equally split 3 ways between "core hours' (as understood for offices) of 09.00-18.00 on weekdays, non-core weekday hours, and weekend hours. Unfortunately, due to the current metering set-up and the poor usability of the BMS system here, it has not been possible to carry out a more detailed sub-system analysis of HH electricity use. This may be a worthwhile exercise if the BMS can be configured to allow this - and it would allow the identification of electrical energy use which may be unnecessary at certain times, or systems which are left running when not required.

6.4.3 Design stage benchmarks

Unfortunately only limited design stage benchmarking of energy use was undertaken as part of the early planning process for the development (in 2003). This was for an earlier iteration of the building design, which did not include the as built ventilation and heating systems, and only considered 'regulated' energy uses - i.e. those covered by the building regulations - so it is of limited value as a benchmarking tool as part of this exercise. The building was constructed under Part L 2002, and whilst an EPC does exist, it has not been possible to access the data from this to carry out a comparison. A DEC has never been created for the building, so it is not possible to use this as a benchmark either.

6.4.4 Carbon Buzz Benchmarking

Though the above findings are disappointing, they are perhaps not unusual. Whilst frustrating, it is generally accepted that most buildings suffer from an energy performance gap, though the size of this gap varies.

The Carbon Buzz database covers a range of mostly recently completed buildings that show a wide variation in total carbon emissions. As with the standard industry benchmarks, this project does not fit neatly into one or another category. However it is possible to compare the offices and the hotel separately against the projects on Carbon Buzz.

Offices:

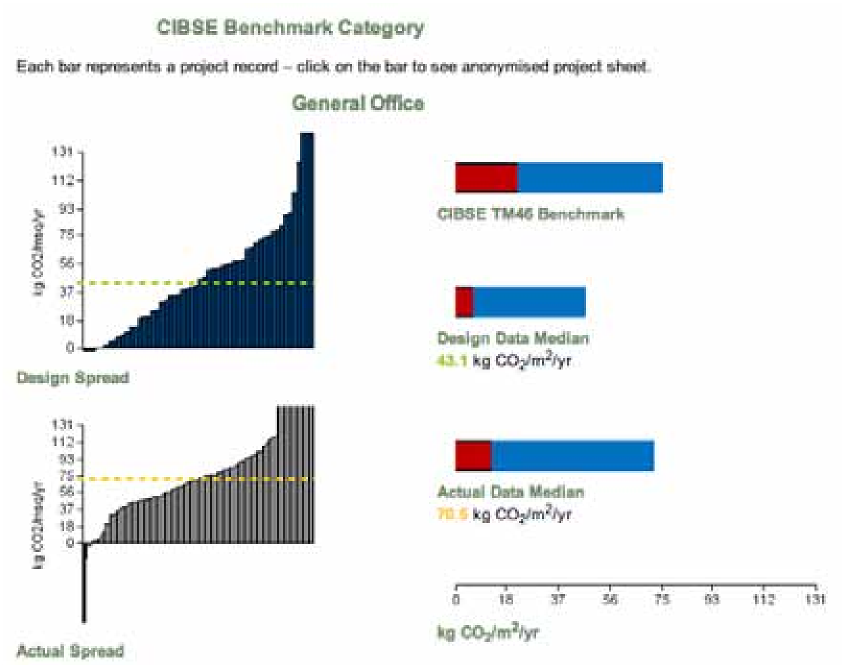
There are currently 111 'office' buildings logged on the carbon buzz database, with actual use data available. These range from small to large buildings, in rural and urban settings, and include both owner-occupied and speculatively developed buildings.

Comparing the offices with the actual performance of buildings gathered through the Carbon Buzz database, shows that whilst the median design stage emissions rate is 43.1 $kgCO_2/m^2.a$, the median of actual carbon emissions is $70.5kgCO_2/m^2.a$. At 111.2 $kgCO_2/m^2.a$ the offices at Bermondsey Square are higher than this. CO2 emissions are also 47% higher than the TM46 benchmark, which is bordering on a display Energy Certificate (DEC) 'G' rating. Obviously this has been affected by the problems described above, which were uncovered during the monitoring period and in some cases not rectified until afterwards. Improvements have now been made to the control regime, such that we would expect these emissions to reduce significantly - though in a complex building like this it is difficult to say by how much without further monitoring.

Examining the more detailed information available for projects within the database shows that whilst the results for Bermondsey Square are disappointing, they are not without precedent. Several comparable high quality office buildings completed after or around the same time as Bermondsey Square, have higher actual CO_2 emissions. Clearly the issues at Bermondsey Square are not unique.

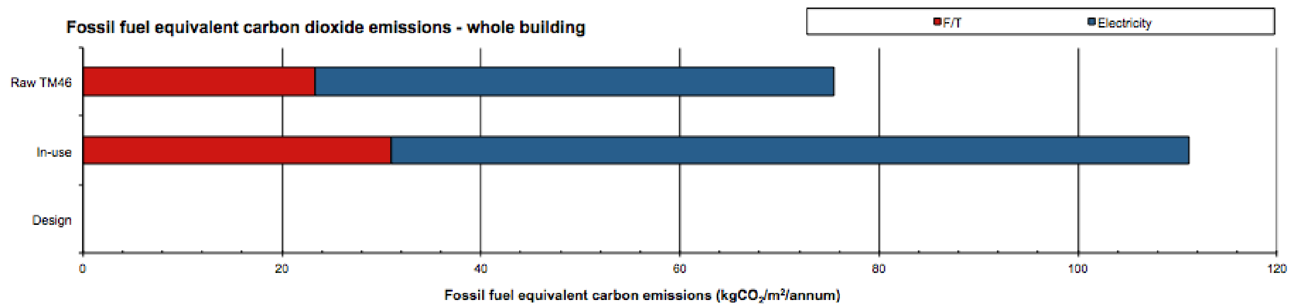
Hotel:

There are currently only four hotel projects in the Carbon Buzz database (other than this one), with very little information on the context of each project, and no actual use data, only design stage information. This makes sound comparisons difficult. With a median carbon emissions rate of 15.3kgCO_2/m^2.a in the database, vs 110kgCO_2/m^2.a for the hotel at Bermondsey Square (and >130kgCO_2/m^2.a for the TM46 benchmark), any comparisons with this very small dataset seem fairly meaningless.

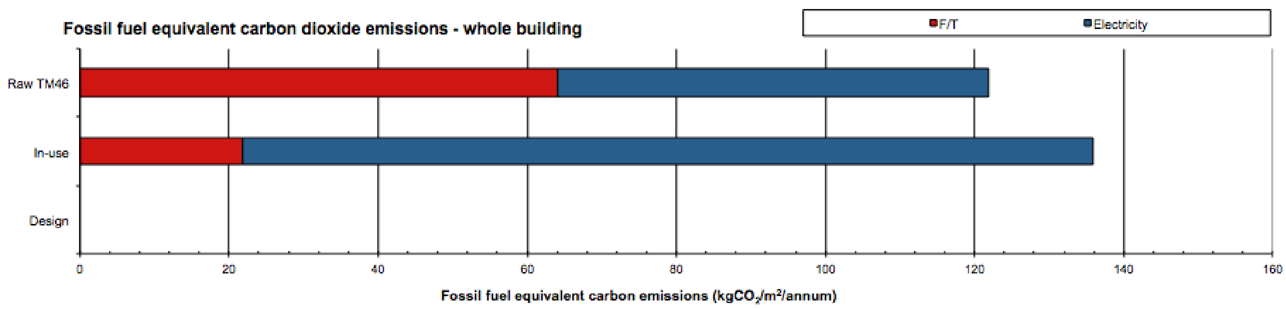


Right: Summary data for office projects within the Carbon Buzz database.

Bench-marked carbon emissions for office from TM22, using ECON 19 (Type 2 Office):



Bench-marked carbon emissions for hotel from TM22, using ECG 36 (Type 2 Hotel):



7. Technical Issues

In the above chapters we have touched upon the technical issues uncovered at Bermondsey Square which may be affecting both energy use and occupant satisfaction and comfort. The following is a summary of the issues uncovered so far.

7.1 Building Management Systems

- Offices: The building management system in the offices was designed to control and monitor the ventilation, cooling and district heating systems. However, relatively early in the life of the building (before this study took place) this system was corrupted, so that much of its functionality was lost. This has had a number of knock-on effects on the operation of the building's key environmental systems.
- Hotel: The hotel's BMS system has no front end control unit, and can only be accessed via a small digital panel in the plant room. This means that much of the potential functionality of this system, and its capacity to help the building management monitor and understand energy use within the hotel, has been lost.

7.2 District Heating

- Metering Design: The metering as designed on the district heating system was insufficient to be able to detect the distribution losses and potentially wasteful circuits. This was partially corrected as part of this study, with new meters introduced to some elements - for example a totalising meter on the flow and return to the residential apartments.
- Metering monitoring: Since the building was completed, the monitoring of energy use within the district heating system has been sporadic, and this combined with the issues with the metering layout caused issues with billing. The failure and corruption of the BMS system, which the metering for the district heating system was meant to be connected to, exacerbated this.
- Metering reliability: Whilst during this study many of the heat meters on the system were checked and calibrated, there are still some questions remaining as to the reliability of metering. In particular the heat demand recorded by the hotel seems unfeasibly low (even considering heat energy is only used for hot water).
- Distribution losses: Notwithstanding the above concerns on

metering, the energy losses associated with the distribution of heat energy in the sytem seem excessive - and appear to approach 50% (so half of all heat energy generated by the boiler plant is lost).

- Potential over-sizing: It is suggested that the above losses may have been exacerbated by potential oversizing of the system, due to lower than expected energy demands. These are likely to be attributed to a number of factors including under-occupied apartments (with some used as 'crash pads' rather than full-time residences, the hotel (which was originally intended to be supplied with both space heating and hot water by the system) and potentially incorrect assumptions generally about space heating demand and the fabric of the building.
- Flow and return temperatures: If the system is oversized, and heat demand is lower than predicted, this may also be affecting the efficiency of the central boiler plant by reducing the difference between flow and return temperatures (though this requires further investigation).
- Monitoring and controls: Several of the circuits on the system have been shown to draw down heat energy when not required, either where a circuit is completely unused, as in the case of a vacant unit, where it should have been closed off, or in the case of the AHUs on the office ventilation system, using heat energy in the middle of one of the hottest periods of July 2013. These show a failure of controls on the system. This is likely to have been exacerbated by a failure to understand and monitor on the part of the building management, made harder by the failure of the BMS interface.

7.3 Office Ventilation and Conditioning

- General maintenance: At handover, the original building management team did not set up the maintenance, cleaning and servicing contracts and checks that would normally be required by this system. This led to filters becoming blocked and serious problems going undetected - so that one of the AHUs had been failing to work for 12 months before it was detected. It also meant the system was not properly commissioned. Until the most recently appointed building management team, it seems management action around maintenance for the system was slow and unresponsive - due to failures in understanding and a failure to budget for the required servicing.
- AHU automatic controls: On several occiasions the automatic controls on the AHUs, which are intended to select the most efficient operating mode given internal and external conditions, have failed. The most serious of these was when the actuator which opened the vents to the outside air on one of the AHUs failed, leading to the AHU being stuck in 'recirculation' mode. This is likely to have added to the levels of dissatisfaction expressed by the building users with the internal environment - stuffiness and over-heating.

- AHU programmed controls: The failure of the BMS and the poor understanding of the building managers led to the operating schedules for the ventilation system being poorly set up. Whilst the building manager when the study started in 2012 was able to adjust the 'set-point' temperatures, it seems that rather than having a schedule set up to accord with the hours of occupation of the building, the system was instead in full 'daytime' operation 24 hours a day. This has since been addressed, but will have affected the energy use results reported above.
- VAV controls: Again, due to the corrupted BMS and failures of understanding by the building management, the Variable Air Volume Valves on each floor and in each zone were not suitably adjusted - leading to discomfort for some office occupants and potentially wasted energy. Again, this has since been addressed and the current building management can now adjust these as required.
- Impact of sub-divisions and standard air-conditioning: The office floors were originally designed to be let as single floors, with mainly open plan office space. They have since been sub-divided into smaller units, and even where let to a single tenant have often been sub-divided. It's not clear whether and how this was allowed for in the design and commissioning of the ventilation system. Several of the office tenants have also added their own air-conditioning systems, and again its not clear how this affects the overall operation of the ventilation and cooling systems for the office block.
- 'Free cooling' assumptions: Questions have been raised by building occupants and others during this study about the design assumptions made for the adiabatic cooling system. The first relates to the temperature of mains water - with mains water in central London, and in summer when cooling is most needed, being several degrees higher than assumed, leading to a reduced capacity for cooling. The second is that this form of cooling relies on relatively dry intake air, and that the humidity of the external air may have been higher than assumed, again reducing the capacity for cooling. Unfortunately, during the life of this study, the more obvious problems with controls on the system have prevented a more detailed examination of these issues - though it may be something for others to consider in future.

7.4 Office External Blinds

- Maintenance and Control: The external blinds on the building, an integral part of the environmental design of the offices to reduce solar gain an glare, were operating at building handover. However, when this study started they had not been working for some time. At some point the automatic controls had been overridden (potentially related to the corruption of the BMS), and the blinds had become damaged. This was only fully corrected in late summer 2013.

8. Key Messages

In summary the key findings for the development are as follows:

- The district heating system at Bermondsey Square appears to be quite wasteful of heat energy - with distribution losses being a particular issue, and controls and metering inadequate in several respects.
- The advanced ventilation and conditioning system has not performed as expected. Though energy used for cooling has apparently been much reduced, the total energy use associated with the system has been much higher than expected, leading to few if any savings overall when compared with conventional air-conditioning systems. Problems with maintenance and control have also led to significant discomfort and dissatisfaction among office users.
- Controls, monitoring and maintenance of the development's critical environmental systems has been inadequate. The corruption of the landlord's Building Management System, poor engagement with commissioning and handover on the part of the first managing agent, and the lack of a proactive approach to building management until recently have all caused problems.
- Potentially as a result of much of the above, whilst performing well in some areas, the development generally compares less well than expected with benchmarks and with design stage expectations for energy use and environmental performance (including comfort).

Throughout this study information has been shared with both igloo, as developer, and the facilities management team for the buildings. The additional focus on the building, with information provided direct to both the building managers and igloo, led to several problems being fixed and new approaches being taken:

- The reports of dissatisfaction from users and initial energy data led to the closer examination of the operation of key building systems - such as the AHUs and office ventilation, external blinds and Building Management System. The study added weight to the argument for repair - especially as these problems were starting to effect igloo's ability to successfully retain tenants and let office space.
- Additional information, which was better checked and verified, was made available on the energy use of the district heating system. This allowed the re-charging of tenants to be done with more confidence and accuracy.

Above: The CCI building/ 'Gloworks' at Cardiff Bay, recently completed by igloo. Learning some of the lessons from Bermondsey Square has meant the adoption of simpler building services systems, well metered and monitored and easier to understand. This building is naturally ventilated by opening windows, with thermal mass to support cooling. Heating is provided by a separately metered gas boiler on each floor, and each floor is also separately metered for water and electricity, with further sub-metering possible.

TSB BPE Project Influence on igloo

Asset management:
An asset management team has now been formed within igloo. This had been developing organically, but this study helped to highlight the need for a collective voice within igloo to have input at the design stage with a focus on user experience, ease of management and metering strategies for billing and recharge of utilities costs to tenants. Asset management and end user input is now obtained much earlier to look for and address possible issues around building system interdependence, over-complication and operation. Generally within the organisation there is now a greater recognition of the resources required for the successful management of more complex systems and buildings - and a desire to reduce this complication where possible during the design stage.

Sharing learning:
Learning from this study and from other post-occupancy activities has been shared around igloo via the relatively recently formed Operations Working Group. This includes people from igloo involved at all stages of development - from concept design and feasibility to facilities management.

Selection of managing agents:
Much greater consideration is now given to sustainability generally and understanding of building environmental systems in particular in the selection of managing agents - both for existing developments where agreements come up for renewal, and in new developments. The asset management team and operations group seek wherever possible to encourage development teams to engage with potential managing agents as soon as possible in the design and development process.

'Soft landings':
Within igloo the Operations Working Group is now exploring the potential for the adoption of a 'soft landings' approach to building design, development and handover. Thought this may prove tricky where buildings are purely speculative, and will be asking some design teams in particular to go beyond their traditional remit, it is felt that this may help igloo achieve best value in their developments. Additional efforts are also now being made by project teams to improve the processes and information around handover of developments, particularly for residential schemes where there will be no future 'facilities management' team.

- The additional metering provided a greater degree of information on losses within the district heating system, with some easy savings made by shutting down unnecessary circuits, helping to better control and manage associated service charges. Igloo are now actively looking to make further savings in this area, where previously there was limited understanding of this potential.
- In appointing a new building management team, there was a greater emphasis on understanding of the systems, and the new building manager had the advantage of being able to examine the information gathered by the study. The complex nature of the scheme and its systems could be clearly explained and understood from the outset.
- Though not formally part of this study, PIRs (movement sensors) have now been fitted on all the communal access corridors within the residential block. This has helped to reduce the heat gains in this area, and consequent over-heating which was a major complaint of residents.

The above actions have resulted in noticeable improvements in the operation of the building and the satisfaction of users. Whilst not yet evident in the hard data available, this has been reported anecdotally via the facebook group for building occupants. The previously quite vocal tenants and residents association has been disbanded due to lack of interest or. However, it may be possible to make further improvements, which whilst less visible, could have a significant impact on the efficient running of the development:

- District heating system: Suspect meters should be checked (e.g. for the hotel) and re-calibrated if necessary to ensure an accurate picture of energy use is being provided. Building management should actively monitor this, and act to address any potential wastage in the system. A review of the insulation of pipework on the different circuits may prove valuable.
- Boilers: Flow and return temperatures to the boilers should be checked and optimised as far as possible.
- Office AHUs: A thorough review of the operation modes, and how they relate to the occupancy of the building may result in further savings and improved comfort for occupants. Continued improved responsiveness of maintenance may be complemented by a more thorough-going re-commissioning of the system.
- Office BMS: This should be maintained and used as a key tool by the building managers. Its functionality, and the potential for improvements, should be reviewed.
- Hotel BMS: The installation of a front-end PC control unit for the hotel BMS system would vastly improve its usefulness and potential as a tool for controlling and monitoring the hotels' environmental services and systems - potentially providing savings.

Beyond these immediate responses to this building, this study has a number of key messages for those involved in development, design, operation and management. From igloo as funder, developer and landlord, to the design and management teams and the tenants of the building:

- **Understanding management implications of design decisions:** It is critical that both design teams and developers understand the implications of decisions made at design stage for the management of buildings. The more complex the building and its systems, the more critical this becomes. There is a danger that if neither party fully considers this designers specify systems for which the burden of future management is too great - with implications for both energy use and user satisfaction. As both developer and landlord, igloo would benefit directly from getting this right. The igloo fund would also benefit, as increased costs of maintenance or management, and dissatisfied users, are likely to affect the returns from their assets.

- **Understanding the value of design elements for users:** At the design and construction stage of this building it was necessary to carry out a 'value engineering' exercise to bring down capital costs. However, some of the decisions made at this stage, such as the removal of opening windows from the offices, have had long term implications for the operation of the building and the satisfaction of building users. Though there may have been other sound supporting reasons for these decisions - in the case of the windows to mitigate the effect of noise from Tower Bridge Road - as a cost saving igloo's view is that this makes no sense as it has had a detrimental effect on the value of the building to its users. In future, in a similar decision, allowing users to choose their own 'trade offs' - in this case between noise and ventilation - would be likely to provide greater value in the long term.

- **Handover and commissioning:** Many of the issues with this building can be traced back to its handover and early operation, where proper maintenance contracts and checks were not set up, and commissioning was not extended into the first year beyond the initial handover. It has taken years and a considerable amount of effort to put right things which should not have been a problem in the first place. This may have been made easier by the fuller involvement of the design team in commissioning and handover, allowing both the landlord and the managing agent to more fuller understand the original design intentions.

- **Tools and metering to enable good management:** The metering strategy as designed did not provide sufficient information for losses in the system to be easily identified and addressed. Improvements have since been made which have identified significant distribution losses in the office perimeter heating and residential circuits. This is something developers, landlords, design teams and managing agents need to be aware of - particularly in complex multi-tenanted buildings where re-charging arrangements are necessary. This is particularlyl important for funders and developers if they wish to understand whether systems which have involved significant financial investment are performing as claimed and assumed at design stage.

- **Engagement and understanding of managing agents:** The ongoing successful management of a relatively complex development such as this requires the full engagement and understanding of the managing agent and building manager. This is so they identify and respond to any issues quickly - minimising energy wastage and occupant dissatisfaction. Many of the problems in this building have been exacerbated by the attitude of building management, in particular their slowness in responding to complaints about over-heating in the offices, or lack of accuracy of billing on the district heating system from occupants.

- **Information management and continuity:** The work of this study was made much more difficult by the lack of clear records on the building. Though these did exist, at least in part, the building manager at the time (in 2012) was unfamiliar with them. It was also found that some of the information was inaccurate or incomplete. The information was not in a format that made it easy to understand the original design intentions. This study, and the management of the building, would have been made much easier by well-kept information presented in an understandable format. This is particularly important as it is likely that personnel in management companies, and even the companies themselves, will change over time.

9. Wider Lessons

Though this study looks at a single mixed-used development, some of the lessons learned are applicable (if not depressingly familiar) to the wider development and construction industry - both for those who design and commission buildings, and for those who manage them.

- **District Heating Systems:** The results of this study call into question the efficiency in operation of district heating. Whilst we acknowledge that at the time this system was developed some of the technology, and particularly the control systems, were relatively new and unfamiliar to the UK construction industry, at the very least they show the potential for things to go wrong - with approaching half of heat generated by the boilers being lost in distribution. It has proved to be difficult to successfully identify, in a complex setting, what the contributory factors are to this poor performance and low energy efficiency. At worst they call into question their use in new build developments, where higher built fabric energy efficiency may have unintended consequences - especially for distribution losses. This is significant as district heating systems are currently being pushed as part of the UK's low carbon strategy, and included in planning and building regulations requirements for new buildings. From the findings here at the least we would suggest that design stage assumptions as to heat demand are checked and double checked, with both potential patterns of use and actual heat demand/ fabric efficiency fully considered. Metering strategies should also be thoroughly investigated before construction, and control systems and management are invested in to drive out any potential inefficiencies.

- **Complex systems and automatic control:** This study has shown, in the case of the ventilation system for the offices in particular but also the district heating system, the potential difficulties in relying on complex inter-related automatic controls for building services - particularly where these controls have the potential to malfunction without being noticed by building management, leading to problems going undiagnosed and unaddressed. This is much more likely to happen with systems where there are no direct physical consequences of the malfunction other than increased energy use (as in the district heating system here). However even where these problems have resulted in serious discomfort for building occupants, they have taken a significant amount of time and effort to address.

- **Unconventional conditioning and ventilation:** Though the main problems with the conditioning system in the offices at Bermondsey Square appear to be due to malfunctioning controls, the results have to some degree called into question the benefits of the multi-mode ventilation and cooling conditioning system installed. Perhaps if the controls had not malfunctioned, or if the building management had responded more quickly, problems could have been avoided. However, the chances of any such complex system avoiding faults altogether are probably slim.

- **Overreliance on fragile systems:** Related to this point, the reliance on potentially fragile inter-related control systems - in the case the BMS linked to the district heating, ventilation and cooling and external blinds - can be problematic. As soon as any of the parts of this system fail, from the BMS interface to a minor actuator on an opening vent, it causes problems. And if the systems are complex and not well understood by building management, these problems can remain unaddressed or be compounded by efforts to rectify them without an understanding of the potential whole system impacts. If the management resources are not available to handle this, it would seem preferable to design systems so they are more robust in control and operation.

- **Metering Strategy:** In any building there is a need for a clear, understandable and usable metering strategy. This should be developed alongside the detailed design of the building and should take into account sub-systems such as external lighting and vertical transport, so that excessive energy use in any quarter can be quickly identified and addressed. In a multi-tenanted, multi-use building, with a shared heating system and communal areas controlled by a landlord, this need becomes even more pressing. This requires thought and input from both designers and future managers - simply relying on a standard set-up, to be compliant with building regulations but no more, is likely to be insufficient. Without such well-thought through metering strategies, understanding actual energy use is made difficult, if not impossible, making both management and learning (as in this study) much more difficult.

- **Handover, commissioning, maintenance and management:** If a building, particularly a more complex building, is to come close to its design stage targets for energy use and comfort, it requires not just that it is designed well, but also requires that handover, commissioning, maintenance and management of the building is treated with due respect and given adequate resources. This may require the services provided by both the design team and the management team to be extended beyond that which has been standard in the industry. A greater cross-over and a greater degree of understanding between design and facilities management may be required.

- **Assessment tools and benchmarks:** This study has raised questions about the suitability of some of the tools used to understand buildings in particular contexts - mostly with regards to the hotel. For example, the BUS questionnaire was originally developed for workplaces and offices in particular. When used in a hotel, where the patterns of behaviour and movements of staff are very different, the environment in which they work is different, and the largest numbers of people in the hotel - the guests - are entirely transient - the standard BUS form does not work smoothly, at least in part because of some of its underlying assumptions. We understand that a revised form has now been developed, suitable for transient building users. We have not had to opportunity to use this and test it here. Similarly, the benchmarks within TM22 are more highly developed for offices, where there is a relatively large existing dataset to draw from. The data for hotels is much more limited and issues were found in this study with assumptions about ‘core hours’ of operation - with the patterns of use of a hotel being very different to that of offices. Similarly, the electrical energy use of the hotel uncovered large users of energy - such as the cool storage in kitchens and room drinks cabinets - that do not appear in the ECG36 (Energy Guide 36: Hotels) benchmarks. We hope that some of the work of this study and others in the TSB BPE programme can contribute to the development of these benchmarks and tools for future use.