201 Bishopsgate

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	450027
Project lead and author	Verco for British Land plc
Report date	2013
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Building sector	**Location**	**Form of contract**	**Opened**
Offices	London	Construction management	2008
Floor area (GIA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
37,000 m^2	12	C (66) / N/A	Excellent

Purpose of evaluation

To gain an understanding of the effectiveness of the control of the mechanical services via the building management system (BMS), including a review of energy saving recommendations. Each tenancy had their own BMS, which controls their local lighting and heating, ventilation and air conditioning (HVAC). The study looked at how effectively these operate, and how they interacted with the landlord's BMS. This study also looked at the extent to which tenant fit-out and occupant behaviour caused electricity demand to be high, and whether the façade contributed significantly to the cooling demand and hence energy demand.

Design energy assessment	**In-use energy assessment**	**Electrical sub-meter breakdown**
Yes	Yes, basebuild and 2 levels	Partial

Three energy models were constructed:
1) Basebuild model representing all landlord meters i.e. common areas and whole building (e.g. chillers, cooling towers, lifts) and external lighting. 2) Level 4 modular type office space (3583 m^2), typical of non-banking occupant i.e. less intensive small power and ICT usage. 3) Level 8 open-plan type office space (3356 m^2), typical of banking occupant i.e. more intensive small power and ICT usage.
Total site fuel/thermal consumption: 14.6 kWh/m^2 p.a. Total site electrcity: 309.7 kWh/m^2 p.a. (Data not quoted in report, only shown in charts).

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based, edited	110 (3 floor levels only)	N/A (4% of total occupancy)

Overall air conditions and comfort were perceived to be excellent, with air conditions specifically considered reasonable. Poor temperature stability was a perceived issue, with the perception that temperature varies during the day in both summer and winter. This result compared badly to the benchmark result, and was in approximately in the third percentile compared to other buildings in the BUS benchmark dataset. Air was considered fresh rather than stuffy, but slightly dry, particularly in summer. Glare from the sun and sky was perceived to be a slight issue, and the quality of artificial lighting did not score so well.

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About this document:

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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 and overview

Technology Strategy Board guidance on section requirements:	This section of the report should be an introduction to the scope of the BPE and will include a summary of the key facts, figures and findings. Only the basic facts etc should be included here – most detailed information will be contained in the body of this report and stored in other documents/data storage areas.

201 Bishopsgate is a landmark building in the City of London. It has been designed for low energy consumption and high environmental standards. This achievement was signalled by its EPC rating (C rating or score of 66), the Building Regulations emissions calculations and the Excellent BREEAM rating. This study analyses how a highly glazed building achieved these design standards, and if it is achieving low energy consumption levels in-use.

One of the primary areas of interest is to gain an understanding of the effectiveness of the control of the mechanical services by the building management system (BMS), including a review of energy saving recommendations made by EP&T, the monitoring and targeting (M&T) contractors. Each occupant has their own BMS, which controls their local lighting and heating, ventilation and air conditioning (HVAC). Our study has looked at how effectively these operate, and how they interact with the landlord BMS. We have carried out a review of findings identified to date by EP&T. It is apparent that the majority of issues identified relate to BMS control and refining the BMS settings has so far been the greatest single factor in reducing unnecessary energy usage in the building. A particularly problematic area is related to the interface between the tenant and landlord BMS. This issue has now been rectified and the change is likely to have resulted in a significant reduction in building energy consumption.

This study also looks at the extent to which tenant fit out and occupant behaviour is causing electricity demand to be high, and whether the façade contributes significantly to the cooling demand and hence energy demand. As part of this latter assessment, we have installed a solar irradiance sensor and temperature sensor on the roof of the building, and we have examined the relationship between these two variables and chiller energy consumption. Given the fact that the building is highly glazed - steel framed with an aluminium curtain walling system – the facade is a specific area of interest for this project.

We have undertaken a post occupancy evaluation (POE) of tenants to understand user perceptions and how they relate to the operation of the building, while at the same time producing a detailed TM22 model to understand exactly where energy is being used. The extensive submetering, along with analysis of profiles, has generated a more reliable TM22 analysis, and has enabled us to see what equipment is being used and when, and compare this with the POE survey of occupants.

This combination of quantitative (TM22 with submeters) and qualitative (POE) analysis yields interesting insights into design versus actual performance of modern office buildings. Our study also investigates the effects of tenant engagement, and seeks to demonstrate what can be achieved through collaboration between tenants and landlord on energy issues. The end result of the study is a demonstration of how low a high spec and highly glazed office building can go with energy demand. This final report will explain why initial performance was poor compared to design, and the operational initiatives required to ensure low carbon operation.

2 Details of the building, its design, and its delivery

Technology Strategy Board guidance on section requirements:	This section of the report should provide comments on the design intent (conclusions of the design review), information provided and the product delivered (including references to drawings, specifications, commissioning records, log book and building user guide). This section should summarise the building type, form, daylighting strategy, main structure/ materials, surrounding environment and orientation, how the building is accessed i.e. transport links, cycling facilities, etc – where possible these descriptions should be copied over (screen grabs - with captions) from other BPE documents such as the PVQ. This section should also outline the construction and construction management processes adopted, construction phase influences i.e. builder went out of business, form of contract issues i.e. novation of design team, programme issues etc. If a Soft Landings process was adopted this could be referenced here but the phases during which it was adopted would be recorded in detail elsewhere. If a Soft Landings process was adopted this can be referenced here but the phases during which it was adopted would be recorded in detail elsewhere in this report and in the template *TSB BPE Non Dom Soft Landings report.doc*.

2.1 Design of building

201 Bishopsgate is located in the City of London, on the west side of Bishopsgate and Norton Folgate, bounded by Primrose Street to the south, Worship Street to the north. It stands above the railway tracks serving Liverpool Street Station. It is adjacent to Broadgate Tower, and is orientated on a north/south axis. It overlooks an open public plaza and a covered retail galleria between 201 Bishopsgate and the Bishopsgate Tower. As part of the Broadgate Estate, 201 Bishopsgate is jointly owned by British Land and the Blackstone Group.

Figure 1 Aerial view of 201 Bishopsgate, with the Broadgate Tower adjacent

Figure 2 View of covered galleria between 201 Bishopsgate and the Broadgate Tower (201 Bishopsgate on right)

Figure 3 View of 201 Bishopsgate façade

2.3 Building construction

The building is a high spec office development with 70% of the façade covered by curtain wall based glazing. The structure is steel and concrete with a basement and 12 storeys of office area totalling over 37,000m^2 of useable floor space. The building sits on a concrete and steel-framed raft which straddles the railway lines. Due to design changes the original 6,000 tonne raft structure needed extensive modification from the design constructed in the mid 1990's, and resulted in an additional 1,000 tonnes of steelwork being incorporated.

In order to limit deflections and settlement it was necessary to distribute the resulting vertical forces from 201 Bishopsgate and the Bishopsgate Tower evenly across the raft support structure, so a series of raking A-frame legs were incorporated that effectively prop the structure at level 5 and transfer the loads to strategically located transfer beams and columns within the raft structure. These provided a challenge during the construction of the frame, and an extensive arrangement of temporary props and trestles was required in order to build the structure up to level 5 before installation of the A-frame legs could begin. This included a sophisticated load transfer operation using a jacking system to transfer the loads from the temporary supports onto the permanent columns. The superstructure columns are separated from the substructure by vibration isolation units to alleviate ground-borne vibration from the adjacent railway. These consist of laminated rubber and steel plates are designed to provide the structural supports for gravity loads. Lateral restraint is provided by separate rubber bearing assemblies.

The main service cores of the structure are constructed in steel and house the lift voids, staircases and service risers. The floor plates are reinforced concrete on steel decking supported by long span cellular beams in the E-W direction. The interior of the building was designed to be free of internal columns so as to maximise flexibility, views out and daylight in to each floor. Raised floors are provided throughout for electrical/IT servicing.

At ground level there is a large open lobby with an atrium rising to roof level that brings daylight into the centre of the building. The building was developed at the same time as the neighbouring Broadgate Tower, a 33 storey office development; however, this is not part of this project.

The project team were as follows:

- Architect: Skidmore Owings & Merrill
- Cost Consultant: Davis Langdon LLP
- Developer: British Land
- Main Contractor: Bovis Lend Lease
- Planning Consultant: DP9
- Services Engineer: Jaros, Baum & Bolles
- Structural Engineer: Skidmore Owings & Merrill

The project started on site in October 2005 and was completed 33 months later in July 2008, at a cost of around £151 million. The form of contract was Construction Management.

2.4 Building tenants

The building is occupied by a number of types of tenants, as shown in the table below. The building is fully occupied.

Table 1 Building occupiers by level

Occupier	Level
Retail units	0
Law firm	1
Law firm	2
Law firm	3

Law firm	4
Law firm	Part 5
Trading company	Part 5
Bank	6
Bank	7
Investment management company	8
Investment management company	9
Investment management company	10
Law firm	11
Investment management company	12

Although the building was built speculatively, a non-binding pre-let was agreed with the law firm.

2.5 Sustainability credentials

The building achieved BREEAM Excellent. The energy efficient design was intended to reduce operational carbon dioxide emissions at 201 Bishopsgate by an estimated 24%[1] compared to current standards. Energy efficient features include:

- Ventilation system which will gather and re-use waste heat
- Motion activated lighting system so that lights are only on when people are present
- High performance glass, which minimises solar heat gain and retains cool air
- Local lighting zones, water metering and electricity metering to enable occupiers to manage their own energy use

Sustainability features include:

- A Green Travel Plan supported by convenient public transport links, 443 bicycle spaces, changing rooms and improvements to pedestrian routes
- A green roof, with drought tolerant plants and nesting facilities for sparrows, enhancing urban biodiversity and improving building insulation
- All timber used came from certified sustainable sources
- A range of water saving devices including low-flush WCs and motion operated taps
- 97% of fit-out waste for both 201 Bishopsgate and the Tower was re-used or recycled; unused materials and packaging were sent back to manufacturers for re-use or recycling via returning delivery vehicles, which diverted 1,693 tonnes of waste from landfill and reduced vehicle movements, cutting carbon emissions[2]

The building has good transport links, with Liverpool Street station just a few minutes' walk away for national rail services, and at least 3 tube stations within a 1 mile radius. There also a number of bus routes which pass

[1] Source: http://www.blmicrosite.com/crReport/2009/fp-bishopsgate-broadgate.aspx#resources
[2] http://www.blmicrosite.com/crReport/2009/fp-bishopsgate-broadgate.aspx#customers

through the area, particularly along Bishopsgate. From 2018, Crossrail will also be passing through Broadgate. The building itself has spaces for a total of 443 bicycles, as well as 148 motor bike spaces and parking is provided for 14 cars using a stacking system - this provision is shared with The Broadgate Tower.

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3 Review of building services and energy systems

Technology Strategy Board guidance on section requirements:	This section should provide a basic review of the building services and energy related systems. This should include any non-services loads – which would therefore provide a comprehensive review of all energy consuming equipment serving the building or its processes. The key here is to enable the reader to understand the basic approach to conditioning spaces, ventilation strategies, basic explanation of control systems, lighting, metering, special systems etc. Avoid detailed explanations of systems and their precise routines etc., which will be captured elsewhere. The review of these systems is central to understanding why the building consumes energy, how often and when.

3.1 Building services

The tenants are provided with chilled water at 10°C and fresh air at 16°C during winter and at 20°C during summer. From these services the tenants are able to condition the office space as they wish. For all current cases this is via fan coil units to provide full air-conditioning to each useable space. The internal design temperatures are 22°C±1.5°C in summer and 21°C±1.5°C in winter. These are relatively 'standard' conditions – the CIBSE recommended temperature range for comfort is 21-23ºC in winter and 22-24 ºC in summer.

Outside air is provided at 16l/s/person, which is 60% higher than the Building Regulations recommended figure of 10l/s/person, and is therefore likely to consume more energy in order to supply fresh air at this higher rate as a result. This is currently British Land's standard fresh air rate for new office buildings, and is based on the upper end of the range recommended by the British Council for Offices, which is 12-16l/s/person. The higher rate is seen as good practice and is used to satisfy more densely occupied spaces such as large meeting rooms.

In the retail units, connections to the landlord's condenser water system via a plate heat exchanger are provided for heat rejection.

The fresh air is provided by three large air handling units (AHUs) located on the roof. Air is extracted from all office floors via bell mouth spigots, above ceiling level, and exhaust duct risers connect to extract fans at roof level. Heat recovery from the office extract air is provided by thermal wheels. Further heating to supply air is via electric heater batteries centrally within the AHU as well as locally within the fan coil units. The chilled water network is supplied by three centrifugal chillers with variable speed drives and inverter pumps located in the basement. Three cooling towers on the roof extract heat from the chilled water circuit.

Three basement AHUs provide fresh air to the back of house areas and reception on a supply only basis. The reception/atrium area also includes electric underfloor heating.

Basement gas boilers provide heat for the hot water network utilised by wash basins on each floor. There is a separate gas connection for the catering facilities as well as a separately metered connection for a gas boiler that supplies one of the tenants with hot water for shower facilities. Some tenants have back up chillers on the roof and specialist split system condensers to maintain cooling for IT systems, should there be a problem with the main chillers.

The electrical installation for the building consists of two incoming electricity supplies, which serve four substations. On each floor, distribution boards are provided within each electrical riser closet connected to the main building distribution for landlord's lighting and small power requirements within the core (e.g. toilets). Separate rising busbars are provided to tenants to install lighting and small power panels and HVAC units. Separate metering is provided to each tenant. Power factor correction equipment is used on major items of plant.

There is a landlord's backup oil generator located on the roof, which serves essential services such as emergency lighting, smoke extract, grounding of lifts, full operation of selected lifts, and the life safety system. There are also tenant owned generators for the backup of IT equipment.

Each fan coil unit (FCU) is provided with an electronic direct digit controller, and temperature sensors mounted in the ceiling void, for each unit. A separate BMS controls system is used to operate tenant plant, which is wired and operated independently to the landlord's BMS system. These typically control the fan coil units and lighting, and also interface with the landlord's BMS for plant start/stop, chilled water demand, after hours plant start and optimum start. The landlord's BMS enables the facilities management team to make changes to individual plant, carry out plant changeover, change set point temps for chilled water and fresh air temps.

The lighting of tenant spaces is installed by the tenant and therefore differs floor to floor; however, the minimum specification is for high frequency T5 fluorescent lamps with daylight control for perimeter areas.

The base build lighting is a mixture of fluorescent and LED. Lighting in tenanted areas is provided from tenant distribution boards located on each floor. Although tenants can specify their own lighting, the Category A fit out specification is for high frequency, T5 fluorescent lamps, recessed modular type luminaires, with reflectors and louvres, which meets CIBSE LG3 guidelines. The design lighting level in open plan office spaces is 400 lux. Perimeter fixtures are controlled by daylight sensors with automatic dimming control.

The building has eight main passenger lifts, which use a destination hall call system. One of these lifts is a dual passenger/fire fighting lift. There are also two further fire fighting lifts, a disabled access passenger lift, and three goods lifts.

Levels 1 and 2 were designed to accommodate trading floors. Measures include greater provision for small power, a deeper raised floor, designed for a higher occupancy density, spare cooling capacity for data centres. However, these floors are currently occupied by a law firm, and are therefore likely to be under-utilising their power 'allowance'. The trading floors were also originally designed for a fan powered variable air volume air conditioning system with electric heating but the installed system is a fan coil unit system, consistent with all other floors.

Major non-services energy uses within the building include electricity for tenants' server rooms and gas for one of the tenant's central catering facilities.

3.2 Comparison with design and installation

A comparison has been carried out between the building as designed and as built. There have been some reasonably significant changes with respect to energy efficiency between the early design stages, through to the later stages of detailed design and installation. Below is a list of the most significant changes that we have identified:

- An initial design statement in 2004 estimated an improvement of 37% compared to Part L Building Regulations 2002. However, in 2006, this was increased slightly to 41%.

- Levels 1 and 2 have been designed to accommodate trading floors. Measures include greater provision for small power, a deeper raised floor, designed for a higher occupancy density, spare cooling capacity for data centres. However, these floors are currently occupied by a law firm, and are therefore likely to be under-utilising their energy 'allowance'. The trading floors were also originally designed for a fan powered variable air volume air conditioning system with electric heating but the installed system is a fan coil unit system, consistent with all other floors.

- During the initial design stages in 2004, ventilation air supplied from the AHUs was originally intended to be heated by indirect gas fired air handlers located on roof. However, by 2006 the proposed heating system had been changed to thermal wheel heat recovery from the return air with back up electric heaters. With a theoretical gross efficiency of 85%, the latter is likely to be considerably more energy efficient, even with electric heating.

- Originally, it was proposed that exhaust duct risers connect to roof-mounted extract fans which also provide smoke extract ventilation to a single office floor at a rate of 6 air changes per hour. What is currently installed is heat recovery from the office extract air by thermal wheels with separate smoke extract fans.

- Variable speed drives on the chillers were not originally proposed in the 2004 design statement, but were added in to the 2006 design statement, and later installed.

- Originally, the main entry lobby at ground floor level was to be heated by electric convectors, but this was later changed to electric underfloor heating. Given the fact that the space is double height, this seems to be a more logical and energy efficient choice.

- The initial design review looked at the potential for renewables. It identified that PV and SHW had the greatest potential but that the savings were modest in comparison to the savings that could be achieved through energy efficiency measures.

3.3 Landlord building management system

The landlord's building management system is a microprocessor based system. Intelligent outstation panels are distributed through the building generally in plant rooms and service riser points. The BMS also has interfaces with the life safety system – for example, staircase pressurisation fans and sprinkler tanks.

The landlord BMS controls/monitors the following key items of plant:

- Ventilation systems i.e. air handling units and extract fans, and fan coil units in landlord areas

- Cooling systems i.e. water-cooled chillers and cooling towers, and all associated ancillary equipment, such as pumps and pressurisation systems, as well as ancillary cooling systems such as direct expansion systems

- Heating systems i.e. gas fired boilers and all associated ancillary equipment, such as pumps and pressurisation systems

- Condenser water loop system for the retail units on the ground floor

- Cold water systems

- Fire systems monitoring e.g. sprinkler tanks levels
- Energy monitoring for each substation

Landlord's BMS controllers are provided at each floor (2 each) to enable interfaces for plant start/stop, chilled water demand, after hours plant start & optimum start. The controllers are able to monitor the tenants' BMSs via a network gateway.

The majority of plant is controlled on a time clock, such that it comes on at 7am and switches off at 7pm. Most of the remaining plant is demand-led. A review of all items of plant controlled by the BMS was carried out to ensure that the assumed hours of operation matched the assumptions used in the TM22 analysis.

Cooling system control

The chilled water cooling system is enabled via a BMS cooling demand. A signal for cooling can come from either the landlord cooling system or from the tenant cooling system, provided it is within occupied hours. Once the chilled water cooling system is enabled, it will be shut down when all of the following scenarios are met:

- There is no signal from the primary CHW timeclock
- When 95% or more of the FCUs from each of the zones have a cooling loop demand of 0% for a period of more than 3 minutes.
- When all AHUs have a cooling loop demand of less than 0% for a period of more than 10 minutes.
- Retail condenser chilled water circuit is not in operation.

The cooling demand will be re-enabled when any of the following scenarios are active:

- There is a signal from the primary chilled water timeclock
- When 10% or more of the FCUs from any one zone, have a cooling loop demand of greater than 10% for a period of more than 3 minutes.
- When any AHU has a cooling loop demand of greater than 7% for a period of more than 3 minutes.
- The retail condenser chilled water circuit is enabled.

Ventilation system control

The AHU is enabled via any of the floor occupancy signals. The BMS continuously monitors the outside air temperature. At start-up, if this is below 5°C, the following procedure is enabled.

- The thermal wheel is enabled at full speed.
- The inlet damper and exhaust damper are commanded to 50% open, confirmation by damper feedback set to 25%.
- The lead extract fan is commanded on at 50%.
- After a 120 second delay the lead supply fan is commanded on at 50%.

- After a further 120 second delay, the inlet and exhaust dampers are opened fully and the plant reverts to normal BMS control.

Free heating and cooling

The thermal wheel operation is as follows:

- For free heating, the thermal wheel is brought into operation when the differential between the extract air temperature onto the thermal wheel is 1°C or greater than that of the supply air temperature onto the thermal wheel, for a period of five minutes.
- For free cooling, the thermal wheel is brought into operation when the differential between the extract air temperature onto the thermal wheel is 1°C or below that of the supply air temperature onto the thermal wheel, for a period of five minutes.
- Once enabled, should the differential between the extract air temperature and supply air temperature onto the thermal wheel, fall to less than 1°C for a period of greater than 5 minutes, then the heat wheel is disabled. The electric heater battery then becomes the only stage of heating.
- If the setpoint cannot be maintained via the heat wheel alone, then the electric heater battery is brought into operation as the second stage of heating.
- If the off thermal wheel temperature falls below 2°C, a frost thermostat will shut down the AHU after 60 seconds.

3.4 Tenant building management systems

The tenant BMSs generally control the following:

- Fan coil units – fan control/speed and electric heater battery
- Separate tenant equipment e.g. comms room cooling equipment
- Separate heating systems e.g. the law firm has three separate boilers, one which provides heating to the auditorium, and two which provide domestic hot water to their showers and kitchen

Although the central HVAC system is no longer controllable via the tenant BMSs, it is possible for tenants to control the electric re-heater batteries in the fan coil units outside usual occupied hours so that a minimum room temperature can be maintained.

Level 4 has a separate Simmtronics lighting control system. Lighting is generally controlled by presence detection with daylight linked controls for perimeter offices.

Level 4's escalators, which consist of a pair between the ground and first floors, and a further pair between the first and second floors, are controlled by a separate control system in their reception. The ground/first floor escalators operate at half speed when no passengers are using them – photoelectric sensors fitted at each end switch the escalator to full speed when a passenger steps on and return it to half speed when passengers step off. The first/second floor escalators remain off at all times unless there is a function in the auditorium, which is located on the second floor.

3.5 Building occupation and usage

The building is located in the City, and many of the occupants of the building are in the banking or legal sector. These types of occupants are likely to work extended hours, and, particularly in the banking sector, are more likely to have a higher 'small power' consumption due to additional PC monitors and other office equipment. The latter is borne out by the TM22 assessment carried out on level 8. This means that the building is used relatively intensively – both over a longer period of time and in energy consumption intensity (kWh/m²).

3.6 Conclusions and key findings for this section

The building services are fairly typical for a highly serviced commercial office building, but they are equipped with energy efficient features. However, outside air is provided at 60% higher rate than the Building Regulations recommended rate, and is therefore likely to consume more energy in order to supply fresh air at this higher rate as a result. The building is likely to be used more intensively than a typical office building, resulting in a higher electricity demand, particularly in small power and ICT. This will also lead to an increased cooling demand, in addition to the possibility that the extensive amount of glazing may also result in increased solar gains – this is discussed later in this report.

4 Key findings from occupant survey

Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the BPE process and in particular with cross-reference to the BUS surveys, semi-structured interviews and walkthrough surveys. This section should draw on the BPE team's forensic investigations to reveal the root causes and effects which are leading to certain results in the BUS survey; why are occupants uncomfortable; why isn't there adequate daylighting etc. Graphs, images and data could be included in this section where it supports the background to developing a view of causes and effects.

4.1 Introduction

Surveys were carried out by occupants on both levels that are being examined in detail as part of the TM22 analysis – that is, levels 4 and 8. However, these surveys proved very difficult to arrange as the tenants' representatives were keen to minimise disruption to employees and to avoid what they saw to be any potentially provocative questions. On this basis, the questionnaires were edited to satisfy tenant representatives, and then agreed with both tenants and Arup, who were responsible for compiling the results. The survey carried out by the fund management company on level 8 was extended to another of their floors, level 9, to increase the number of responses. In total, level 8 and 9 completed 100 responses (level 8 had 61 responses and level 9 had 39 responses), while level 4 occupants submitted only 10 responses. The total number of responses represents approximately 4% of total building occupants.

Because the two types of office space are so different (open plan/banking use versus cellular/legal use, etc.), it was felt that it would be most valuable to process the results separately. However, due to the limited responses from level 4 occupants, and therefore the lack of statistical significance, it was not possible to process these results.

The occupant survey covers the following areas:

- Building overall – e.g. design, space, cleaning
- Working in the building – e.g. desk space, furniture, storage space, overall experience
- Comfort – temperature, air quality and air movement
- Noise – inside and outside
- Lighting – artificial, natural and glare
- Productivity
- Health
- Control over the environment – e.g. lighting, heating, cooling

The responses to the survey form a critical part of the Building Performance Evaluation, with the objective being to collect as much information on different buildings as possible. The results are compared against a range of buildings.

The complete set of results is appended to this report. The key findings are summarised in this section of the report.

4.2 Occupant survey results

Air conditions

Overall air conditions and comfort were perceived to be excellent, with air condition specifically considered reasonable. However, one area that was identified as an issue – perhaps the most critical issue identified within the survey - was poor temperature stability, with the perception that temperature varies during the day in both summer and winter. This result compared badly to the benchmark result, and was in approximately the 3rd percentile compared to other buildings in the dataset. There has been feedback from the occupants' FM staff that this result could be due to thermal radiant effects from the façade, and particularly the mullions - i.e. in winter, radiation exchange with the adjacent cool glazing and mullions, and in summer, radiation from the adjacent warm surfaces of the glazing and mullions.

Air was considered fresh rather than stuffy, but slightly dry, particularly in summer – this may be a direct result of the higher rate of 16/s/person at which outside air is supplied (see Section 3) but is not uncommon for buildings without any humidification. Air temperature was thought to be slightly too hot in summer and too cold in winter but the building still performed well compared to other buildings.

Lighting

Overall, lighting scored very well, with natural lighting perceived to be very effective. However, glare from the sun and sky was perceived to be a slight issue, and the quality of artificial lighting did not score so well, with the quantity and glare identified as issues.

Noise and productivity

Occupants perceived some slight noise identified from colleagues and from the outside. However, overall, noise levels are very good in comparison to other buildings. There was a perceived increase in productivity at work as a result of the environmental conditions in the building – the score obtained here was excellent compared to other buildings.

Occupant control

Occupants perceived that they had very little control over lighting and ventilation, and little control over heating, cooling and noise. However, excluding noise, overall satisfaction with these areas was good, and therefore lack of occupant control does not appear to have impacted on the perception of comfort.

Overall comfort and satisfaction

The BUS Summary Index is calculated as the mean of Comfort and Satisfaction Indexes. The result here is 1.06 which, in a range from -3 to 3, is in the 92st percentile when compared to other buildings, which is a very positive result.

Occupant tolerance

The Forgiveness Index is used to measure how tolerant occupants are of the conditions in the building. This is calculated by dividing the Comfort Overall score by the mean of six summary variables encompassing summer and winter air and temperature conditions, overall satisfaction with lighting and overall satisfaction with noise. The result is in the 81st percentile, suggesting that the occupants are very tolerant.

4.3 Responses from occupants seated adjacent to windows

The following graphs show an indicative breakdown of responses from occupants seated in the first two rows of desks adjacent to the windows on two specific issues: temperature stability and glare. Occupants were not directly asked if they sat by a window by senior management request. It was therefore inferred from a seating plan where the occupant had a maximum of one other desk between theirs and the window.

The graphs of temperature stability show a wide range of responses from occupants, although those who are not located by a window show slightly more satisfaction with this issue, with a slightly higher number of responses in the 1-3 categories. The effects of temperature stability therefore appear to be experienced across a greater area than the first few rows of desks. It is not possible to conclude whether close proximity to the facade has a direct effect on occupant satisfaction.

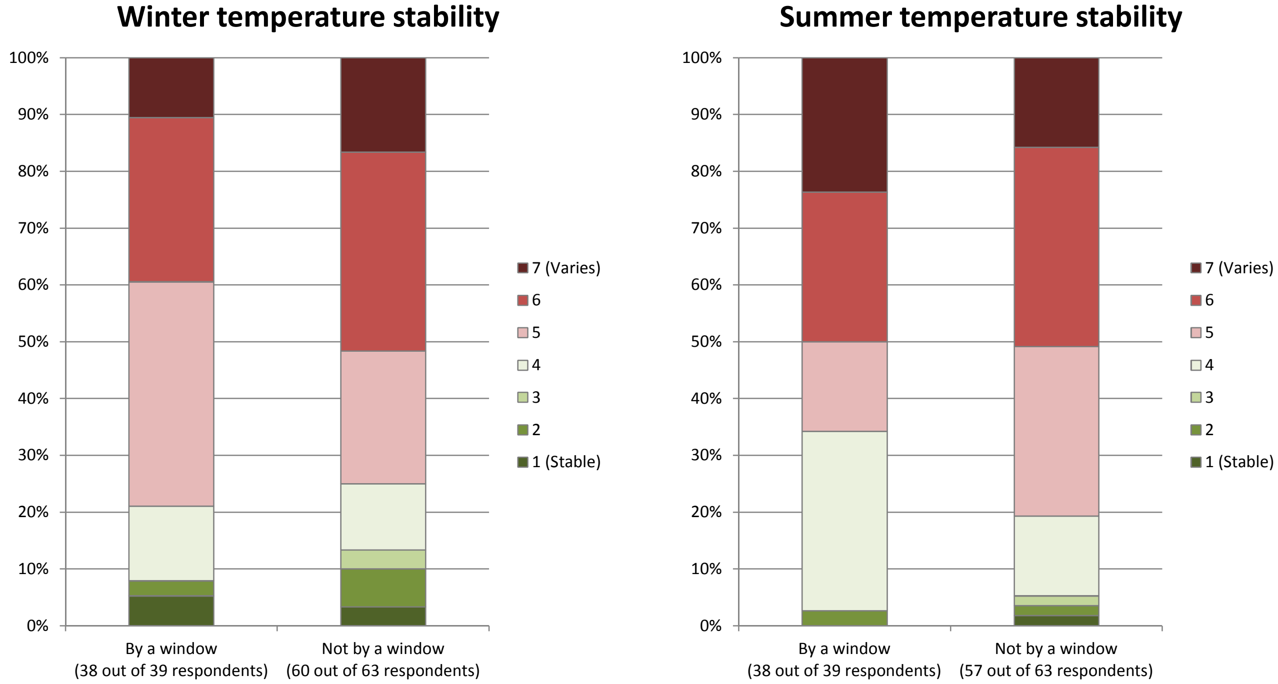


Figure 4 Perceived temperature stability depending on proximity to windows

The following graph shows that there is greater dissatisfaction from occupants seated close to the façade, with a higher number of responses in the 3-7 scores. However, the number of responses in the highest scores (6-7) are higher for those occupants seated away from the façade. It could therefore be concluded that the issue of glare is experienced across a much greater area of the office space. This is further supported by some of the comments extracted from the survey responses, shown in the table below.

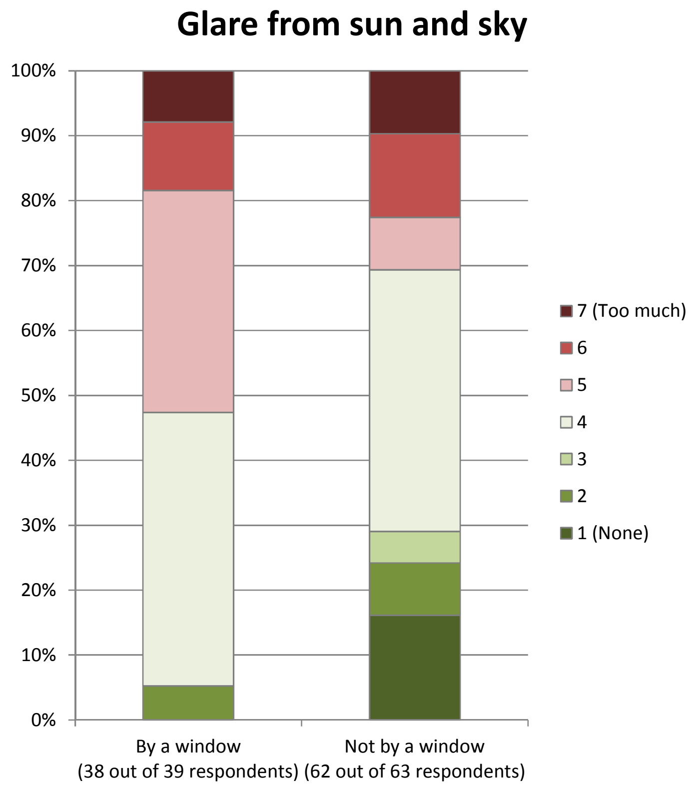


Figure 5 Perception of glare depending on proximity to windows

Table 2 Comments relating to glare from occupants

Directly next to a window	Not directly next to a window
White furniture and walls provide little relief for eyes as reflective *[Natural glare – 7, artificial glare – 4]*	If the sun comes out the blinds do not always provide enough protection *[Natural glare – 3, artificial glare – 4]*
I have the light above my desk switched off to prevent glare *[Natural glare – 4, artificial glare – 6]*	Sun light can cause problems particularly in the mornings *[Natural glare – 7, artificial glare – 4]*
On very sunny days the blinds don't always block the sunlight, causing glare on computer screen. *[Natural glare – 5, artificial glare – 4]*	There is often a glare from reflection of surrounding buildings *[Natural glare – 7, artificial glare – not answered]*
	Desks positioned with VDU screens facing windows - too much glare and have to close blinds (shut out natural light) *[Natural glare – 7, artificial glare – 1]*

4.4 Conclusions and key findings for this section

Overall, the building performed very well, with overall comfort and satisfaction being excellent. The Summary Index, which is calculated as the mean of Comfort and Satisfaction Indexes, gives a result which is in the 92nd percentile of all buildings assessed. However, a critical issue that was identified was air temperature stability, possibly related to thermal radiant effects from the façade.

5 Details of aftercare, operation, maintenance & management

Technology Strategy Board guidance on section requirements:	This section should provide a summary of building operation, maintenance and management – particularly in relation to energy efficiency, metering strategy, reliability, building operations, the approach to maintenance i.e. proactive or reactive, and building management issues. This section should also include some discussion of the aftercare plans and issues arising from operation and management processes. Avoid long schedules of maintenance processes and try to keep to areas relevant to energy and comfort i.e. avoid minor issues of cleaning routines unless they are affecting energy/comfort.

5.1 Building operation, maintenance and management

5.2 Monitoring and targeting recommendations

EP&T, the metering and M&T contractors, are appointed by British Land to identify energy saving opportunities through the use of a monitoring and targeting system, and installation of sub-meters. For Verco, developing the basebuild TM22 model has been a complex process due to a large number of items of equipment in the building and the complex sub-metering arrangements. Meter tree diagrams are provided in the Appendices of this report.

EP&T began their engagement with 201 Bishopsgate in 2010 with a contract for 3 years, under a guaranteed savings approach.

EP&T issue monthly MARS reports which summarise identified discrepancies/anomalies in sub-meter energy consumption and log notes between EP&T and the client to try to identify a solution. Verco have reviewed the last six months' worth of logs and noted some of the key issues, as well as their corresponding savings – these are listed in the appendices.

Verco attended a Monitoring, Analysis and Reporting Service (MARS) meeting which takes place monthly between Broadgate Estates and EP&T in order to gain a better understanding of the recent issues with the building's operation and those picked up by EP&T. MARS meetings are held monthly, on the first Wednesday of each month. Its format is a conference call between EP&T's technical support team and Broadgate Estates FM team.

The meetings are typically structured around issues and actions logged in EP&T's monitoring and reporting system. The status of each issue and corresponding action is methodically discussed. Key points of interest include:

- Plant operating times were a major issue early on in the building's occupation. These have now been fine-tuned. However, one of the recurrent themes during the meeting is issues relating to the BMS. These issues appear generally to relate to inappropriate time clock or demand settings for equipment, particularly out of hours plant operation. For example, control loops have been amended for the heater battery in AHU2 which was providing excessive heat.
- A major issue already identified is that occupier's BMS can call for HVAC equipment at any time, over-riding the central BMS, and often these demands are considered unnecessary. The reason for

the facility is to enable flexible working. Broadgate Estates have now modified the BMS to limit this facility, and had discussions with the occupiers on the impact on energy usage. This change has resulted in a significant reduction in building energy consumption. Monthly Out of Hours Request Logs are now sent to EP&T by Broadgate Estates (BE) so that EP&T can review the energy usage and ensure that plant energy consumption is consistent with operational requirements, and there was extensive discussion around this topic.

- Out of Hours (OOH) allocation of energy costs to tenants is based on lighting and small power energy consumption, as well as a proportion of an early plant replacement charge. For tenants not using OOH plant services, they are credited with a corresponding proportion of the latter charge.
- The heating in the reception area is an issue – it is provided by electric underfloor heating which isn't working effectively in providing heat to the receptionists. In addition, the disabled door is used quite a lot instead of the revolving door, which is creating draughts. Door seals were thought not to be considered suitable in terms of their appearance when the entrance lobby was designed, and so could not be integrated into the door frame. Therefore, these air gaps are also contributing to the air infiltration.
- There have been on-going issues with a low temperature differential in the refrigerant circuit on all the chillers, and also with the control valves – this issue has/is being resolved.

During the period May to December 2011, EP&T identified 29 issues which have led to energy savings, generating around 2,800MWh of electricity savings, or roughly 20% of the total building electricity consumption. A further 59MWh's worth of opportunities are yet to be realised.

The graph below shows the breakdown of the energy saving measures which had been implemented by December 2011. This clearly shows that the vast majority of savings relate to the faulty interaction between landlord and tenant plant, which impacted on equipment such as the AHUs, chillers and pumps. Nearly all measures have been implemented by making adjustments to the BMS. The only measure which was not implemented through changing the controls relates to the unnecessary operation of the underfloor heating in the reception area, which was rectified by isolating the system in summer.

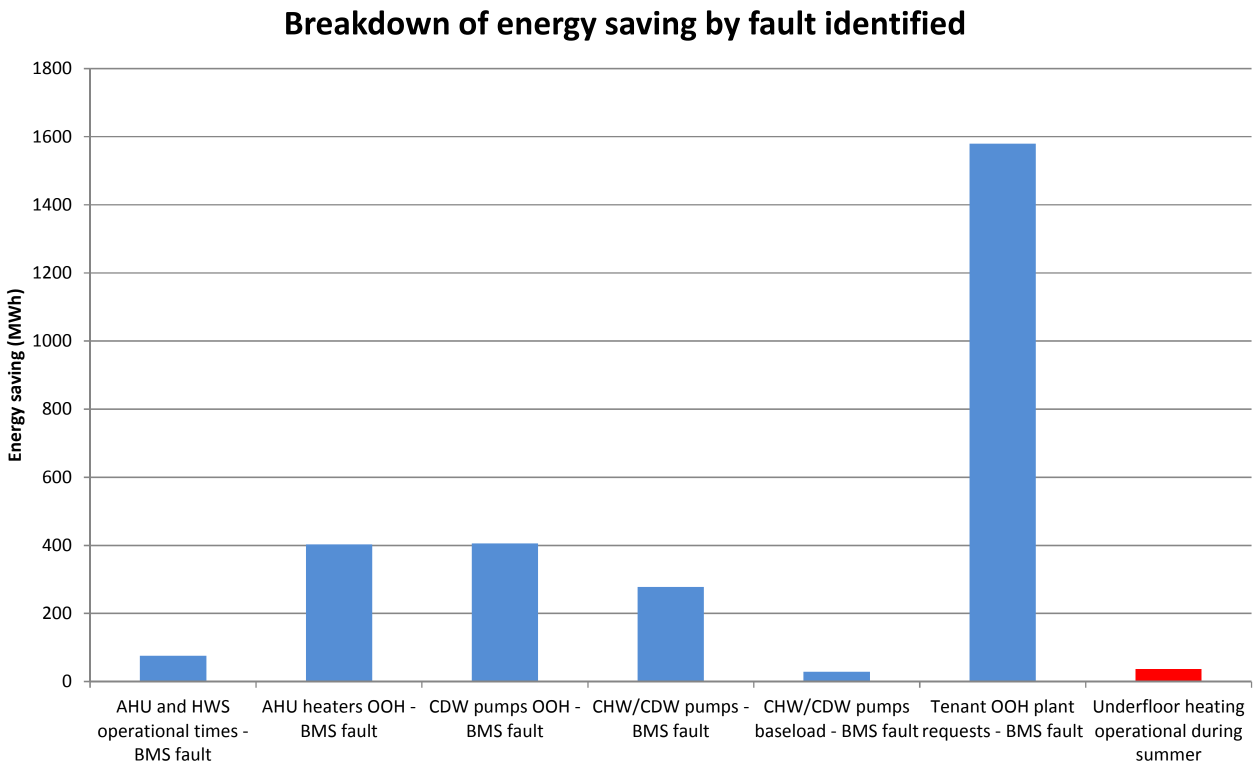


Figure 6 TM22 analysis month selection

5.3 Conclusions and key findings for this section

In general, it is apparent that the majority of issues identified relate to BMS control and therefore the BMS has so far been the greatest single factor in unnecessary energy usage in the building. These issues generally relate to inappropriate time clock or demand settings for equipment. One of the major issues identified is that occupier's BMS can call for HVAC equipment at any time, over-riding the central BMS, and often these demands are considered unnecessary. The reason for the facility is to enable flexible working. Broadgate Estates have now modified the BMS to limit this facility, and had discussions with the occupiers on the impact on energy usage. This change is likely to have resulted in a significant reduction in building energy consumption. It should be noted that out of hours energy use will be examined in further detail as part of the follow on study to determine the reduction in demand and any change in energy demand patterns.

6 Energy use by source

Technology Strategy Board guidance on section requirements:	This section provides a summary breakdown of where the energy is being consumed, based around the outputs of the TM22 analysis process. This breakdown will include all renewables and the resulting CO_2 emissions. The section should provide a review of any differences between intended performance (e.g. log book and EPC), initial performance in-use, and longer-term performance (e.g. after fine-tuning and DEC – provide rating here). A commentary should be included on the approach to air leakage tests (details recorded elsewhere) and how the findings may be affecting overall results. If interventions or adjustments were made during the BPE process itself (part of TM22 (process), these should be explained here and any savings (or increases) highlighted. The results should be compared with other buildings from within the BPE programme and from the wider benchmark database of CarbonBuzz.

6.1 Introduction

Overall approach to TM22 analysis

For our detailed energy end use analysis of 201 Bishopsgate, Verco have built three energy models (using the CIBSE TM22 methodology) for 201 Bishopsgate:

- **Basebuild model** – representing all landlord meters i.e. common areas, machinery serving the whole building (e.g. chillers, cooling towers, lifts) and external lighting
- Occupant models – representing energy consumption in each occupied area ('levels' submeters) and occupant owned equipment on other floors (kitchen areas and server rooms)
    - **Level 4 occupant model** – modular type office space, typical of non-banking occupant i.e. less intensive small power and ICT usage
    - **Level 8 occupant model** – open plan type office space, typical of banking occupant i.e. more intensive small power and ICT usage

These three models separate out the energy use of the occupant and landlord spaces in the building. A single TM22 model then combines these three outputs to represent the whole building. This is done by scaling up each of the occupant models to represent the total occupant energy consumption.

The final year of data used was from 1st April 12 – 31st March 13. This represents the period when the building was fully occupied, issues were resolved with control of the chillers and AHUs operating during out of hours periods (refer to Section 5), and the sub-metering was fully operational (see Section 7). Setting up the sub-metering proved to be complex because the quality of O&M literature relating to the electrical system in the building and its descriptions of where specific equipment is served from was not detailed as expected, and labelling of equipment was not as clear as it should have been.

For each of the three models described above, an average month, a winter month and a summer month were examined in detail, and these were scaled up to represent a full year, based on actual weather data over the period analysed, collected from the pyranometer and temperature sensor on the roof of the building. Each of these three models were reconciled against meter readings for an average month, a summer and a winter month. The following months were selected as representative of their respective seasons:

- Summer month: July 2012
- Spring/autumn month: October 2012
- Winter month: November 2012

The categorisation of each month of the year is shown in the graph below.

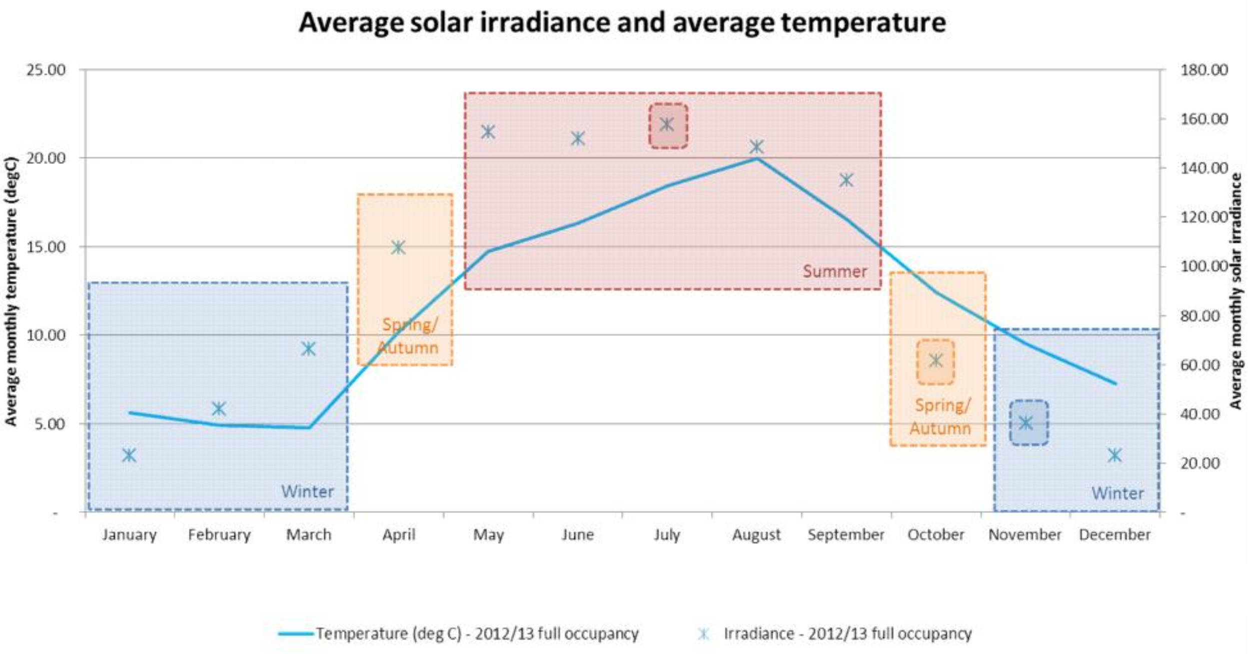


Figure 7 TM22 analysis month selection

Scaling up results to generate whole building model

The TM22 analysis has allowed us to split the consumption in each of the three models into end use categories (e.g. lighting, small power, space heating) to determine how the electricity on each floor is typically used by an occupant. We are then able to apply these end-use splits across all of the other floors based on the assumption that 50% of tenant energy consumption is consistent with the level 8 model and 50% with the level 4 model. This should give a representative blend of each of the two profiles associated with each occupancy type. The following diagram shows this methodology graphically. The profiles for each are described later in this section of the report, and TM22 results are also shown for each of the levels individually, as well as the total building model.

To build a model for the whole building, results from each of the tenant models for every end use have been added to the basebuild TM22 model. Energy consumption for major energy consuming tenant uses which are not found on levels 4 or 8, and therefore not modelled in TM22, and not separately sub-metered, but are known to exist within the building, have been estimated and also added to the whole building model – these are ICT (e.g. servers) and catering (e.g. a staff canteen). Energy consumption for the retail units have also been incorporated into the whole building model as a single end use, based on sub-metering data.

ICT has been calculated using all available sub-metered data for comms rooms and server rooms, as well as an estimate for the likely proportion of energy consumed by computers which is metered together with all small power on each floor. For the level 6 tenancy, there is no known sub-metering for these energy uses and therefore an allowance of 34% of its total electricity consumption has been allocated to ICT. This figure is based on the same proportion allocated to ICT on the investment bank's tenanted floors (levels 8, 9, 10 and 12).

Gas consumption was only properly submetered from April 2013 - this was partly because of faults which were showing in the gas submeters from the date of their original installation up until May 2013, when they were replaced. This made it difficult to accurately apportion gas consumption between the different end uses. The estates team were able to provide us with indicative gas usage based on one week of meter readings; the split of consumption over this one week was then extrapolated across all gas consumption in our evaluation period. This is considered a reasonable approach as all consumers (catering, retail and hot water) should not vary on a seasonal basis.

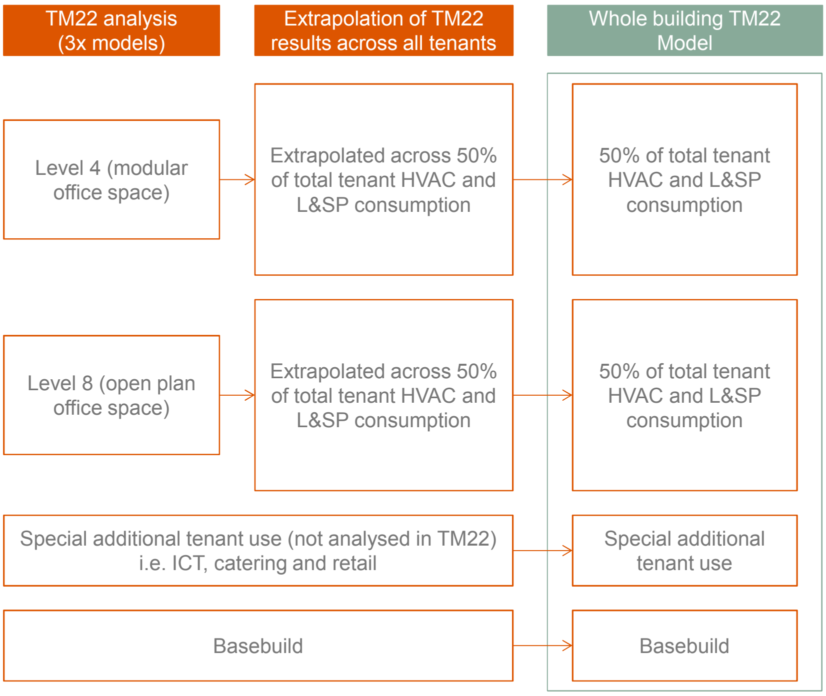


Figure 8 Process for scaling up each of the TM22 models for obtaining a whole building TM22 model

Occupied and non-occupied hours split

In order to compare the modelled consumption in TM22 to the original estimates at the design stage, it was necessary to split consumption between in hours (i.e. core hours - 7am to 7pm for tenant use and 7am to 8pm for basebuild uses, Monday to Friday when the building is occupied) and out of ours periods (i.e. all non-core hours). This enables a more representative comparison to be made since the design stage estimates are based on standard occupancy profiles. As each item of equipment modelled in TM22 had been assigned an appropriate time profile, we were able to change the profile in all TM22 models such that they only displayed consumption occurring during the core hours. This analysis then informed the results shown later in this report.

Final year TM22 outputs

A single TM22 model for the whole building has been produced. This section of the report analyses the key results for this first year of analysis

6.2 Historical data analysis

Historical data analysis has been carried out on energy data obtained from October 2008. This is shown in the graph below.

The graph shows two peaks in January and December 2010. The peak in January is likely to be as a result of an issue experienced with an occupier's BMS, which was incorrectly configured. The BMS was sensing a low temperature within the building and, as part of a fabric protection function, was starting the fan coil units, which in turn was placing a demand to operate the plant. This issue has now been rectified. The later peak may be due to fit-outs coming to an end and heat loads coming online.

In general, the higher consumption for 2011 is due to a higher occupancy – level 6 was occupied by this time, which includes a trading function, and the investment bank's number of employees working in the building increased. Full building occupancy was reached in April 2012. The reduction in energy consumption as a result of efficiency measures implemented may be counter-balanced by the increase in occupancy, thus explaining the relatively 'flat' consumption.

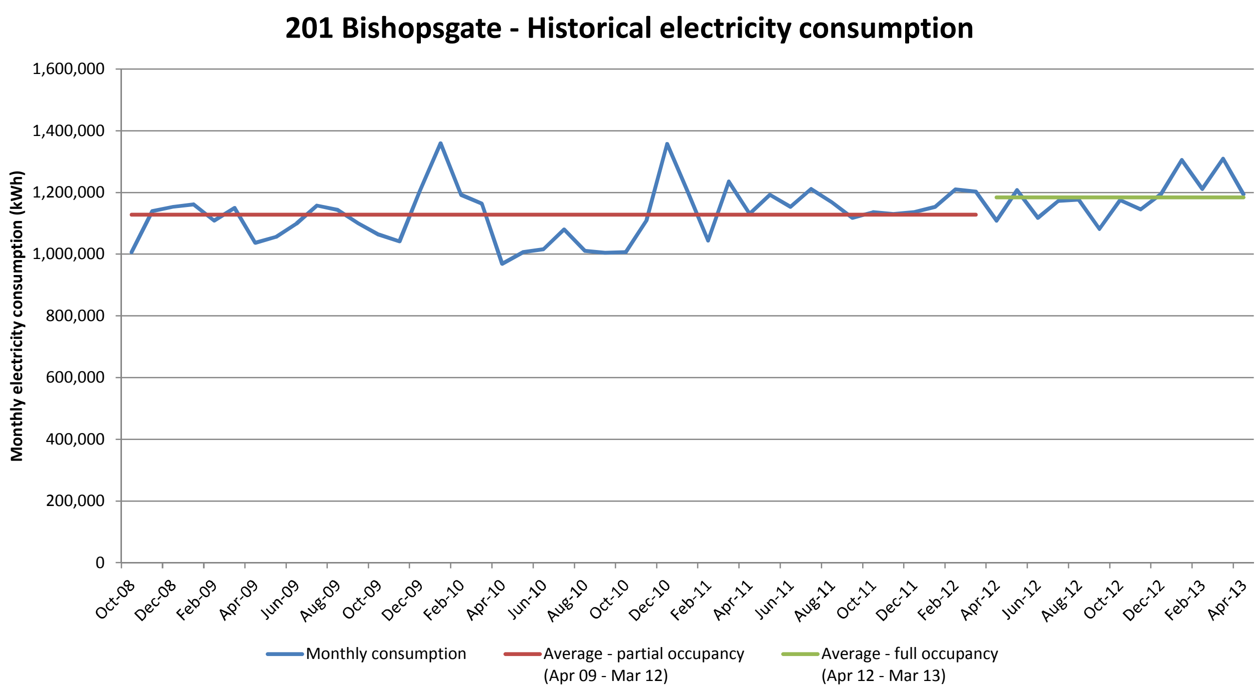


Figure 9 Graph of historical energy consumption October 2008-April 2013

The following graph shows a comparison of annual historical data with ECON19 benchmarks for the last four years. Since this building uses electricity for heating, but the benchmarks assume gas for heating, the gas consumption has been converted to an equivalent electricity consumption by applying an efficiency of 85%, the typical efficiency of a gas boiler. Heating energy generated by electricity is assumed to be 100% efficient.

The graph shows that the building's total electricity consumption appears to be marginally better than the ECON19 'good practice' benchmark for an office of this type (type 4, 'prestige air conditioned'), and this performance has remained relatively constant, despite the changes in occupancy levels.

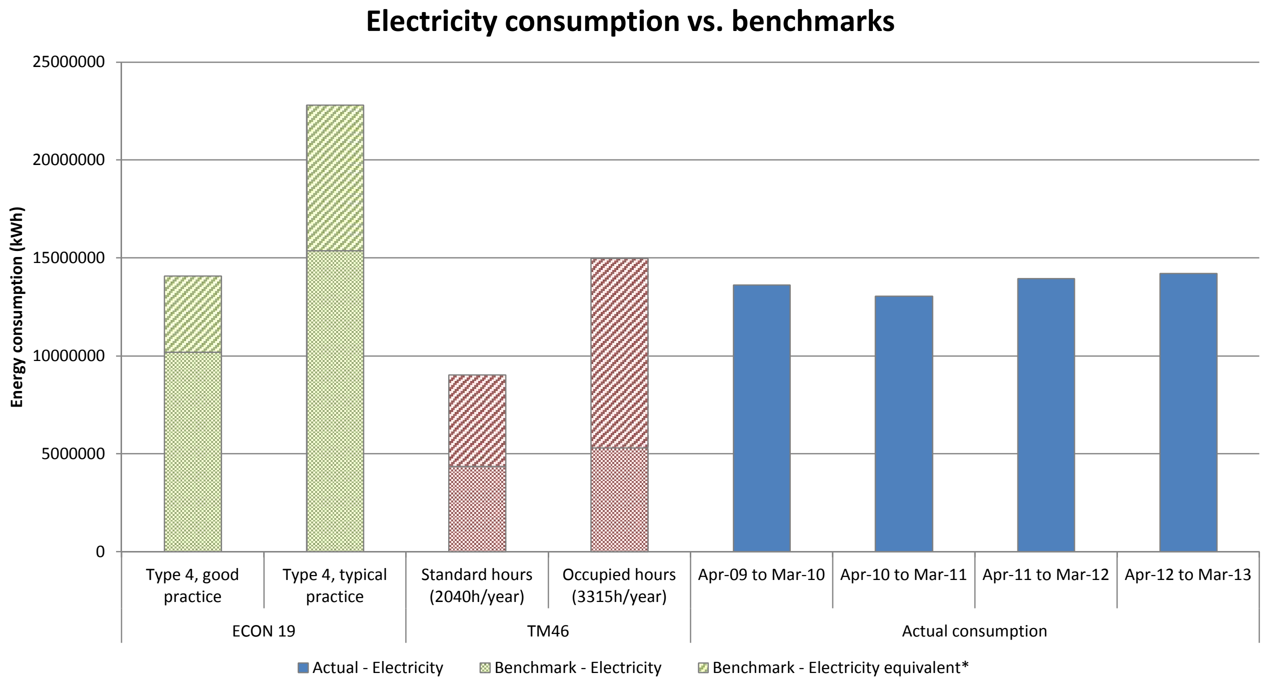


Figure 10 Comparison of historical energy consumption with ECON19 benchmarks

6.3 Base build energy end uses

The following graph shows the breakdown of energy consumption for the base build end uses for each representative month of the year analysed. The following conclusions can be drawn:

- 'Unaccounted energy consumption' is where known equipment on sub-meters cannot account for total energy consumption, suggesting that the sub-metered consumption includes additional, unknown equipment energy supplies. 'Sub-metered discrepancy' is the difference between substation consumption and the sum of sub-meters, indicating that there is plant/equipment energy consumption which is not being sub-metered at all. Together, these end uses account for around one third of the total energy consumption. Sub-meter discrepancy accounts for the slightly larger proportion of these energy end uses, and is an area for further investigation by the building's FM team.

- Despite the 'sub-metering discrepancy', the building's metering was designed in accordance with TM39 (Building Energy Metering) so as to ensure that all energy consumption is metered. The design was carried out by a consultant, and the final design was sent to EP&T, who reviewed it to check that there is sufficient metering for their purposes. They identified 11 additional metering points that were required.

- The have been occasional gaps in metered energy data. This is caused by a loss of communication with the meter where it is not equipped with redundant memory. This means that when a meter goes offline, EP&T would investigate this, and if the meter is an EP&T meter, the meter will have two months of on-board memory so it is straightforward to repair gaps. However, third party meters do not have this functionality so the data gap is much more difficult and time-consuming/expensive to fill, so sometimes a decision is made not to try to retrieve this data.

- It should be noted that heating energy in the basebuild is used for heating the fresh air in the air handling units and heating landlord areas – the remaining heating energy in tenanted areas is not included here as it is provided locally i.e. electric heater batteries in the fan coil units. In the cellular models, the fan coil units were on their own submeter. On the open plan floor the fan coil unit fans are found on the lighting and small power meter along with a number of other end uses such as lighting and cooling, while the fan coil unit heaters are on the mechanical meter with some smaller end uses (i.e. controls and fans). For both floors, the meters are fed by the main lighting and small power and HVAC risers.

- In summer, refrigeration is the most significant energy end use. In spring/autumn, this is less, with a small amount of heating energy use. In winter, there is still a considerable amount of refrigeration energy consumed – more than 5000kWh/month – in conjunction with heating energy. Although the base build provides cooling to some tenant ICT rooms in the building, this does not explain this extent of refrigeration energy consumption in winter. The potential to reduce the supply temperature of the fresh air in winter to avoid unnecessary cooling has been identified as a significant energy saving opportunity and is being investigated by the FM team.

- Lighting energy is slightly lower in summer – it might be expected that this would be significant lower in summer, but many of the landlord areas with lighting are internal and therefore independent of daylight.

- Energy consumption for other end uses, including fans and pumps, remains relatively uniform throughout the year, which is consistent with expectations as these are generally independent of seasons.

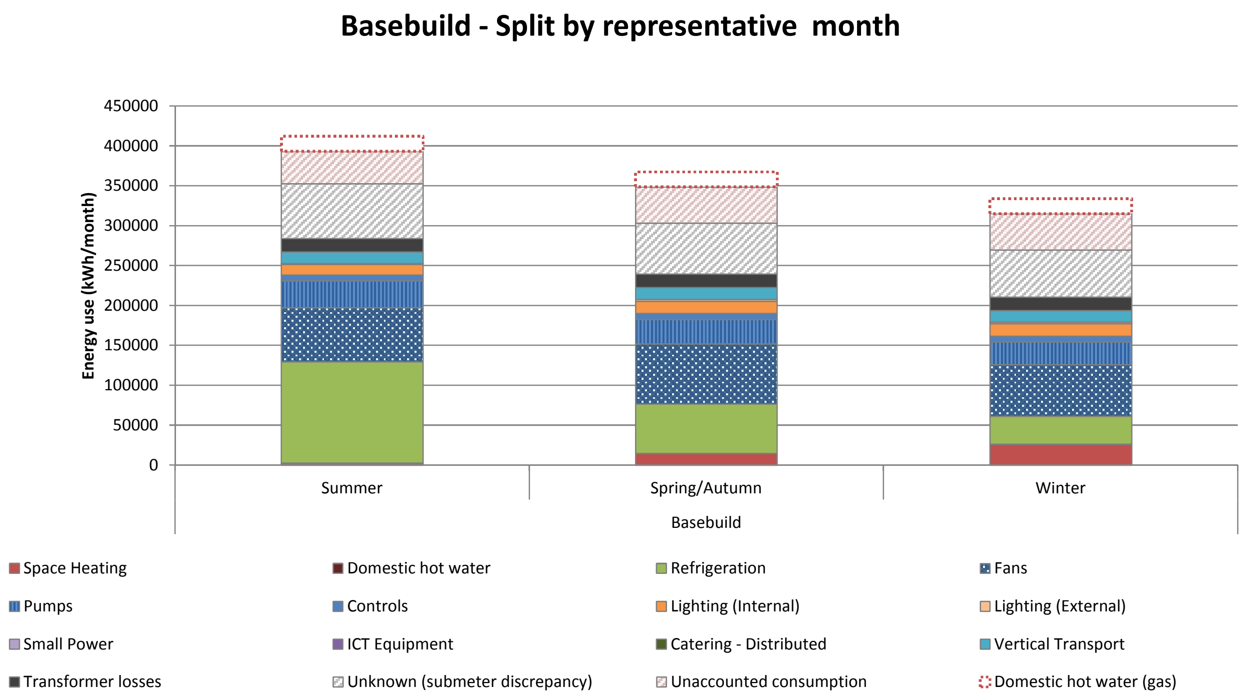


Figure 11 Seasonal variation of energy use in base build model

6.4 Tenant energy end uses

The following graphs show the TM22 results for each of the level 4 (cellular) and level 8 models (open plan) on an annual basis and for each of the three months of the year analysed. They show the increased electricity consumption on level 8, largely due to a much higher small power demand.

The floor areas of the levels are similar - the net lettable areas are 3,583m^2 for level 4 and 3356 for level 8.

Lighting energy consumption is slightly higher for the open plan model. This was expected to be lower than the cellular model because of the ability to make greater use of natural daylighting. Both floors benefit from lighting control systems which provide occupancy detection. However, level 8 operates on a timeclock between 7am and 9pm, and is therefore on continuously during this period once activated at the start of the period by the PIRs – usually by the cleaners. This may explain the higher energy consumption. In addition, the cellular offices are ideally suited to presence detection, where smaller banks of lights can be controlled by each presence detector.

Catering energy uses are higher for level 8 because this floor is equipped with a large café area, while level 4 only has small vending areas.

The remaining energy end uses are broadly similar for both types of office space. Assumptions have been made for electricity consumption for ICT equipment on level 4 as detailed information was not available, and these were based on the information obtained for level 8 ICT equipment.

Level 8 includes electricity demand for instantaneous domestic hot water, while no such equipment was identified on level 4, hence the lack of DHW demand in the graph. Central DHW demand, for toilets and showers, for example, is included within the base build model.

The seasonal differences are accounted for primarily by the change in space heating demand throughout the year, rather than any other end use.

Interestingly, energy for space heating is higher on level 8 compared to level 4, despite the likely higher internal gains arising from a greater occupancy density and greater small power energy use. This may be partially caused by simultaneous heating and cooling in the fan coil unit system, known as ‘fighting’, which can often occur in open place office space where there are inadequate controls settings (e.g. deadbands). This could also be exacerbated by solar gain where adjacent zones are experiencing very different environmental conditions – particularly, for example, during periods of winter sunshine. During a review of the HGI BMS, one fan coil unit’s setpoint was set to 24°C and was in cooling mode, whilst the adjacent unit’s setpoint was 27°C and was therefore in heating mode.

This issue would also result in an increase in cooling energy but as this is a landlord service, the impact of this cannot be seen here. The only cooling in tenant areas that has been modelled is for server rooms, and is therefore included under the ‘ICT’ end use.

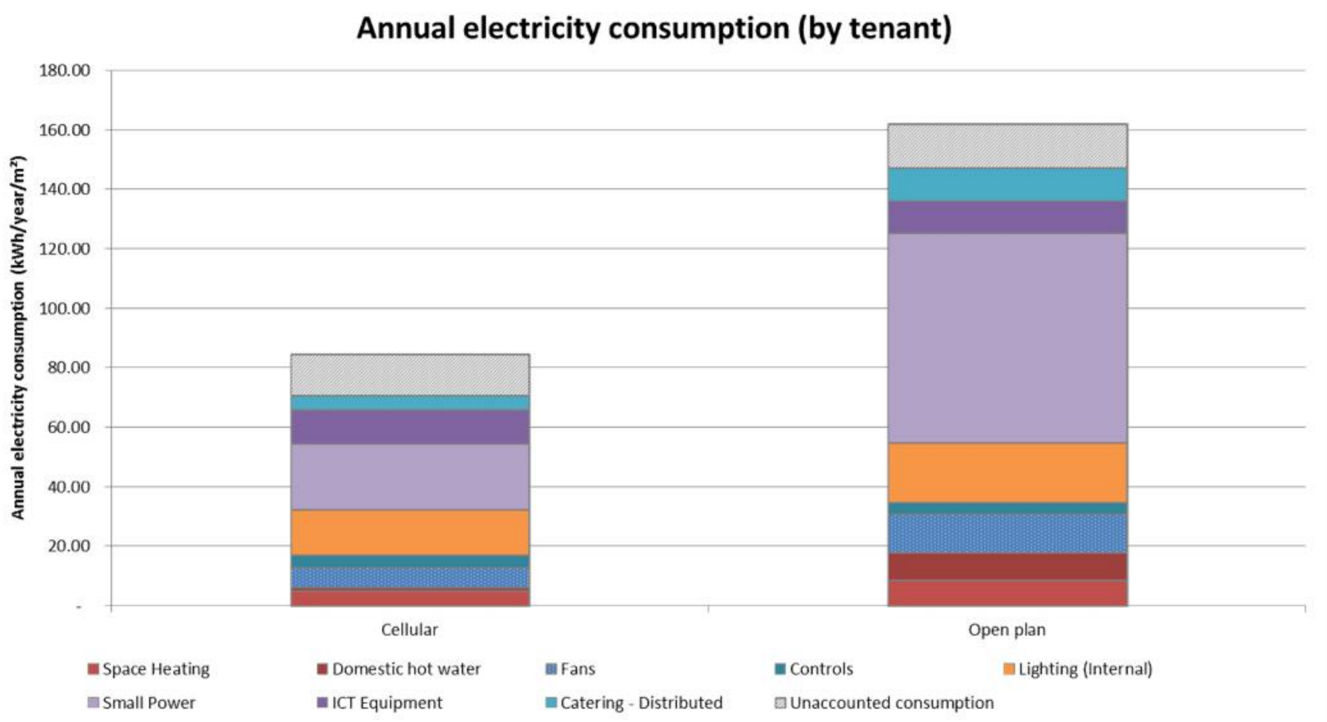


Figure 12 Level 4 versus level 8 TM22 analysis – whole year

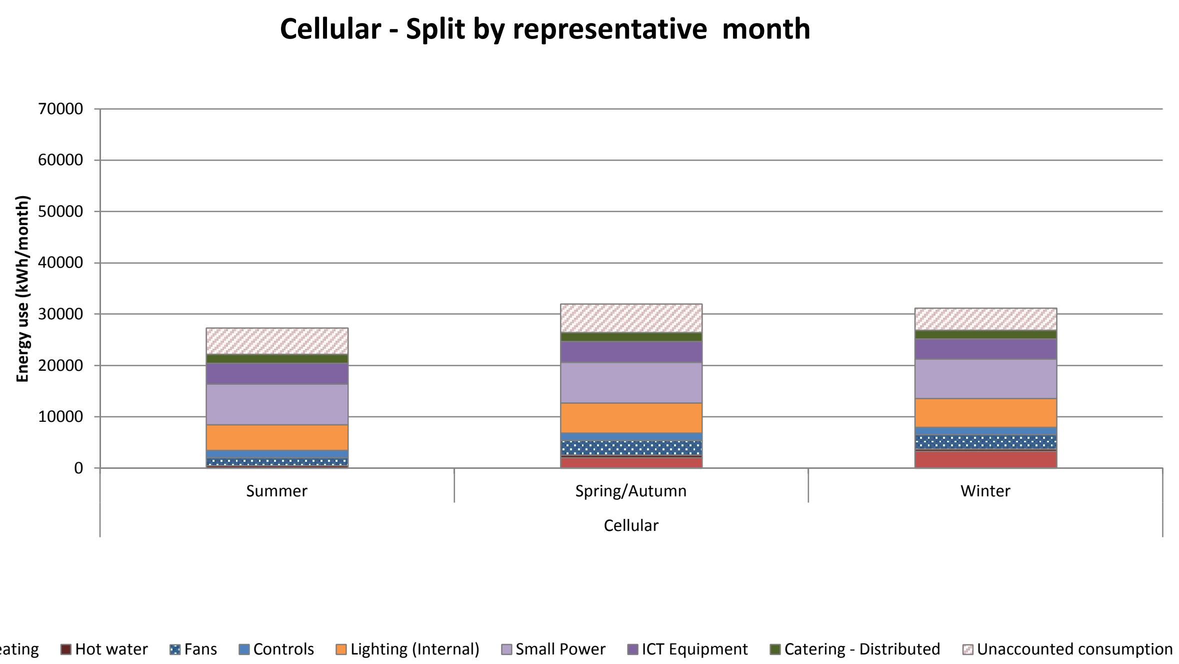


Figure 13 Level 4 TM22 analysis – by season

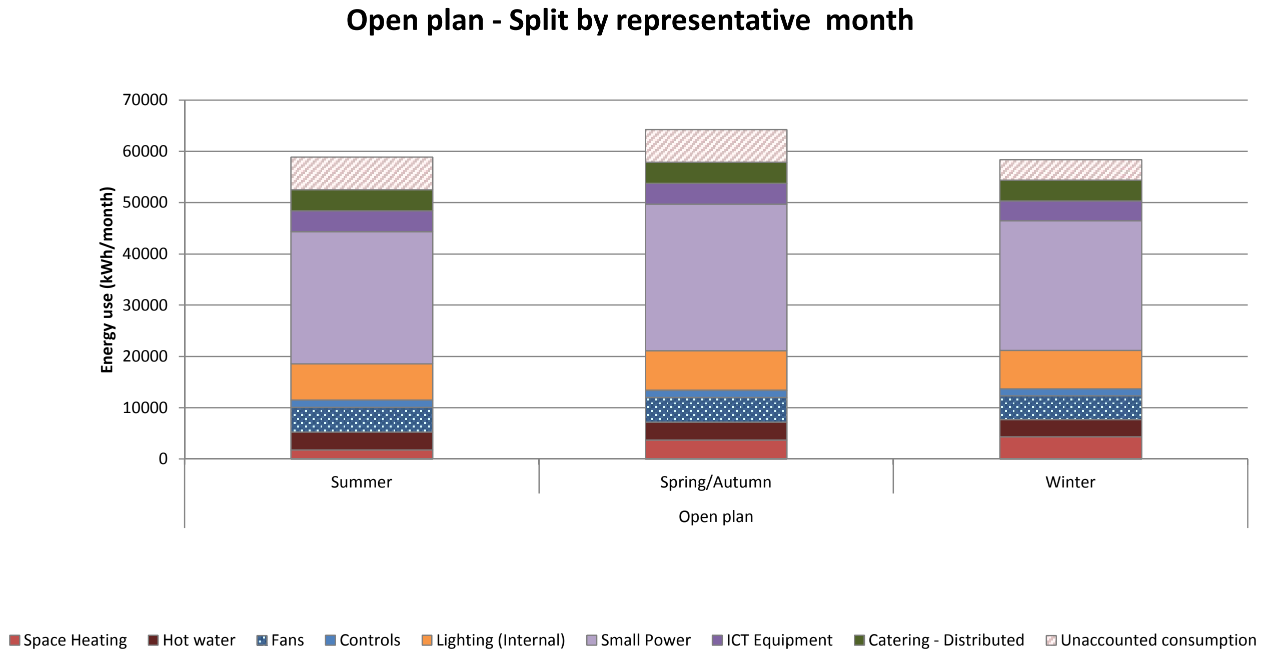


Figure 14 Level 8 TM22 analysis – by season

The following graphs show that occupancy density has a significant impact on energy consumption. The occupancy for level 4 is approximately 190 and, for level 8, approximately 397. This equates to 19m²/person and 11m²/person respectively. Taking this into account, the energy consumptions for each occupant type are in fact very similar, with only 7-8% difference over the year analysed. Lighting energy is shown now to be higher on level 4 using this metric, while small power remains higher on level 8.

Seasonal graphs are shown in the appendices.

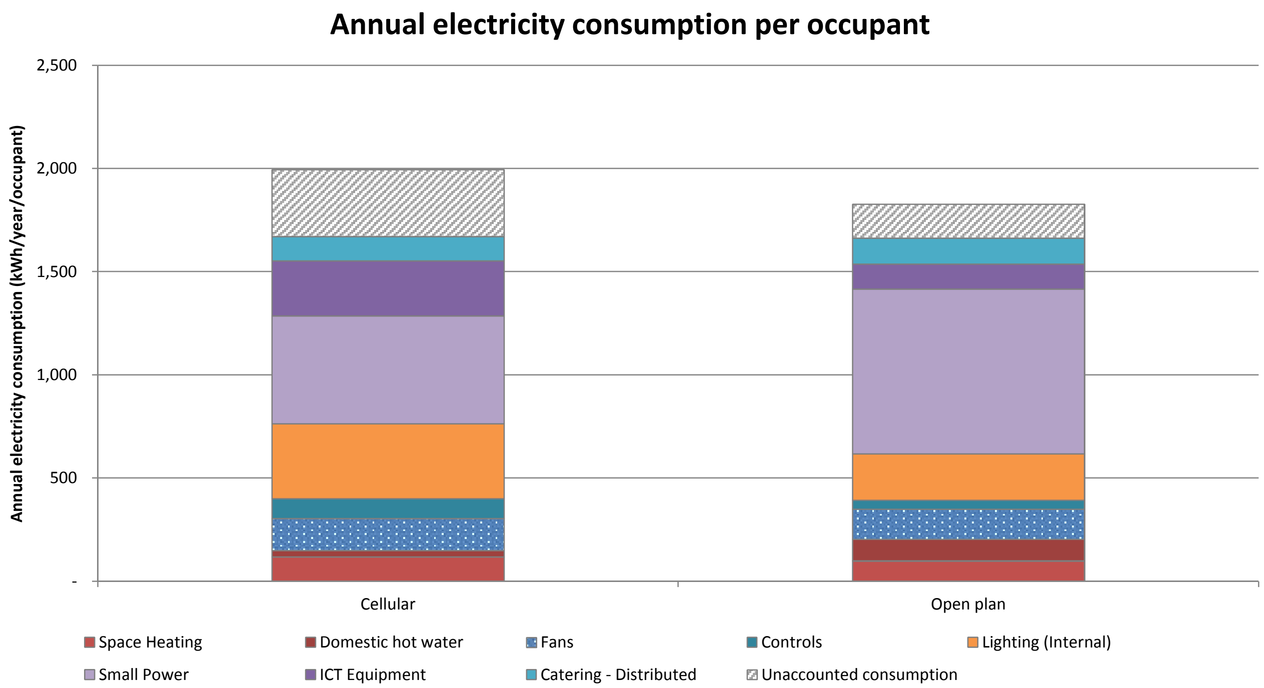


Figure 15 Tenant energy consumption for each occupant type, normalised for occupancy – whole year

6.5 Primary energy use breakdown

In order to assess the effect of seasons on building energy performance, sub-metered data for a typical winter month and summer month has been analysed for each representative seasonal month (refer to Section 6.1), using information from the pyranometer and temperature sensor on the roof.

Figure 16**Error! Reference source not found.** shows the electricity consumption for the primary uses within the building, comparing a spring/autumn month, a winter month and a summer month. It shows that, at the total consumption level, there are only small differences between each of the three periods – constant consumption across summer and spring/autumn, and a small increase of around 5% in winter.

The breakdown between tenant and basebuild consumption is relatively consistent in spring/autumn and winter. However, in summer, the tenant consumption is slightly lower, whilst the basebuild consumption is slightly higher. This appears to be due to the reduction in heating energy, as indicated in Figure 13 and Figure 14
above.

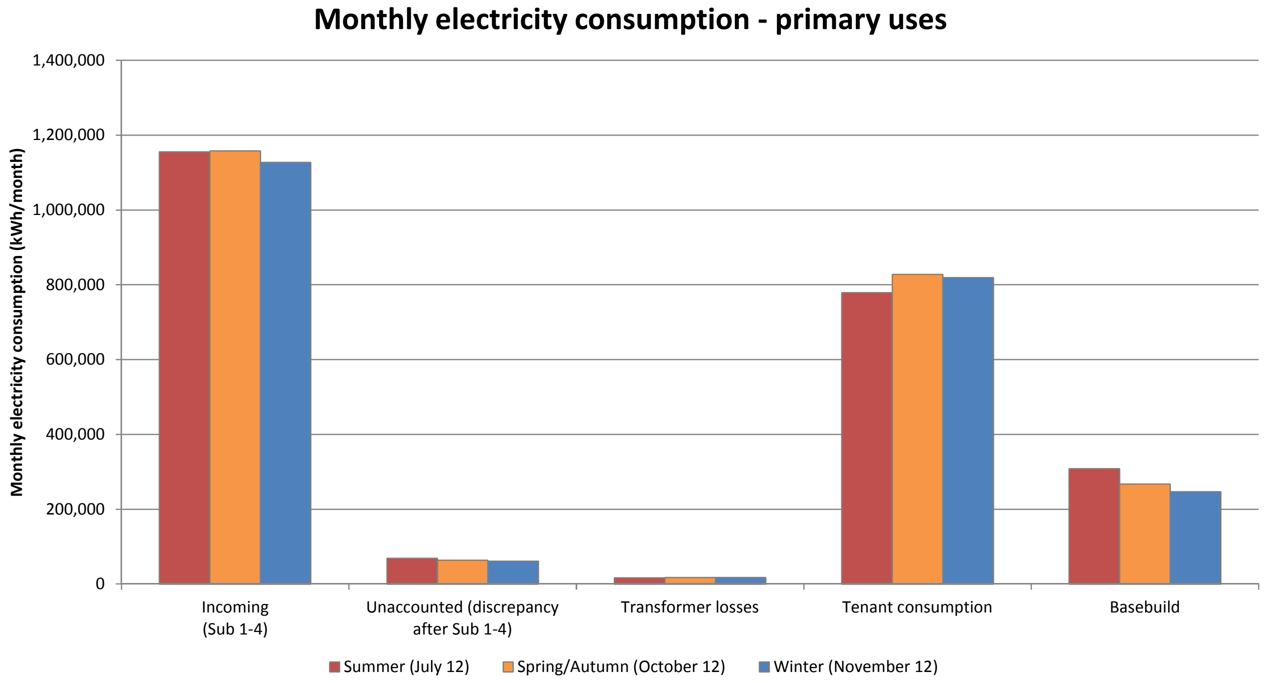


Figure 16 Primary energy consumption – seasonal comparison

6.6 Whole building energy use comparison

Benchmark comparison

The following graphs show the breakdown of electricity uses for the whole building model. They provide a comparison of design predictions (Part L and energy statement data), against our TM22 model based on the actual occupancy of the building and also extrapolated downwards for 'standard' hours.

The following graph shows the results for regulated and non-regulated energy uses, compared against ECON19 and TM46 benchmarks. It shows the following:

- The building performs slightly better than ECON19 'good practice' – however, it should be noted that these benchmarks were produced more than ten years ago and building energy efficiency performance is expected to have improved since then
- When excluding electricity for heating, the remaining total electricity consumption is higher than ECON19 'good practice' but slightly better than 'typical practice'
- The building's extended occupancy profile increases the total energy demand by around 45%; however, ECON19 benchmarks take account of out of hours energy use and it is reasonable to compare these benchmarks with the building's 'in and out of hours' energy use
- The building performance is also compared against CIBSE TM46 benchmarks[3]. These are shown for the standard occupancy, and adjusted for the estimated actual hours of occupancy of the building. The building's energy consumption is considerably higher (almost 50% more) than the former but slightly lower than the latter. The extended occupancy benchmark may be slightly conservative since not all the floors in the building will be occupied during this period, even though the central plant will be operating for this number of hours. It is possible that the extended operation of the plant, and the need to operate all base build plant to meet the needs of tenants who use the building for extended periods is a key reason for the additional energy consumption.
- However, it should be noted that the TM46 benchmark for offices is based on an "average office" – hence it represents a mix of naturally ventilated and air conditioned buildings, which is less energy intensive than this building. This at least demonstrates the quantum of additional energy that this type of 'prestige' office building uses.
- Small power and ICT account for around 40% of the total building energy consumption, which is slightly higher than the proportion allocated to this in ECON19; however, it is around 5 times higher than the energy statement prediction and therefore this is an area for further investigation as part of the follow on study
- There is a significant proportion of unaccounted energy consumption which cannot be attributed to an energy usage type, as well as energy losses across the transformers; the former demonstrates the difficulties in modelling hours of use accurately with extended building occupancy
- There are a number of energy end uses which do not explicitly appear in the ECON19 categories, such as vertical transportation and controls, although these may be included in 'other'
- There is no humidification in the building, and therefore this has been excluded from the benchmark comparison.

[3] TM46 benchmarks are used for calculation of DECs and are based on a rationalisation and simplification of value taken from a range of sources, including CIBSE Guide F, which uses ECON19 benchmarks for offices

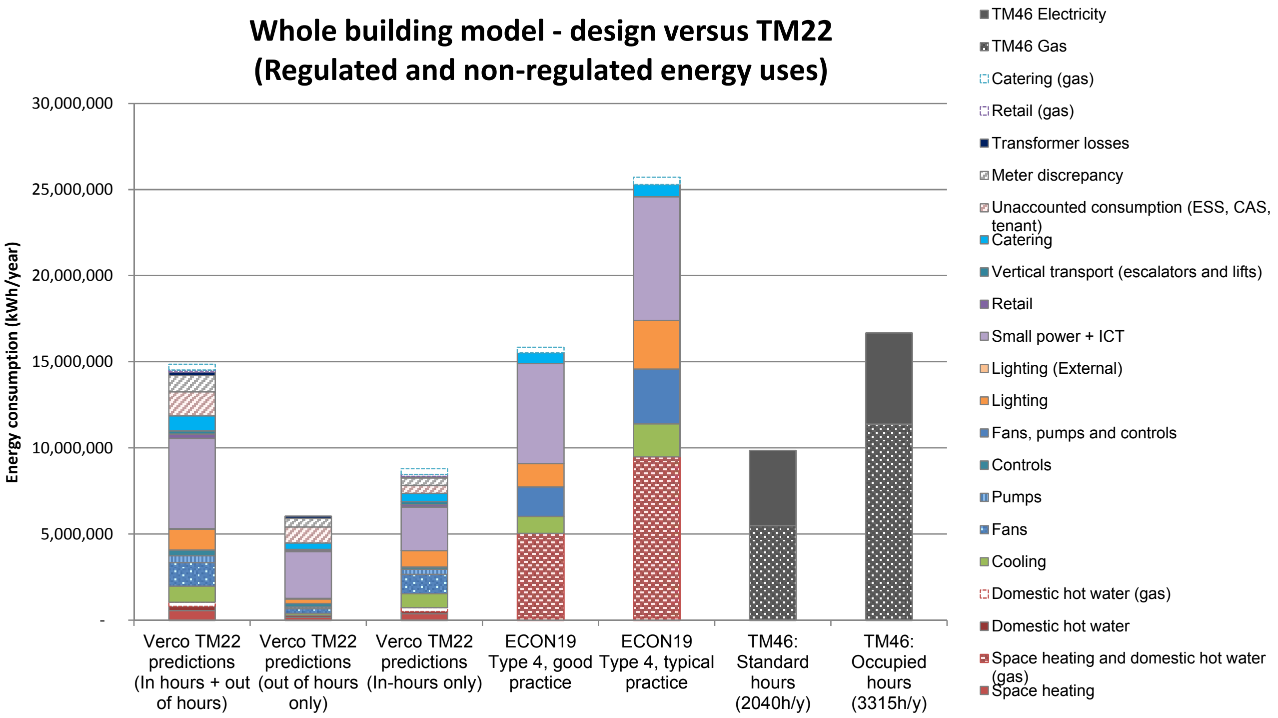


Figure 17 ECON19 versus TM22 predictions– breakdown by energy uses, regulated and non-regulated

The graph below shows the results for regulated and non-regulated energy uses, expressed as carbon emissions. This demonstrates the change in performance as a result of using electricity for heating, when compared to a conventional office building – in comparison to ECON 19, the building's performance now falls between 'good' and 'typical' practice.

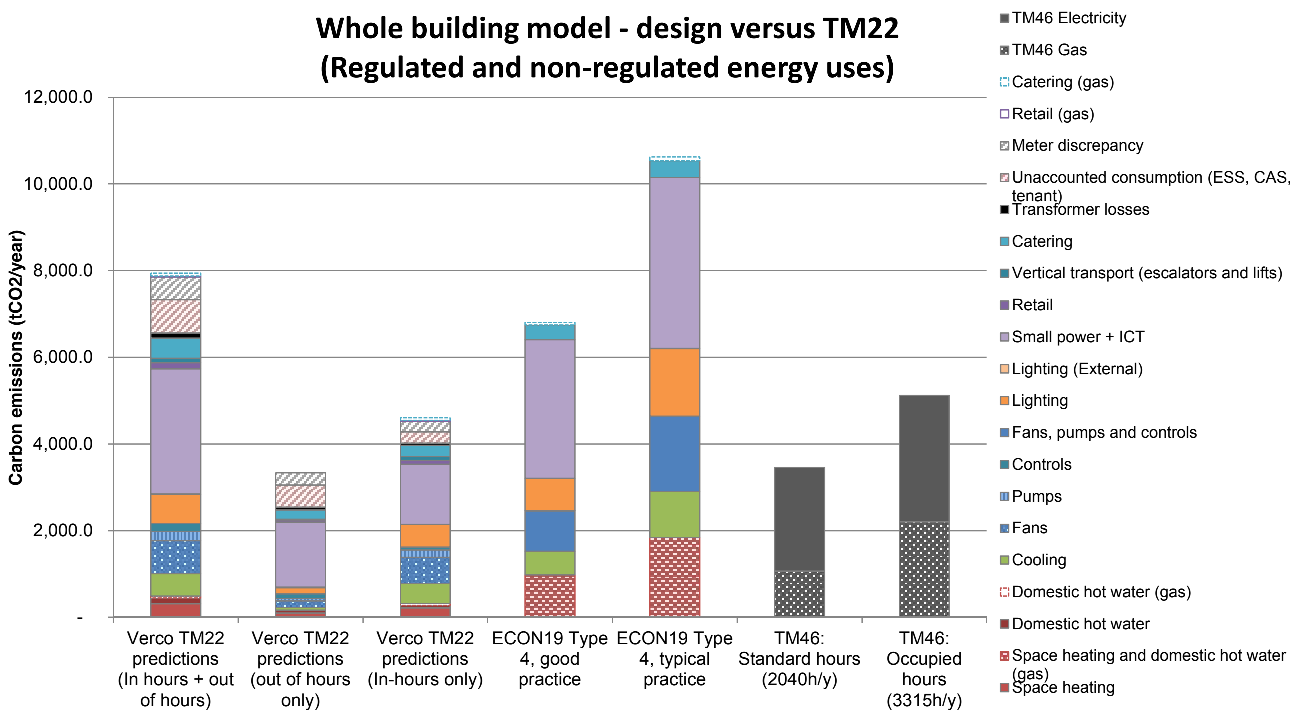


Figure 18 ECON19 versus TM22 predictions– breakdown by carbon emissions, regulated and non-regulated

Design predictions comparison

The graph below shows regulated energy uses, compared against design predictions:

- The standard occupancy profile compares reasonably favourably against the design predictions for total energy – although it should be noted that Part L analysis is not intended to 'predict' energy consumption, but is simply a compliance tool
- Cooling energy is higher than design predictions; heating energy is lower than predicted design predictions; this could be partially accounted for by the increase in heat gains from small power and ICT
- Lighting energy consumption is lower than design predictions, even under full occupancy conditions, and despite blinds being drawn a lot of the time – both MB and HGI have well controlled lighting systems
- Energy consumption from fans is higher than design predictions, even for standard occupancy, although this compares well with ECON19.

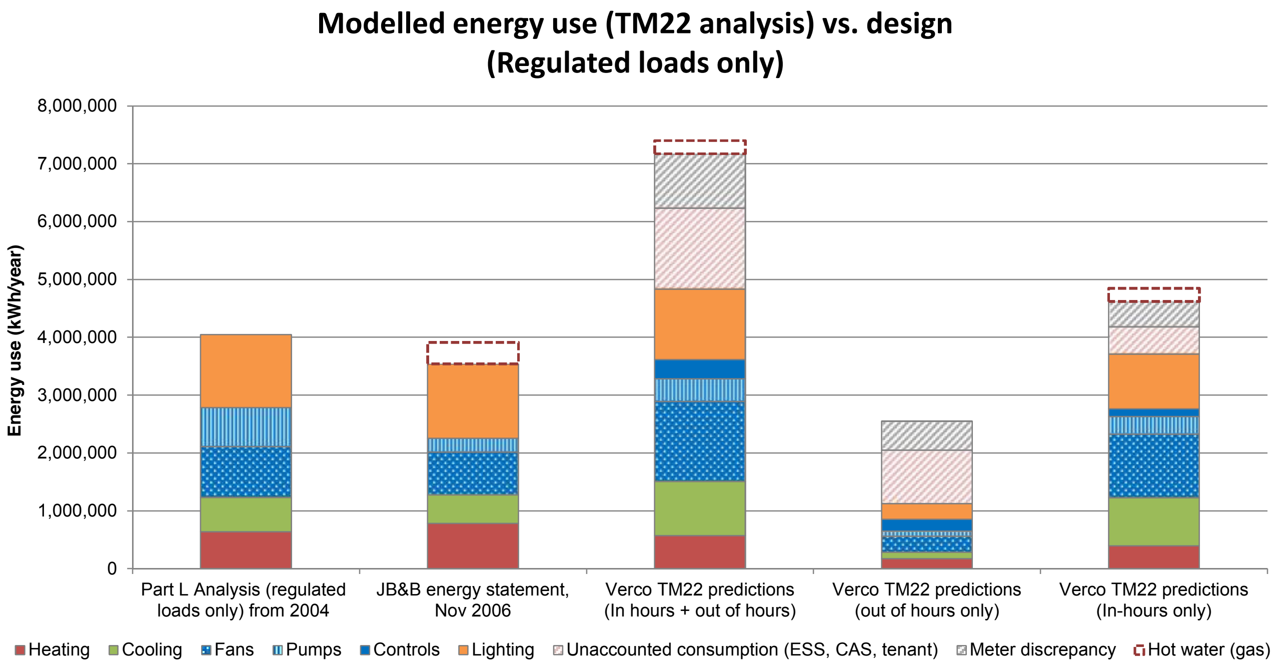


Figure 19 Design versus TM22 predictions– breakdown by energy uses, regulated only

6.7 Conclusions and key findings for this section

The following conclusions have been drawn on the building's energy performance:

- The building performs slightly better than ECON19 'good practice' – but these benchmarks were produced more than ten years ago

- Its performance is worse than the TM46 standard occupancy benchmark, but this may be partially due to the benchmark being based on naturally ventilated/mixed mode buildings and because of the extended hours of use
- Since the building has a BREEAM rating of 'Excellent', its energy consumption is considered high
- The building's higher energy consumption may be due to its extended operation and the need to operate all base build plant to meet the needs of any tenants requiring out of hours operation
- Another major contributing factor may be controls issues with the BMS in the building, resulting in inefficient and unnecessary operation of plant and equipment
- Building performance has remained relatively constant since 2009, but this does not take into account changes in occupancy levels
- When excluding electricity for heating, remaining total electricity consumption is higher than ECON19 'good practice' but slightly better than 'typical practice'
- Standard occupancy profile compares reasonably favourably against the design predictions for total energy – although it should be noted that Part L analysis is not intended to 'predict' energy consumption, but is simply a compliance tool
- The building's extended occupancy profile increases the total energy demand significantly – the out of hours energy consumption is around 45%, but a small proportion of this relates to equipment which requires a 24 hour operation, regardless of occupancy e.g. server room cooling
- Occupancy density has a significant impact on energy consumption.

For specific end uses, this analysis has shown that:

- Small power is a more significant component of energy consumption than benchmarks suggest, at around 50% of total building energy consumption, compared to around 35% in ECON19
- Cooling energy is higher than design predictions; heating energy is lower than predicted design predictions, and considerably lower than ECON19; this could be partially accounted for by the increase in heat gains from small power and ICT
- Lighting energy consumption is lower than design predictions and ECON19 'good practice', even under full occupancy conditions, and despite blinds being drawn a lot of the time – both level 4 and level 8 have well controlled lighting systems, although level 4 benefits from the ability to control on occupancy during core hours in its cellular offices
- There is a significant amount of sub-metered discrepancy (the difference between substation consumption and sum of sub-meters) – this is approximately 8% of the total electricity consumed. The reason for this discrepancy could not be determined; it could partly be down to erroneous meters – EP&T know that, for instance, the Mech 6 sub-meter was not showing accurate readings – and also faulty or missing meters - the CAS 2 sub-meter is missing from EDGE and therefore an approximation had to be made about the consumption
- There is a significant amount of unaccounted consumption (where known equipment on sub-meters cannot account for total energy consumption) – this is approximately 13% of total electricity; difficult to

model hours of use accurately with extended building occupancy . This is seen both in the basebuild model and the tenant models. In the tenant model, an unknown consumption is seen on the lighting and small power meters. In the basebuild model, it is seen on two landlord meters which are supplying essential services to the building; this is potentially due to equipment which is missing from the O&Ms and was not picked up in the site audit

- Fan energy is higher than design predictions, even under standard occupancy, but it still compares well with ECON19.

7 Technical Issues

Technology Strategy Board guidance on section requirements:	This section should review the underlying issues relating to the performance of the building and its systems. What are the technical issues that are leading to efficiency results achieved to date? Are the automated or manual controls effective, and do the users get the best from them? Are there design related technical issues which either need correcting/modifying or have been improved during the BPE process? Did the commissioning process actually setup the systems correctly and, if not, what is this leading to?

7.1 Sub-metering set up

As mentioned earlier in this report, the building's sub-metering was not fully operational until early 2012. Setting up the sub-metering proved to be considerably more complex than anticipated because the quality of O&M literature relating to how electrical systems serve equipment was not sufficiently detailed, and the physical labelling of equipment was not as clear as it should have been.

7.2 Chiller energy consumption

A pyranometer has been installed on the roof of the building. This is a Skye Instruments model SKL 2665 4-20mW. Quarter hourly solar irradiance data from the pyranometer is being recorded in the energy monitoring system, which is known as 'EDGE' and is maintained by British Land's metering and M&T contractors. Temperature data for the roof is also available. Together, the two variables enable a comparison to be made against chiller energy consumption, for which an initial assessment is shown in the graphs below.

This is indicated by the graph in which shows a wide range in daytime external temperature with a corresponding range in chiller energy consumption.

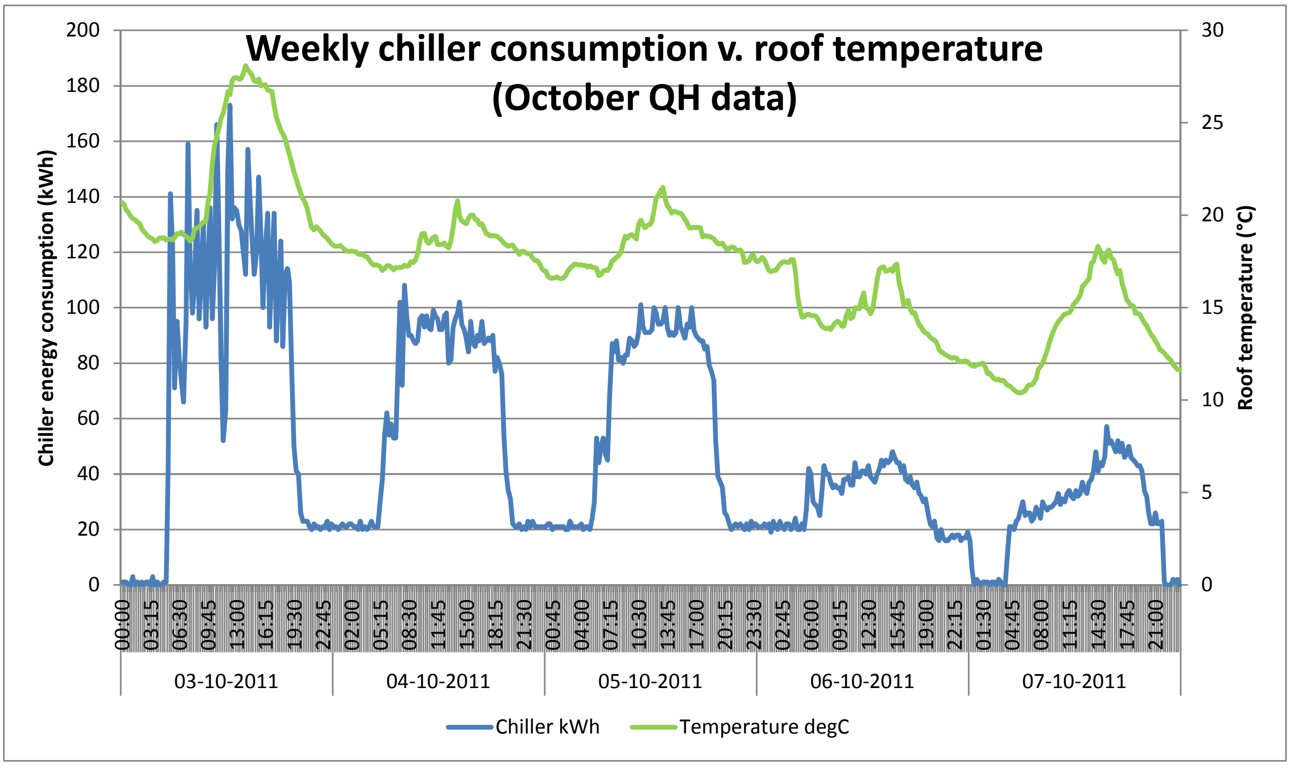


Figure 20 Comparison of chiller electricity consumption with roof temperature

However, the correlation between chiller energy consumption and solar irradiance is less strong, as demonstrated in the figure below.

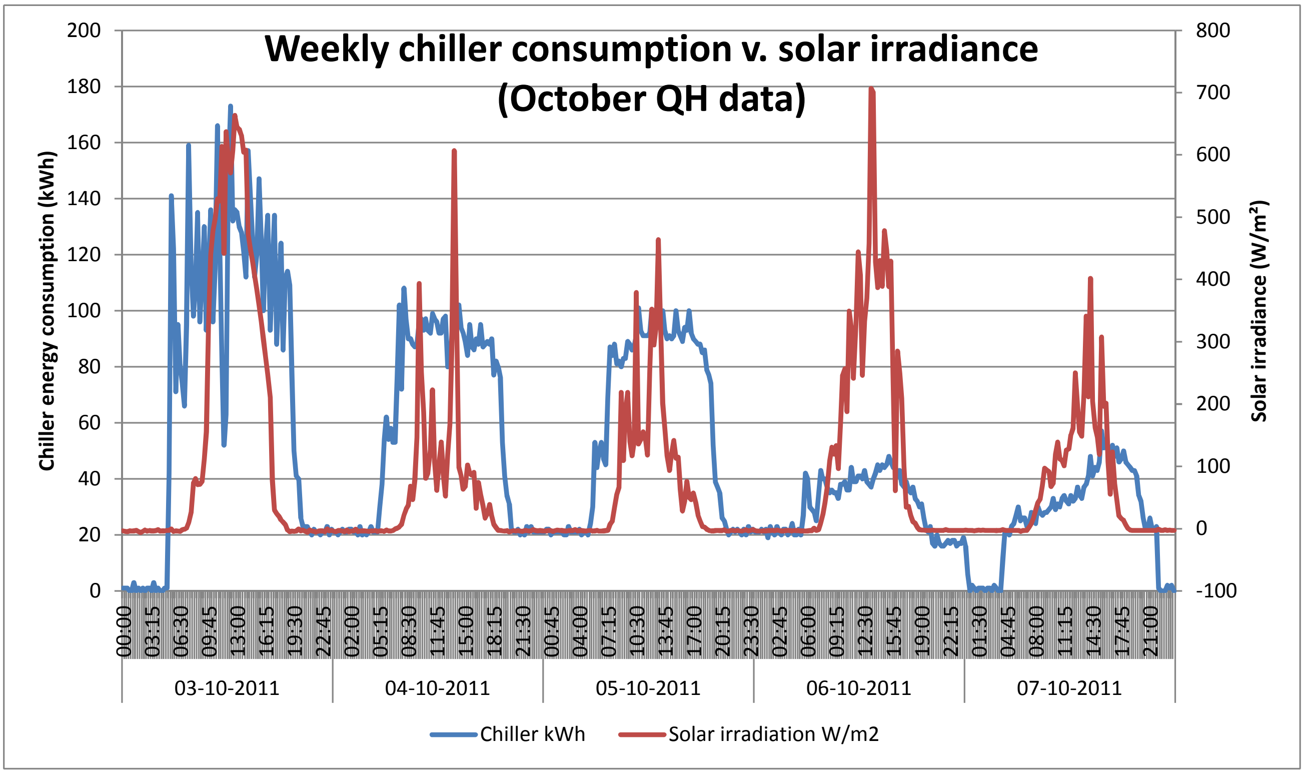


Figure 21 Comparison of chiller electricity consumption with solar irradiance

Interrogation of data over a longer period, April 2012-March 2013, has been carried out to determine whether these are accurate observations, and to understand the relationship between cooling demand, solar irradiance, and internal gains.

Figure 22**Error! Reference source not found.** below confirms that there is a strong correlation between external temperature and chiller electricity consumption, above an external temperature of around 12-13°C. This is reasonably consistent with the supply air temperature in the building, which is around 16° - there would typically be 1-2°C of temperature increase through the ventilation systems as a result of fans and/or duct heat pick up.

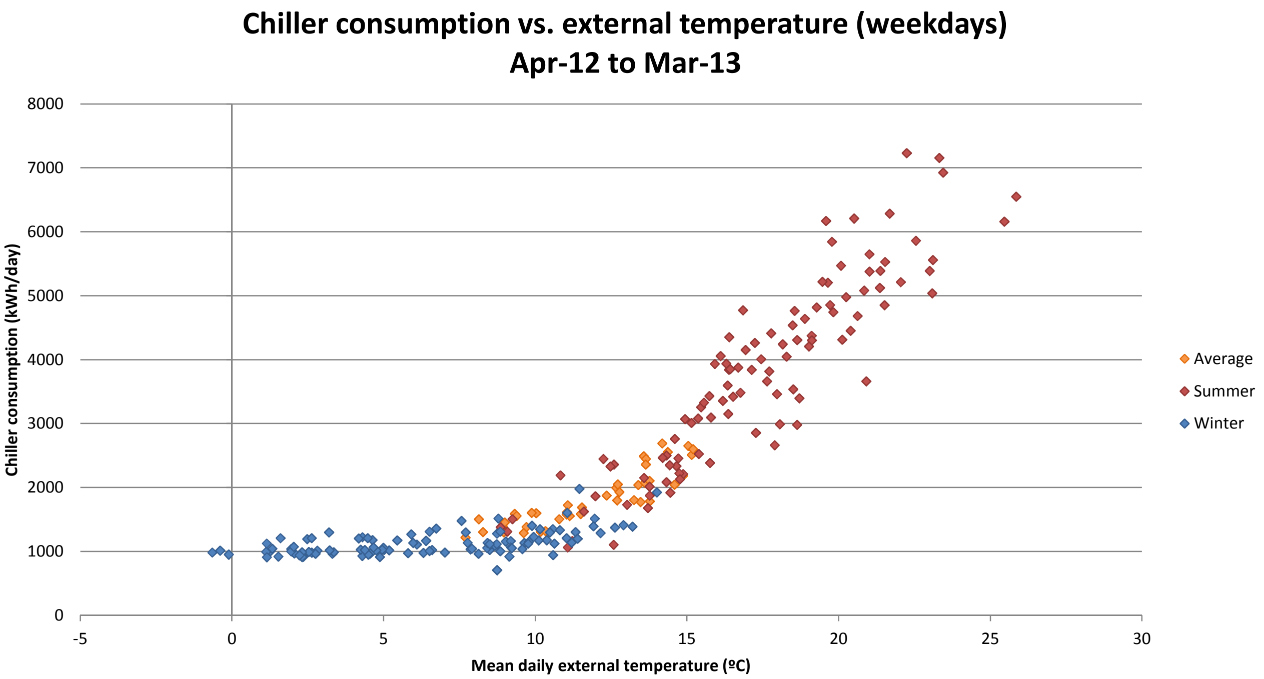


Figure 22 Chiller electricity consumption vs external temperature: April 2012-March 2013

The following graph shows that the correlation between chiller energy consumption and external temperature is considered strong (R^2 value of 0.9) i.e. the external temperature has a significant impact on chiller energy consumption.

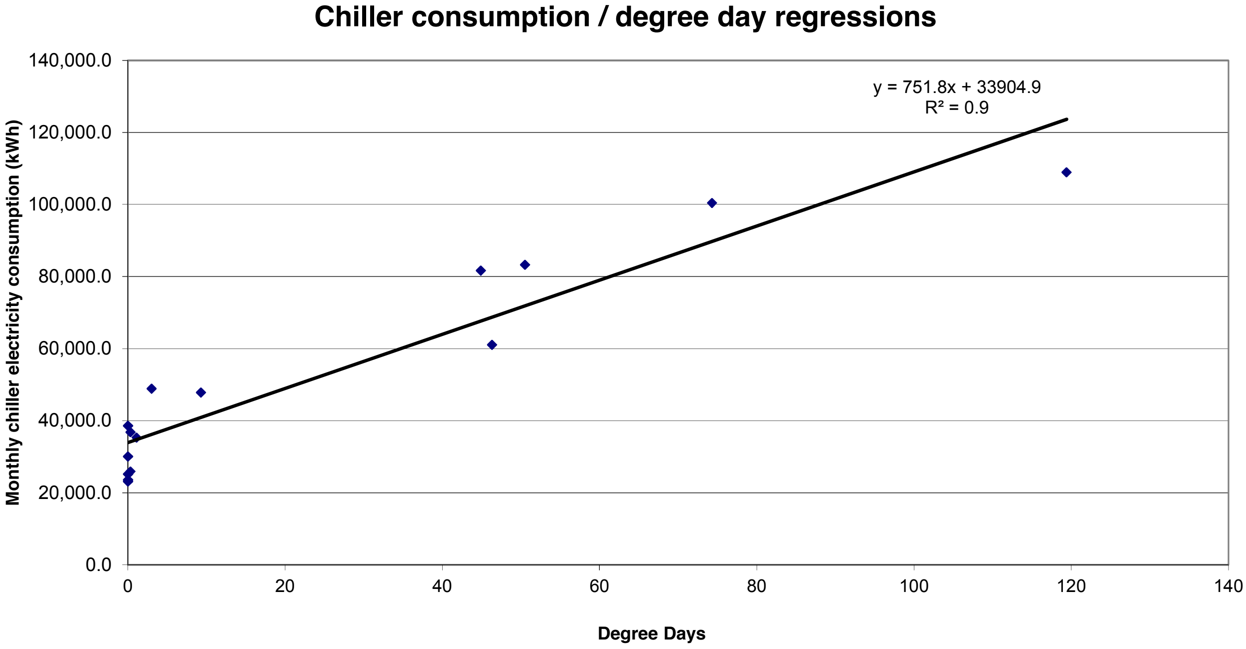


Figure 23 Relationship between chiller energy consumption and degree days

Figure 24**Error! Reference source not found.** shows chiller electricity consumption versus solar irradiance for varying cooling degree days, over the same 12 month period. This analysis reinforces the premise that there is a poor correlation between these two variables, and suggests that external temperature and internal gains must be the dominating factors in chiller electricity consumption. There does, however, appear to be a relatively clear energy baseload at around 1200kWh/day which is likely to be due to 24 hour cooling. This equates to approximately 312MWh/year, which is a significant number of operating hours, particularly during the winter.

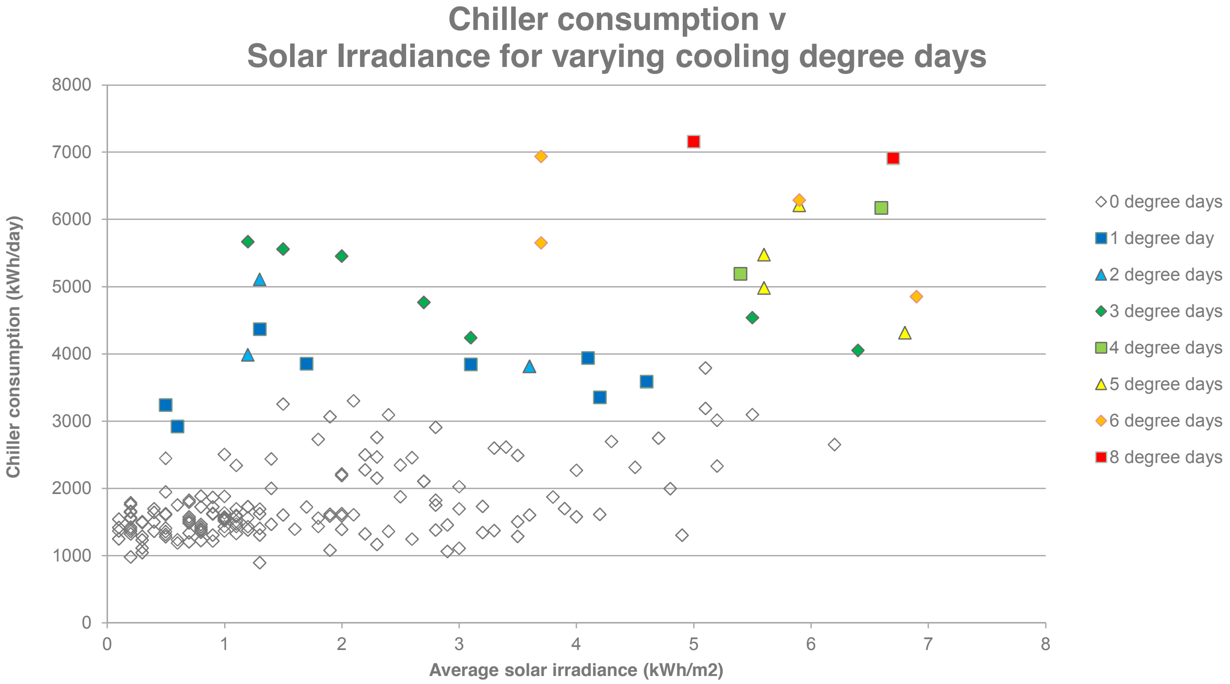


Figure 24 Chiller electricity consumption vs solar irradiance for varying cooling degree days: October 2011-June 2012 (weekdays only)

The figure below shows a bird's eye view of the building, showing how it is shaded by other buildings - the west façade is heavily shaded by Broadgate Tower, the south façade is well shaded at the lower levels, and the east façade is relatively un-shaded. In addition to the intensive usage of the building, with longer than typical occupancy and high internal loads from small power and IT, this may also suggest why solar irradiance has such limited influence on chiller energy consumption.

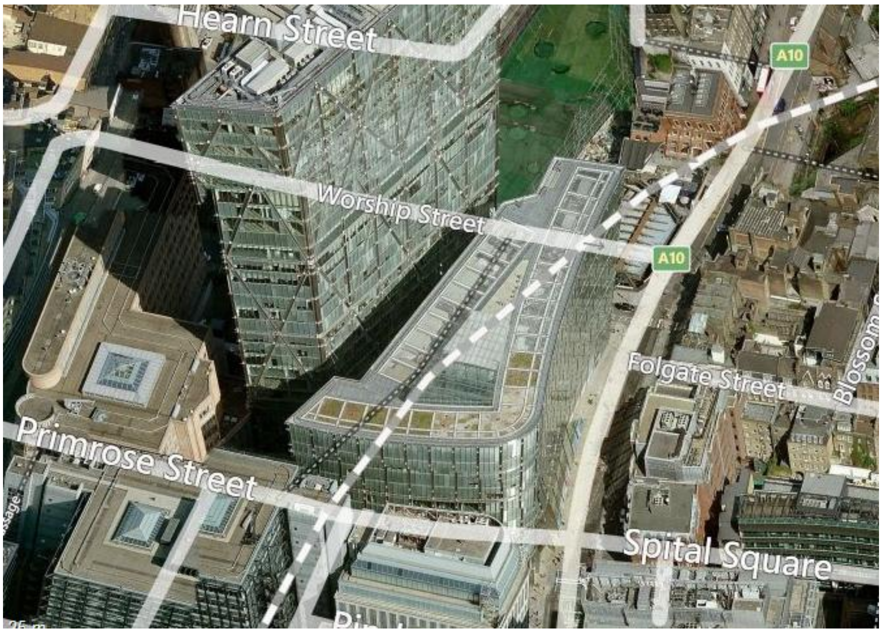


Figure 25 Bird's eye view of 201 Bishopsgate

Further investigation is required to understand the chiller's energy baseload and the impact of external conditions, both during the day to estimate internal gains and during the night to determine which plant or areas of the building are being served during these periods. It is intended that this will be examined through the follow on study.

7.3 Façade and thermal bridging review

Given the fact that the building is highly glazed (see the figure below) - steel framed with an aluminium curtain walling system – the facade is a specific area of interest for this project. Our TM22 analysis suggests that cooling energy is around 100% higher than predicted in the design calculations. During the early stages of this project, it was identified that the building tenants had previously mentioned that there were problems with the solar shading within the building and comfort issues, suggesting the installed blinds are difficult to operate and therefore are often not used, which could also have a detrimental effect on cooling loads. However, it is now known that both glare from the façade and temperature variation, also likely to be a result of radiant effects from the facade are significant issues in the building, as indicated by the feedback in the occupant survey from level 8 occupants.

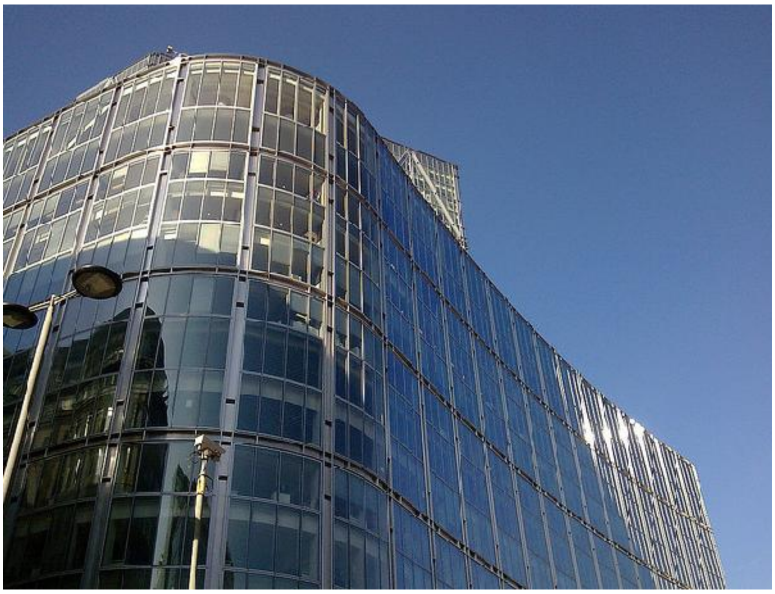


Figure 26 201 Bishopsgate's heavily glazed façade

Gifford M&E engineers were commissioned by British Land in 2010 to investigate the façade's performance following comments from tenants that the glazing system made the working environment uncomfortable at certain times. Specifically, the areas of concern were glare on computer monitors and temperature fluctuations. Gifford's study produced three reports:

- Solar gain study – to assess the performance of the installed glazing system to ensure compliance with the original system
- Glare study – to assess the performance of the installed venetian blinds and comment on the glare issues
- Thermal bridge study – to assess the performance of the installed glazing system using thermal analysis and to compare with the original specification

Measurements were taken of light levels, solar gain and temperatures at three locations on the east side of the building, on the unoccupied 6th floor. Readings were taken on 9th August and 1st September 2010, with reports issued in September 2010.

Solar gain

This report identified that there was very little difference in the glazing g-value compared with design data sheets. The manufacturer's data sheet gave a design g-value of 0.378, whilst the effective measured g value was 0.335 on average, approximately 11% lower. This means that the glazing appears to perform slightly better than expected, transmitting around 11% less solar gain than designed for. However, it is likely that the difference in g-values is attributable to potential inaccuracies associated with the measurement of the solar gain (accuracy of the solar meters, positioning of the sun relative to the solar meters, etc).

The report identifies further areas for investigation to address the overheating issue:

- Investigate whether the overheating issue is affecting only those in perimeter zone of the floor
- Determine whether there is sufficient mechanical ventilation/cooling to offset the solar gain
- Determine whether the periods of cooling coincide with the working hours of the tenants (some occupiers work outside standard office hours)
- Investigate whether some perimeter vents have been disabled due to drafts, and whether this has contributed to the solar gain issue
- Determine whether the heat loads in the space (occupants, computers, etc) are in line with the design brief

It is not clear from the information available whether this further investigation has been carried out. However, of all the above issues, the only one that could directly impact on cooling loads is the final issue.

Thermal bridging

Computational thermal analysis was carried out to determine whether the internal mullions (shown in the following figure) should be 'hot' to the touch as tenants had reported that this issue during the summer months. The frames are aluminium with thermal breaks.

The analysis only considered heat transfer, with an assumption that the external surface temperature could reach 50°C when in direct sunlight. In this situation, the internal surface could reach up to 36°C.

In addition, an IES model was developed to look at the surface temperature increase due to solar gain throughout the year - this showed a peak temperature of 37°C.

Hence it was determined that it is likely that surfaces will feel warm, specifically mullions, and metal blinds when lowered, despite the fact that the frames are thermally broken.

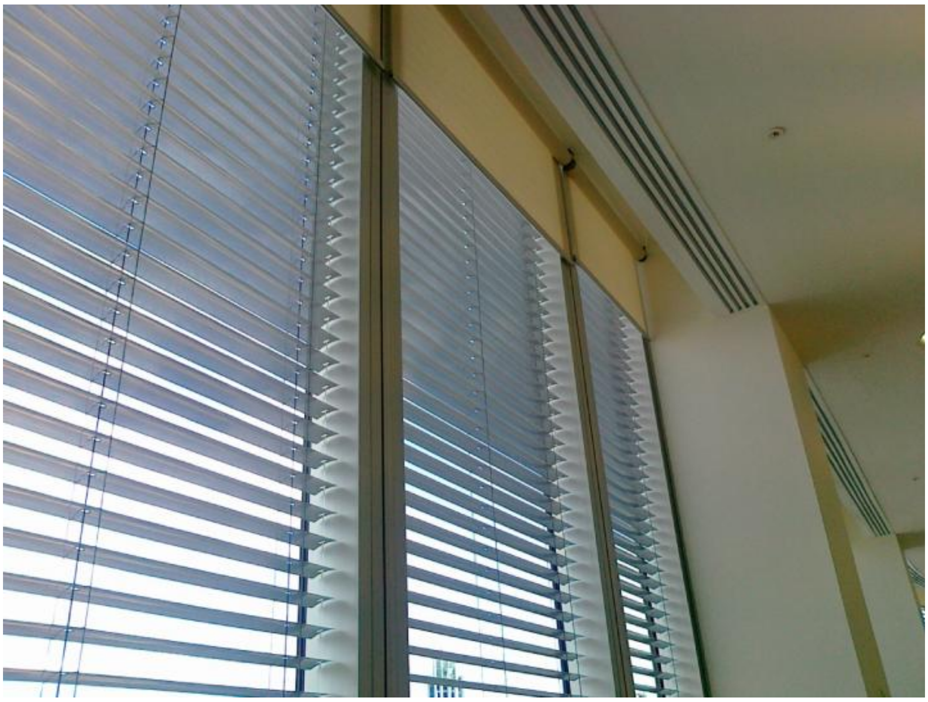


Figure 27 internal view of façade showing mullions and blinds

U values

The study also assessed the U-values for the windows and identified that the average system U-value for the windows and frames was 1.61 W/m2K. In the original Part L calculations, a glazing U-value of 1.8 W/m2K was assumed. On this basis, the expected heat loss for the building should be around 10% lower than the Part L model predicts. However, initial TM22 results indicate that the heating energy consumed is comparable with the Part L prediction, suggesting that there are other factors at play, such as an extended heating period or higher temperatures being maintained in the space during the heating season.

Glare

This study assessed the lux levels in the office space with and without blinds. The blinds used are perforated, aluminium with a metallic finish, and have a small gap between the side face of the mullion and the slats. The slats are 80mm wide with 1.1mm diameter perforations at 3.5mm spacings.

Based on lux levels measured at a range of locations in the office space and corresponding readings taken on the roof, the study determined that the blinds reduce light transmittance by 85-90%.

However, it has been identified that light passing through perforations in the blinds, gaps around the edges of blinds and from small holes within the blinds is not reduced. The resulting contrast in light levels is exacerbating the glare issues.

The study appears to identify that the blinds are used, but this is not quantified. These are non-perforated, light-coloured roller blinds and can be seen in Figure 9 above.

Further general observations from the study include:

- The aluminium blinds with metallic silver finish heat up, causing discomfort for those sitting close by

- Some vents near windows have been covered or blocked after complaints of draughts, which is believed to be contributing to overheating in these areas.

It should be noted that, since this study was carried out, secondary blinds have been installed in some areas of the building which may help to alleviate some of the glare and localised solar heat gain issues in the building.

Conclusions

The studies carried out by Gifford seem to corroborate the predictions of performance carried out at design stage. The issue of blinds often not being used does not appear to be an issue in terms of increasing cooling loads as the study has identified that they are used, although it does not identify how often. The problem associated with glare appears to lie with the extent of the perforation of the blinds and the resulting light transmittance, which is resulting in glare in the space. Feedback from the HGI FM team have stated that the blinds are in fact used extensively because of problems experienced with glare and, furthermore, they are currently trialling a number of different blinds to potentially replace the existing ones.

There are also some other issues which have been identified for further investigation in relation to the overheating problem. It is not yet clear whether these have been resolved, but the majority of these issues are unlikely to result in an increase in cooling demand. Nevertheless it was felt necessary to install further set of internal blinds.

7.4 Conclusions and key findings for this section

The following conclusions can be drawn:

- Glare and temperature stability are the biggest issues in the building from an occupant's perspective. The occupant survey has identified that these issues have not been overcome yet.

- There is a significant cooling energy baseload throughout the year. However, external temperature and internal gains appear to be the dominating factors in chiller electricity consumption. Solar gain may have less of an influence because the west façade is heavily shaded, and the south façade is well shaded at the lower levels.

- The chiller baseload is approximately 312MWh/yr, which indicates that there are significant operating hours and winter operation and the potential for some optimisation of fresh air supply and tenant FCU setpoints – this is an area which British Land and Broadgate Estates intend to explore further.

8 Key messages for the client, owner and occupier

Technology Strategy Board guidance on section requirements:	This section should investigate the main findings and draw out the key messages for communication to the client/developer, the building owner, the operator and the occupier. There may also be messages for designers and supply chain members to improve their future approaches to this kind of building. Drawing from the findings of the rest of the report, specifically required are: a summary of points raised in discussion with team members; recommendations for improving performance, with expected results or actual results where these have already been implemented; a summary of lessons learned: things to do, things to avoid, and things requiring further attention; a summary of comments made in discussions and what these could be indicating. Try to use layman's terms where possible so that the messages are understood correctly and so more likely to be acted upon.

8.1 Building owner

Building performance

- The building performs well overall in terms of occupant satisfaction, but for a building with a BREEAM rating of Excellent, its energy consumption is considered high
- Substantial energy efficiency improvements have been made already but there is scope for further improvement
- The building's higher energy consumption may be due to its extended operation and the need to operate all base build plant to meet the needs of any tenants requiring out of hours operation
- Another major contributing factor is likely to be controls issues with the BMS in the building, resulting in inefficient and unnecessary operation of plant and equipment
- Occupant satisfaction would be raised from the level of 'very good' to 'excellent' if there were no perceived issues with the façade

Monitoring and targeting energy consumption

- Implementation of monitoring and targeting performance contract at an early stage of the building's life delivered guaranteed savings; this ensured an ongoing responsibility for maintaining sub-metering and regularly reviewing the data and making operational changes as necessary - this is a critical part of monitoring and targeting; there has been a pro-active approach to energy management from both the M&T contractors and the building facilities management team
- Detailed sub-metering is easily accessible online

Tenant engagement

- There has been good tenant engagement with respect to wider sustainability issues, and this has included energy management e.g. quarterly Environmental Working Group meetings held with the building operator and representatives from each of the occupiers

BMS optimisation

- BMS optimisation is key to achieving substantial energy savings in new buildings - as demonstrated by EP&T's opportunities identification e.g. plant operating times, the interaction between landlord and tenant BMS

Key lessons learned include:

Glare and comfort issues arising from the fully glazed façade

- The extensively glazed façade has had less of an impact on cooling energy consumption than expected; however, temperature stability has been identified as an area of occupant dissatisfaction and therefore careful design of the façade in fully glazed buildings is required to minimise solar gains and glare

Sub-metering

- Sub-metering is critical to understanding and optimising building operation – this is particularly important for fine-tuning new buildings
- It is essential that there is sufficient sub-metering, installed in the right locations in the system, and that is operational before handover of the building
- Inadequate sub-metering in this building has resulted in the gas consumption not being fully understood for some time
- Faulty sub-metering has also resulted in data gaps; these data gaps are due to loss of communication with meter that doesn't have redundant memory. These gaps can be fixed if but this would come at an additional cost to the landlord, so is it only done if necessary.

Operation and maintenance information

- For more complex buildings, accurate O&M information and adequate labelling of equipment and services is particularly critical; this needs to be kept updated as changes to the building are inevitably made

Setting energy reduction targets

- The M&T contractors were very engaged and met the energy saving target relatively early on in their appointment; for other buildings, the setting of a higher target should be considered

8.2 Building operator

The building management team has taken a proactive approach to energy management, as described earlier in this section of the report. Suggested areas for further investigation include:

- Identify the unmetered consumption in the building, and try to understand the unknown energy consumption

- The chiller baseload has scope for reduction: investigate the chiller operating hours and fresh air supply temperatures, particularly in winter operation; establish whether there is scope to serve continuous tenant cooling demands from separate chillers rather than the main landlord chillers

8.3 Occupiers

Key messages for occupiers are:

- Small power and ICT represents a significant energy saving opportunity
- When considering the need for out of hours plant requests, the additional energy consumption should be taken into account
- The unknown energy consumption on level 8 should be further investigated

8.4 Designers

Servicing strategy

- The building has a relatively straightforward HVAC servicing strategy – for large office buildings such as this, the simpler the strategy, the greater the chance the building has of operating as designed
- Despite the benefits that simpler building servicing solutions bring, as well as probable space efficiencies, there is also an energy penalty for having a single HVAC system serving multiple occupiers, resulting in a reduced operational efficiency and extensive out of hours operation
- A significant amount of energy was consumed unnecessarily through problems with the interaction between the tenant and landlord BMS; the automated system has been replaced by a system of manually adjusting timeclocks, where there is a risk that settings may not be returned to their original values
- Metering systems should be carefully designed to make the post-construction monitoring of energy as simple as possible

Glare and solar gains from the façade

- As a fully glazed building, façade design has impacted on occupant satisfaction, resulting in complaints of glare and temperature stability – this needs to be taken into account during the design process, even on east façades; simply sizing plant to accommodate increased solar gains
- According to the analysis carried out post-occupancy by the building owner's engineers, the façade performs as designed, and therefore the building form design should perhaps have addressed such issues e.g. less glazing or a double skin façade.
- The choice of blinds is important in ensuring that they are effective at reducing glare and solar gain

8.5 Points raised in discussion with team members

Below is a summary of the key points which have been raised in discussion with the client and facilities management team:

- The building performs well in terms of overall occupant satisfaction but energy consumption indicates further room for improvement
- BMS optimisation is key to achieving substantial energy savings in new buildings - as demonstrated by EP&T's opportunities identification e.g. plant operating times, interaction between landlord and tenant BMS
- Getting energy metering fully operational has taken time but has been crucial to understanding energy consumption
- Out of hours energy consumption is significant proportion of the total – this has increased actual energy consumed well beyond design predictions
- As a fully glazed building, façade design has impacted on occupant satisfaction – and has resulted in glare and temperature stability
- The façade has had less of an impact on cooling energy than expected
- Identification of unmetered energy consumption may help to reduce energy consumption further
- Electricity for small power and ICT is much more significant than predicted
- ICT and small power represents a significant energy saving opportunity for tenants

9 Wider lessons

TSB Guidance on Section Requirements:	This section should summarise the wider lessons for the industry, clients/developers, building operators/managers and the supply chain. These lessons need to be disseminated through trade bodies, professional Institutions, representation on standards bodies, best practice clubs etc. As well as recommendations on what should be done, this section should also reveal what not to do on similar projects. As far as possible these lessons should be put in layman's terms to ensure effective communication with a broad industry audience.

Wider lessons for the industry should include:

- The time and complexity of setting up adequate sub-metering, which should be operational once the building is completed, must be taken into account during the construction process and the design of these systems is critical
- Fully glazed façades produce attractive buildings which appeal to the prospective tenants, but may result in comfort issues which are difficult to resolve
- There is an energy penalty for having single system serving multiple occupiers, with a significant increase in out of hours operation
- Occupant density is a major influence on energy consumption
- Careful design of the façade in fully glazed buildings is required to minimise solar gains and glare – compliance with minimum standards won't necessarily achieve this
- A structure for ensuring ongoing monitoring and targeting is recommended
- Small power use is typically underestimated in standard design stage assessments

10 Appendices

Technology Strategy Board guidance on section requirements:	The appendices are likely to include the following documents as a minimum: • Energy consumption data and analysis (including demand profiles) • Monitoring data e.g. temperatures, CO2 levels, humidity etc. (probably in graph form) • TM22 Design Assessment output summaries • A DEC – where available • Air conditioning inspection report – where available • TM22 In-Use Assessment output summaries • BUS Occupant survey – topline summary results • Additional photographs, drawings, and relevant schematics • Background relevant papers

10.1 Tenant energy end use breakdown

The graphs below show that there is no difference in summer, around 5% difference in spring/autumn, and around 10% difference in winter.

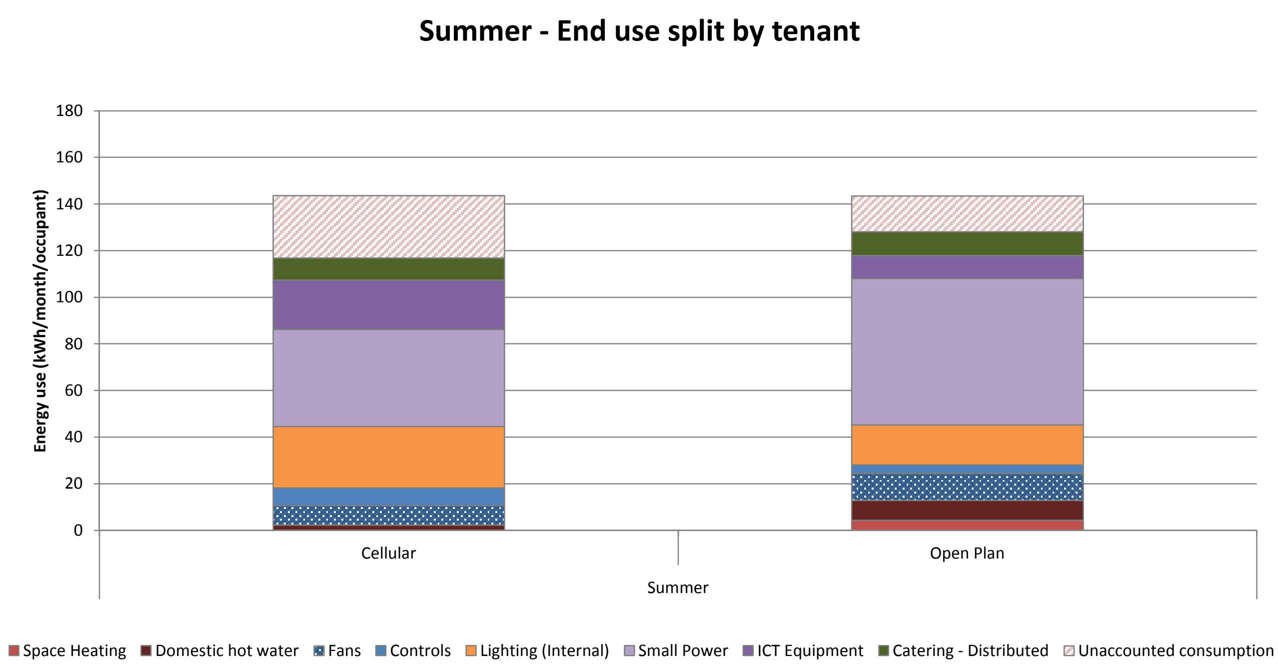


Figure 28 Tenant energy consumption for each occupant type, normalised for occupancy - summer

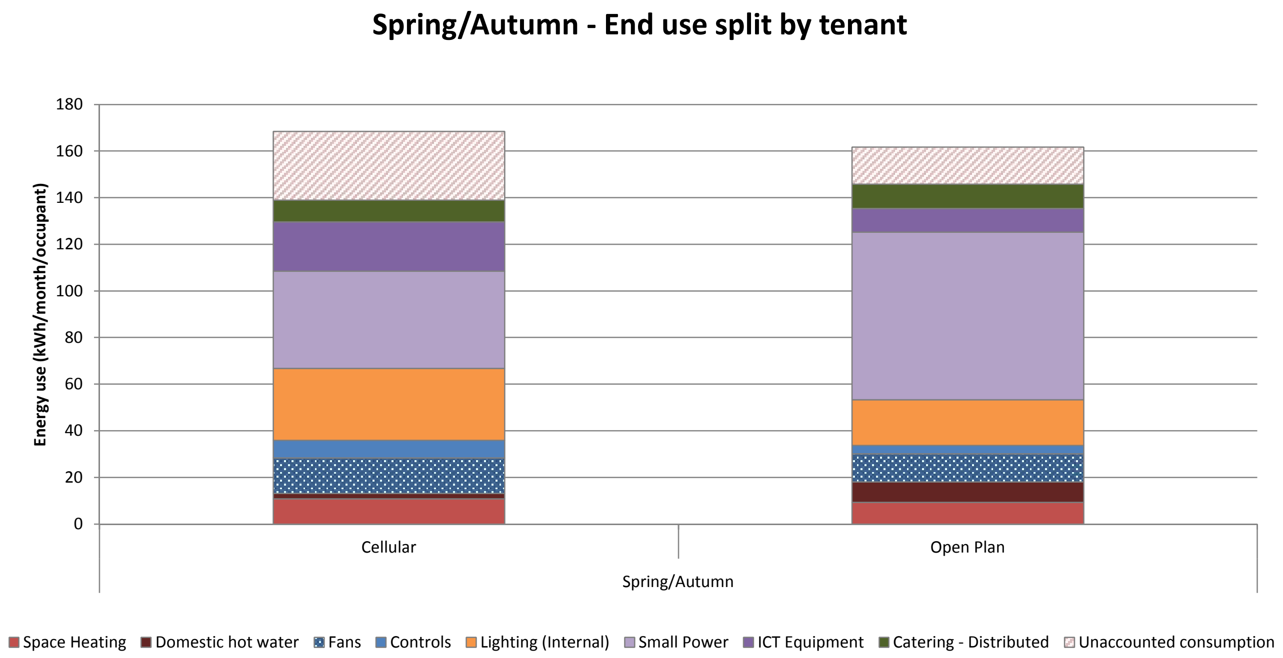


Figure 29 Tenant energy consumption for each occupant type, normalised for occupancy – spring/autumn

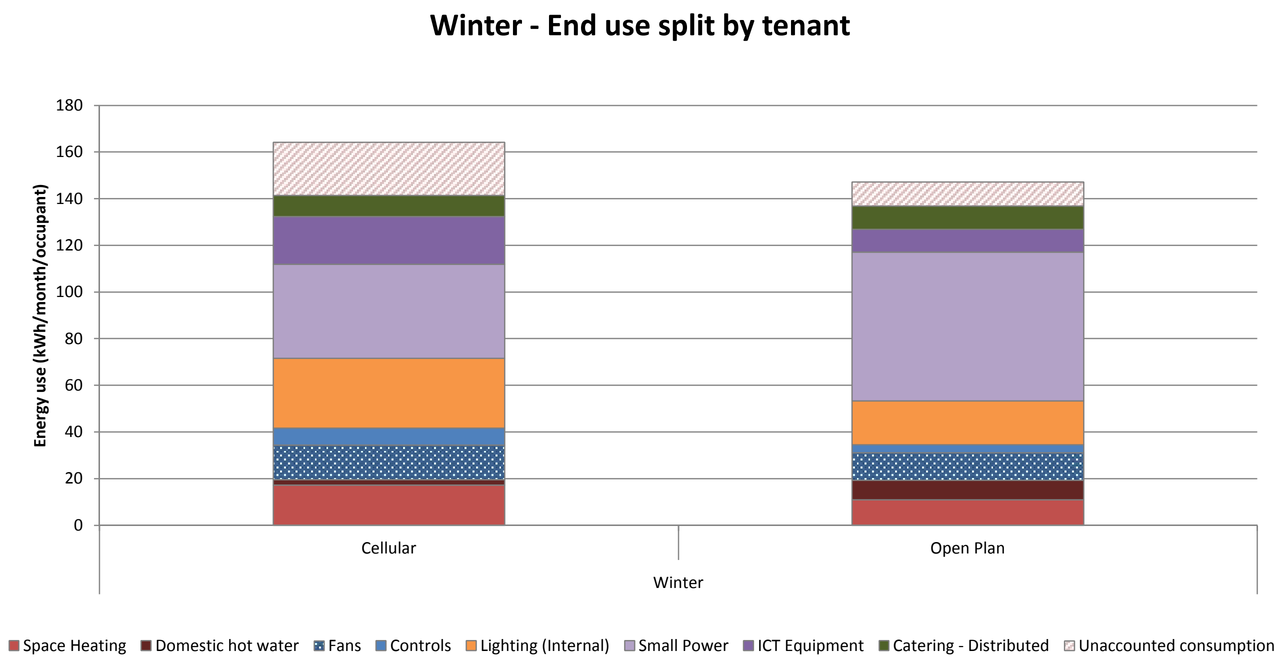
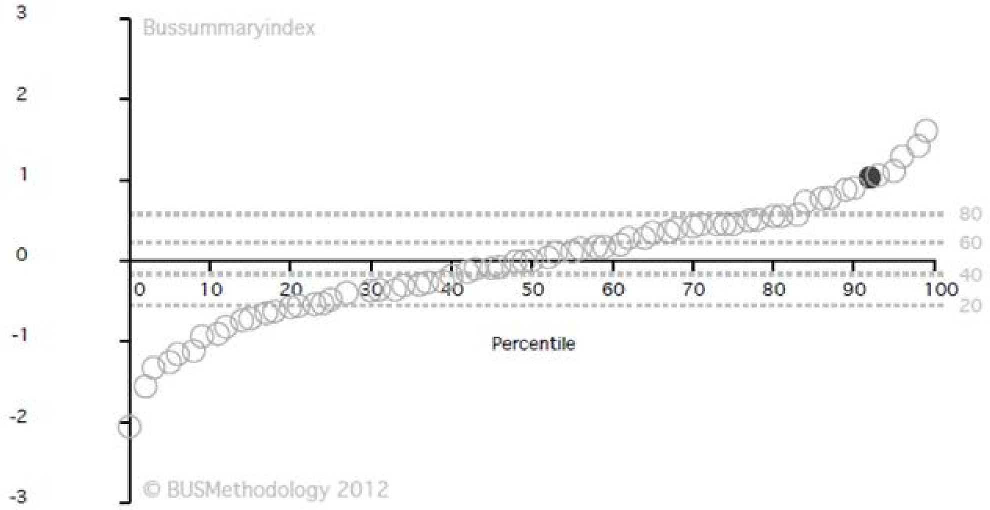


Figure 30 Tenant energy consumption for each occupant type, normalised for occupancy – winter

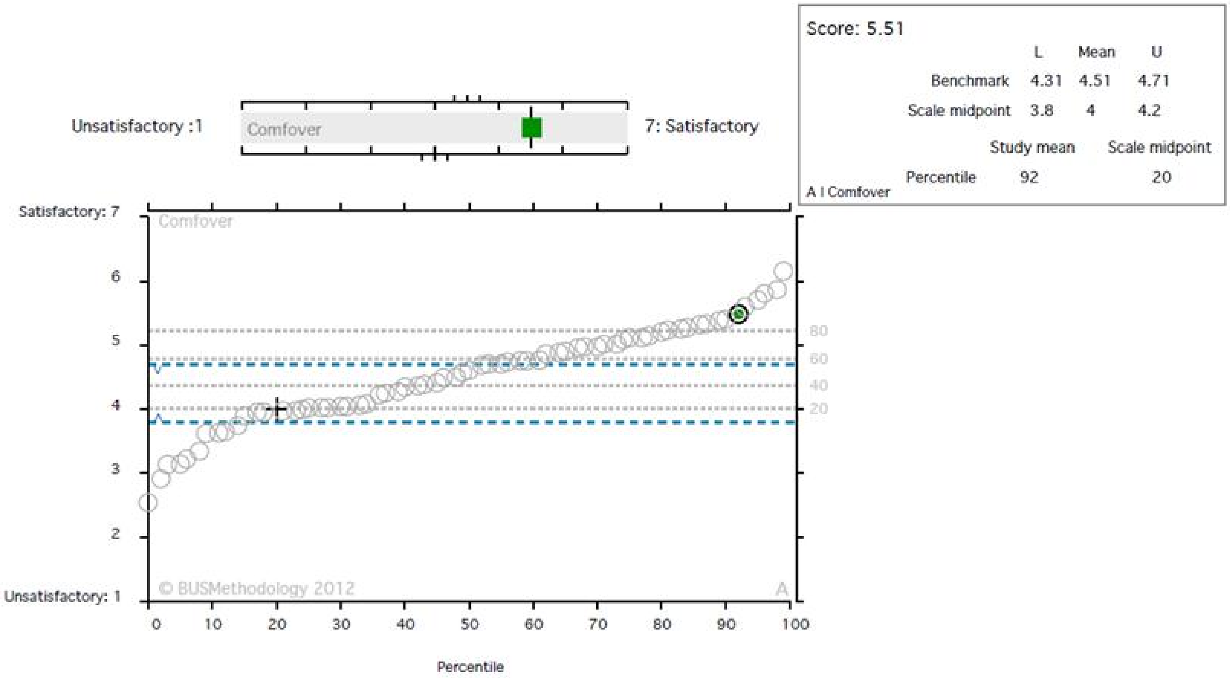
10.2 BUS occupant survey

How did the building perform overall?

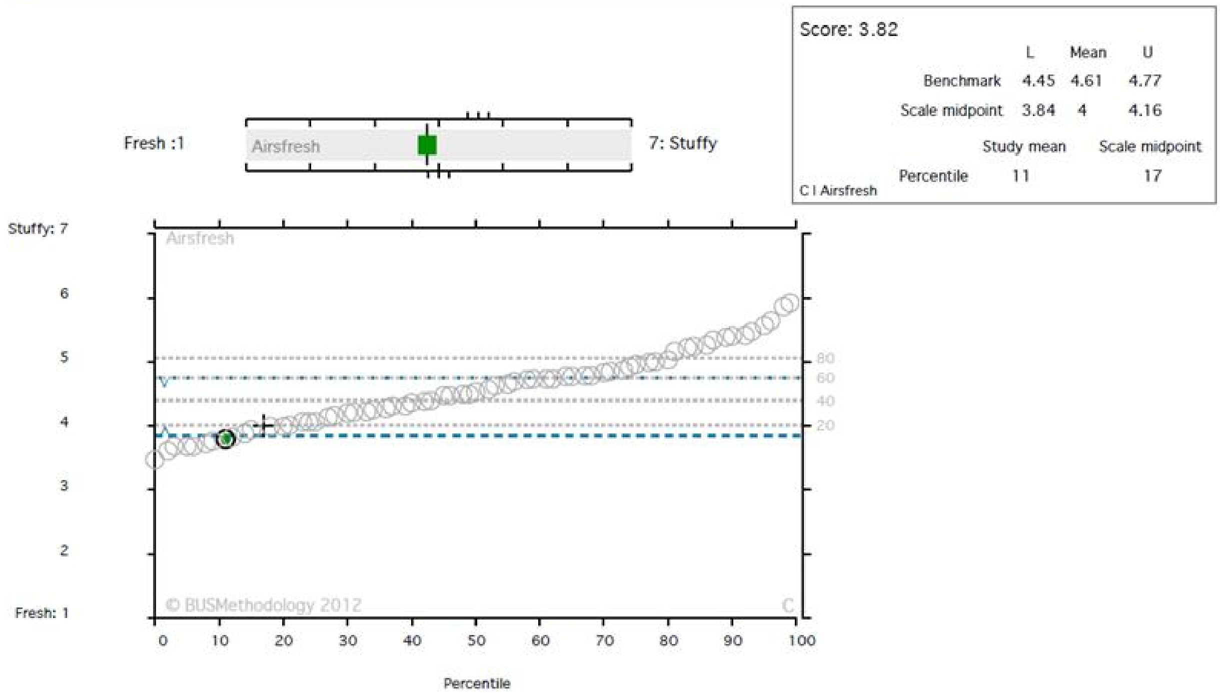
- Very well!
- Overall comfort and satisfaction with building is excellent
- Summary index: mean of comfort and satisfaction indexes – ~90th percentile



Comfort: overall



Air in summer: fresh/stuffy



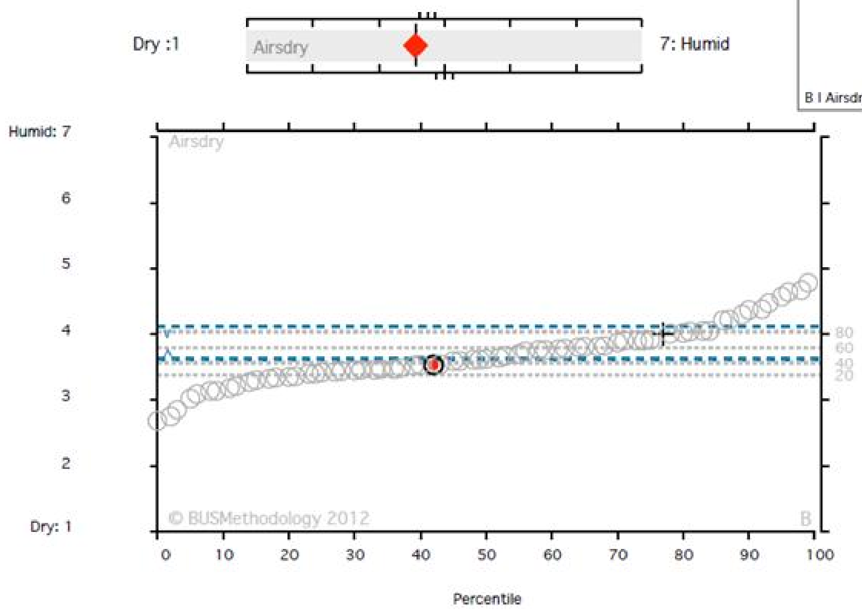
Air in summer: dry/humid

Score: 3.56

	L	Mean	U
Benchmark	3.62	3.74	3.86
Scale midpoint	3.88	4	4.12

	Study mean	Scale midpoint
Percentile	42	77

B I Airsdry



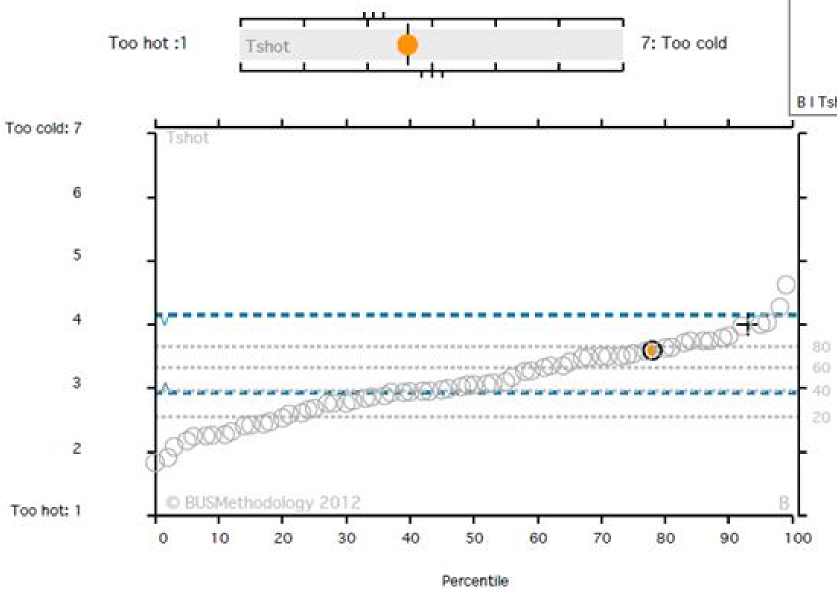
Temperature in summer: hot/cold

Score: 3.62

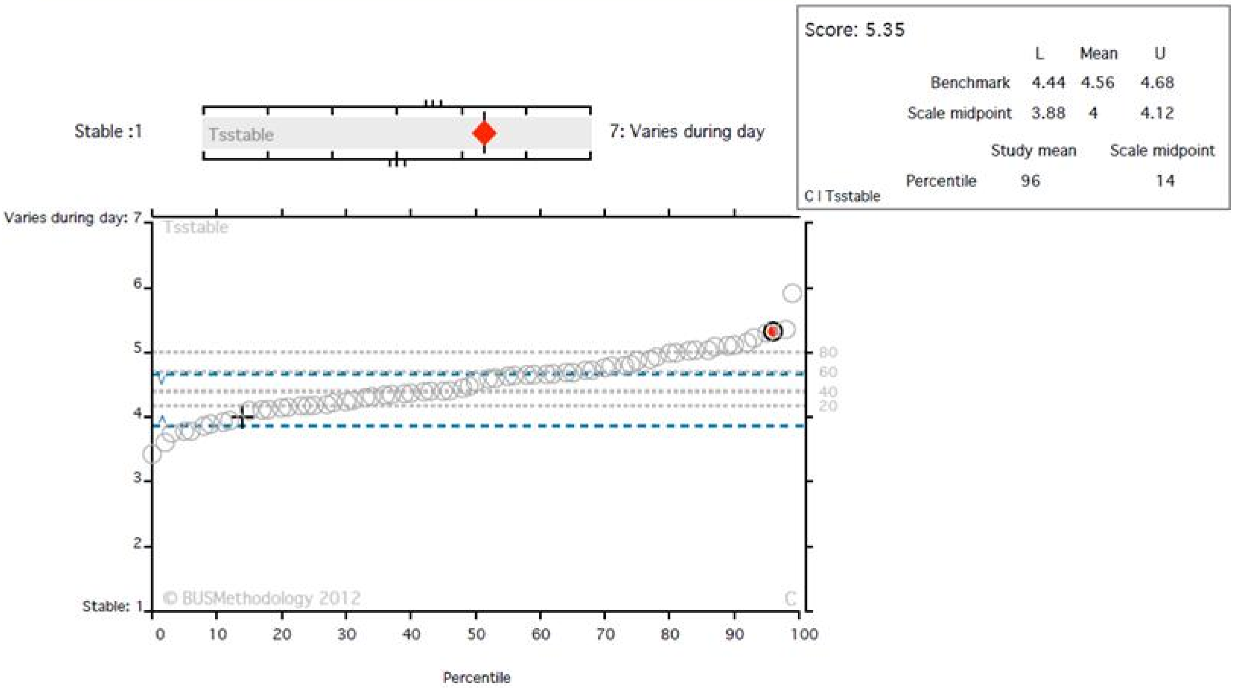
	L	Mean	U
Benchmark	2.93	3.09	3.25
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	78	93

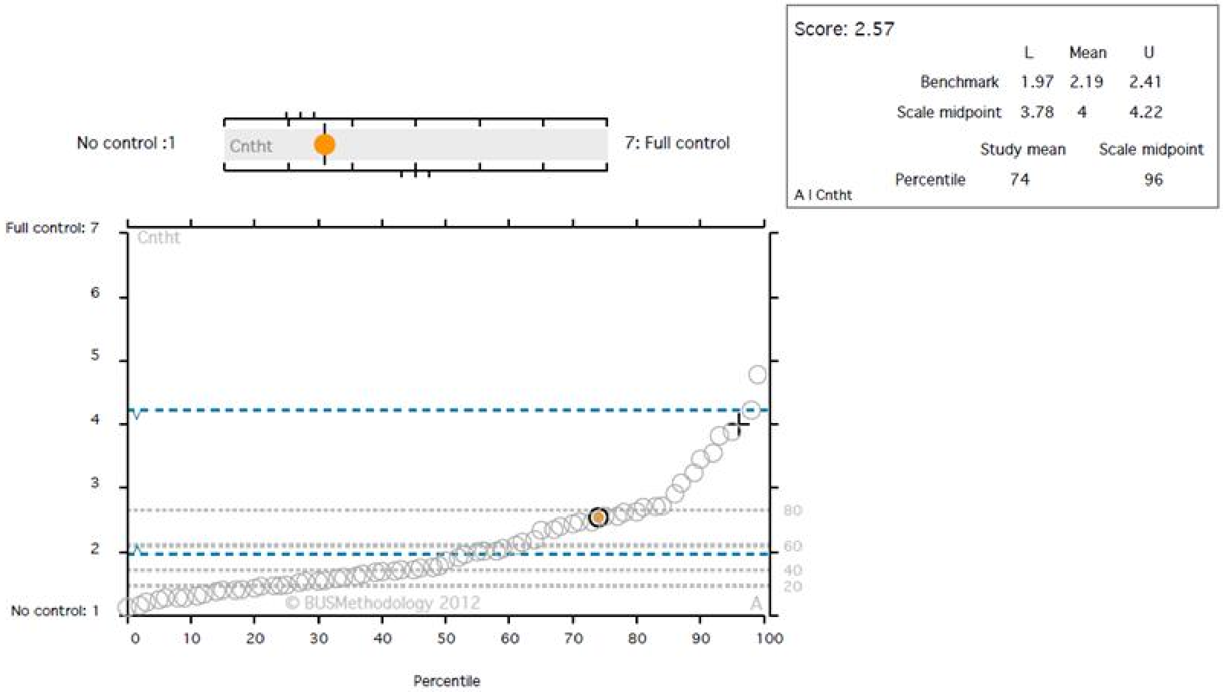
B I Tshot



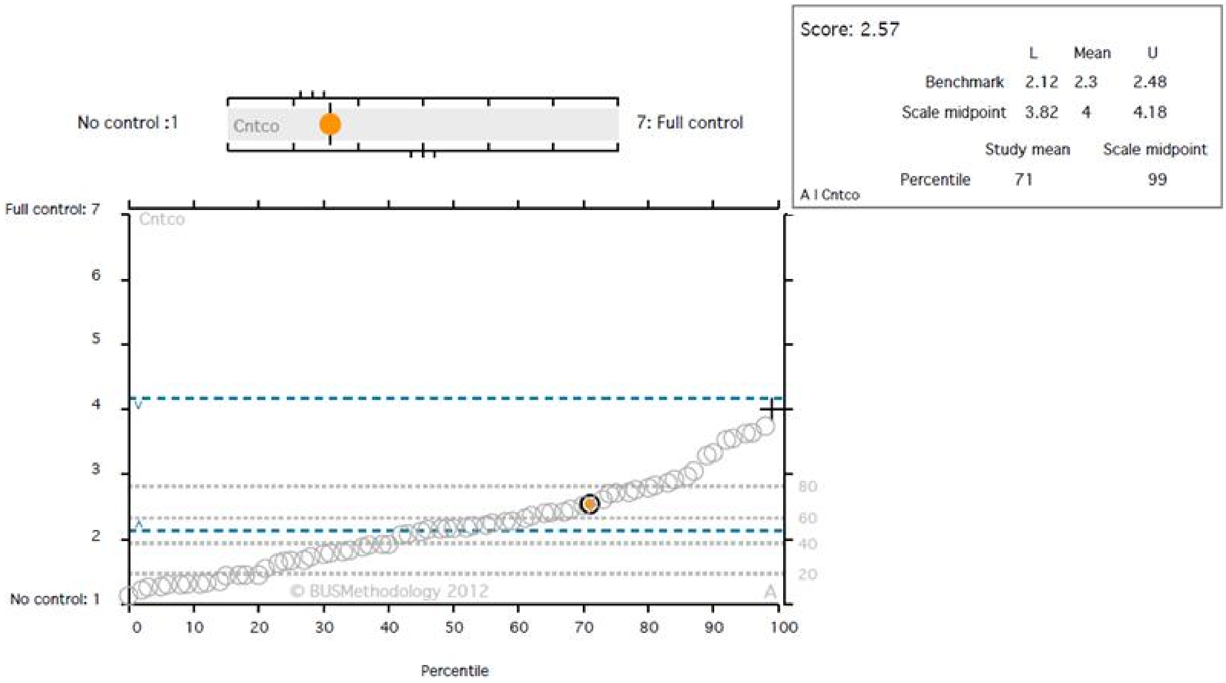
Temperature in summer: stable/varies



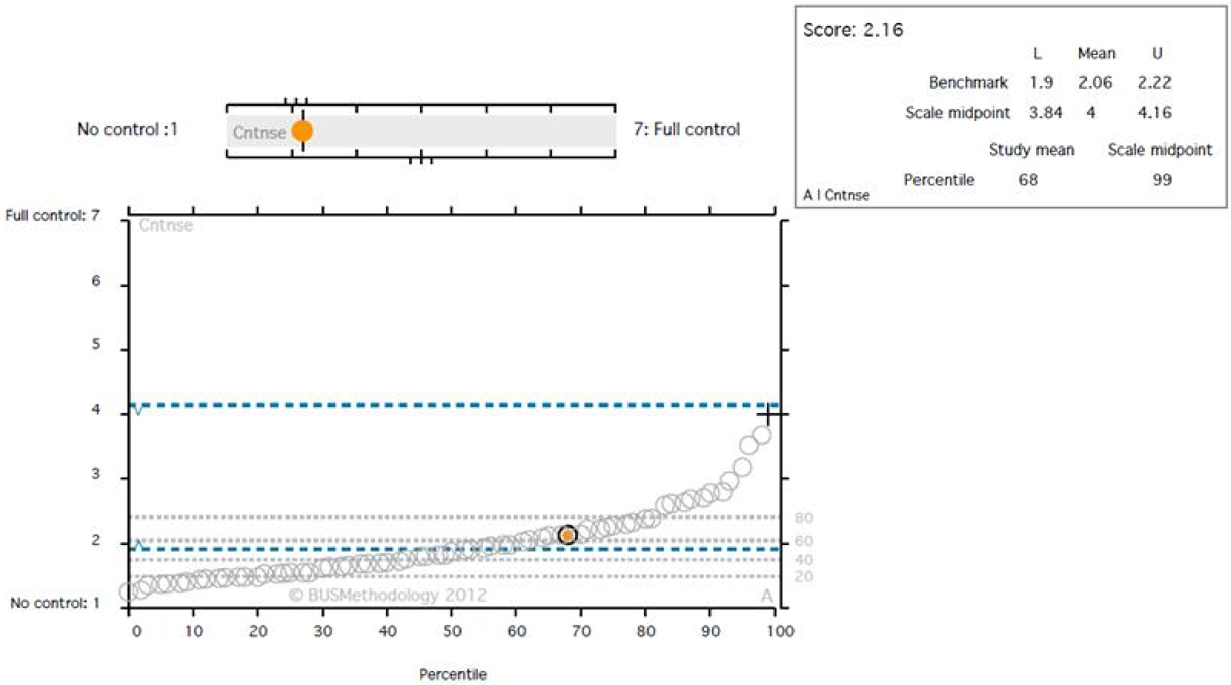
Control over heating



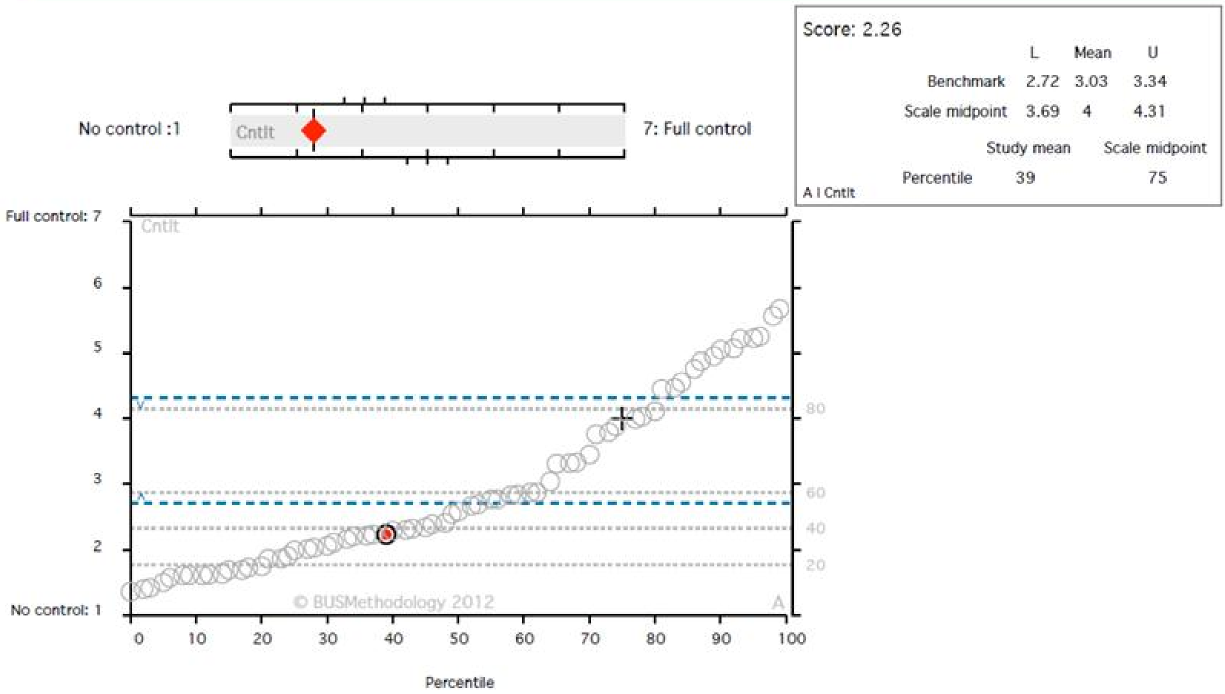
Control over cooling



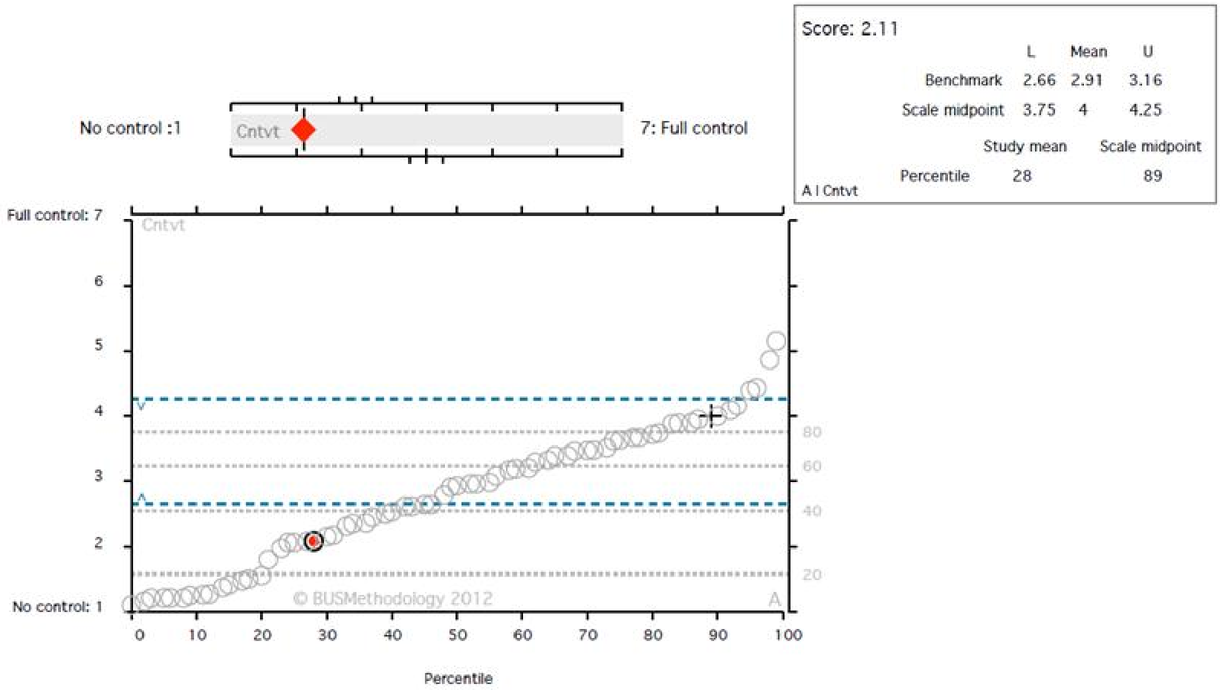
Control over noise



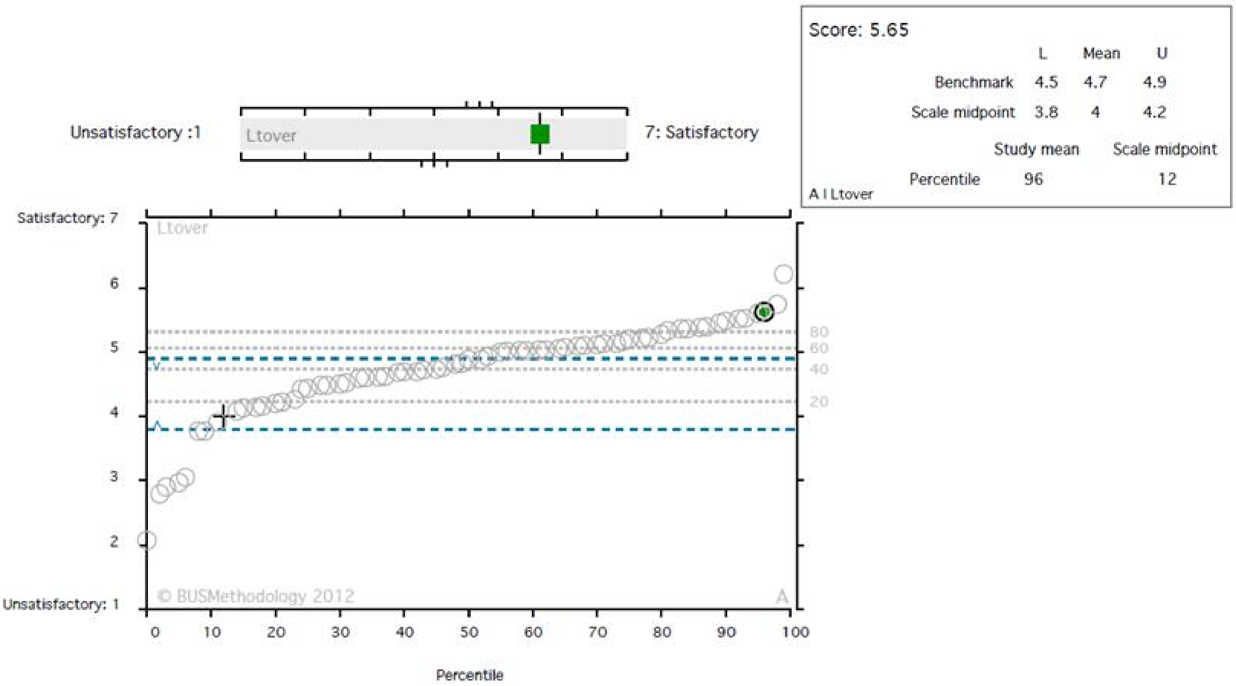
Control over lighting



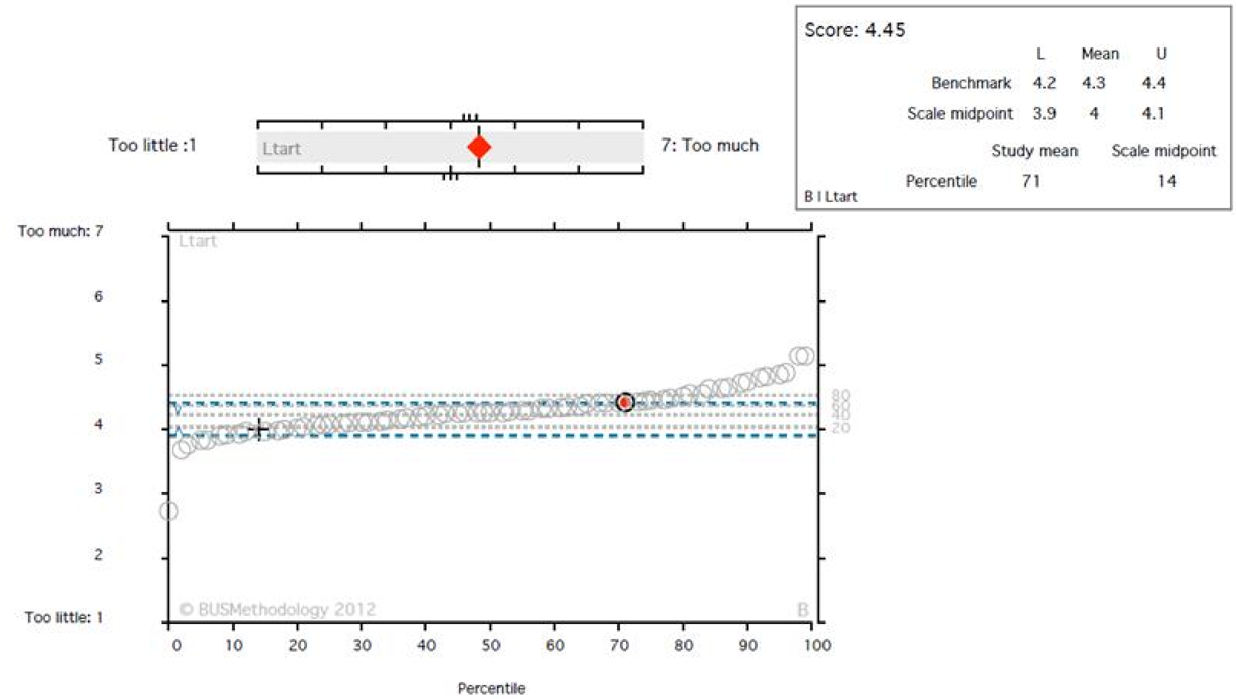
Control over ventilation



Lighting: overall



Lighting: artificial light



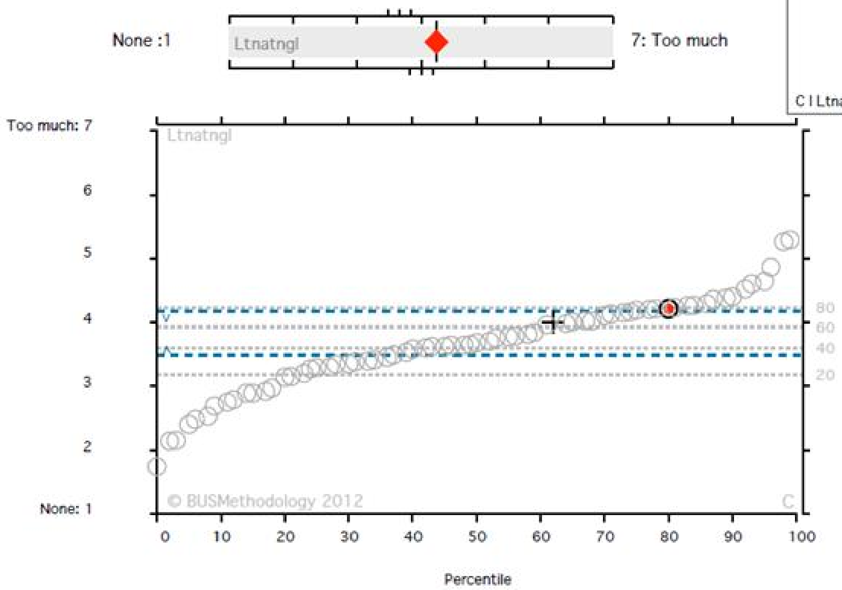
Lighting: glare from sun and sky

Score: 4.24

	L	Mean	U
Benchmark	3.48	3.66	3.84
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	80	62

C I Ltnatngl



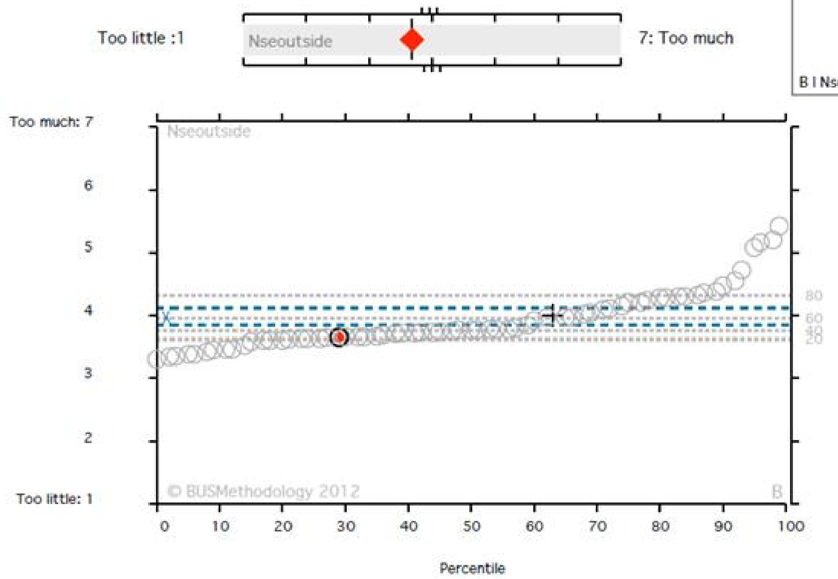
Noise: from outside

Score: 3.68

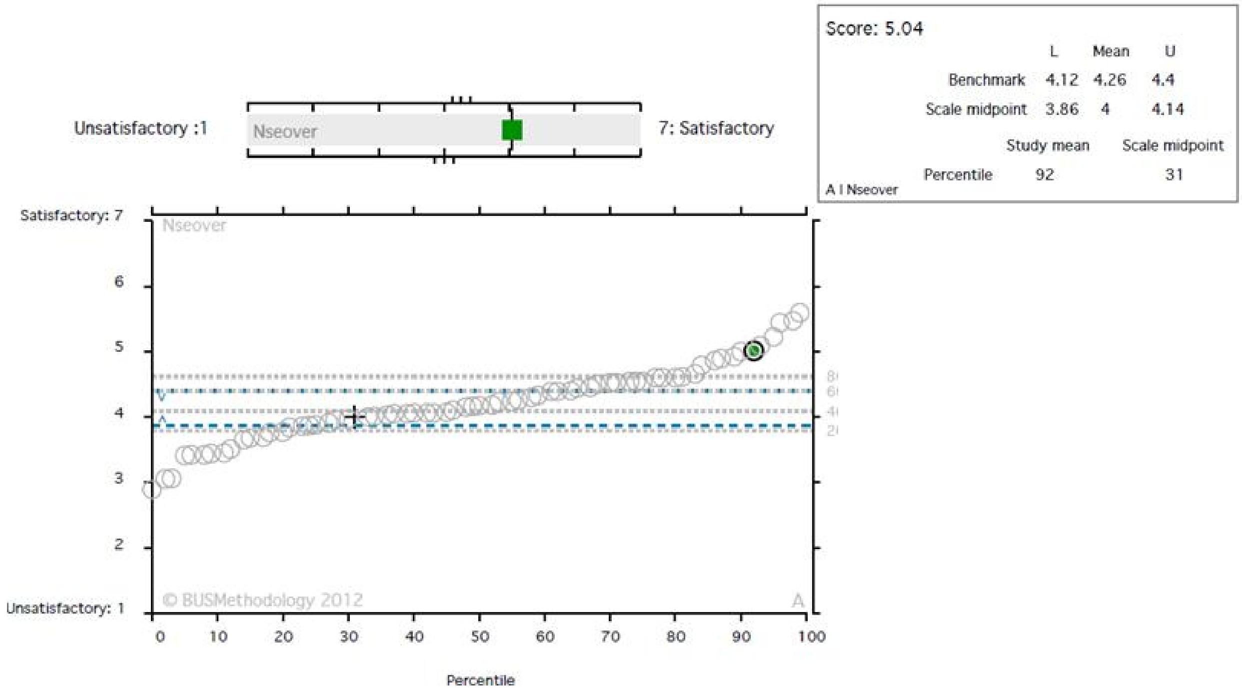
	L	Mean	U
Benchmark	3.84	3.96	4.08
Scale midpoint	3.88	4	4.12

	Study mean	Scale midpoint
Percentile	29	63

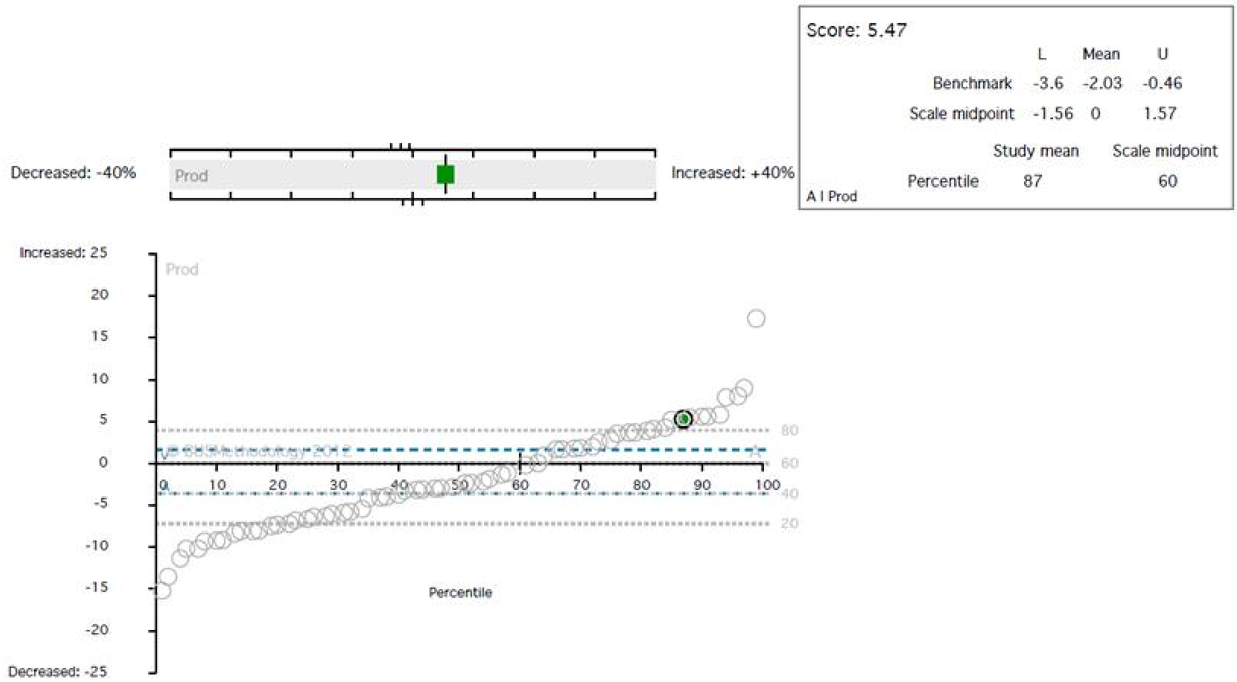
B I Nseoutside



Noise: overall



Productivity (perceived)



10.3 Occupant survey - raw data responses from occupants seated adjacent to windows

The following tables show an indicative breakdown of responses from occupants seated in the first two rows of desks adjacent to the windows on two specific issues: temperature stability and glare.

Table 3 Raw data response to temperature stability

Score given by respondent		Winter temperature stability		Summer temperature stability	
		By a window?		By a window?	
		Yes	No	Yes	No
Stability (1 = stable, 7 = varies during the day)	1	2	2	0	1
	2	1	4	1	1
	3	0	2	0	1
	4	5	7	12	8
	5	15	14	6	17
	6	11	21	10	20
	7	4	10	9	9
	.	1	3	1	6

Table 4 Raw data response to glare

Score given by respondent		Natural glare		Artificial light glare	
		By a window?		By a window?	
		Yes	No	Yes	No
Glare (1 = none, 7 = too much)	1	0	10	1	7
	2	2	5	3	6
	3	0	3	3	4
	4	16	25	25	26
	5	13	5	3	8
	6	4	8	2	7
	7	3	6	1	3
	.	1	1	1	2

10.4 Sub-metering hierarchy

The diagram below shows a meter tree which we have developed to help generate the basebuild model. All known meters are mapped, green boxes highlight those modelled in the basebuild TM22 model. A more detailed meter layout is also shown below.

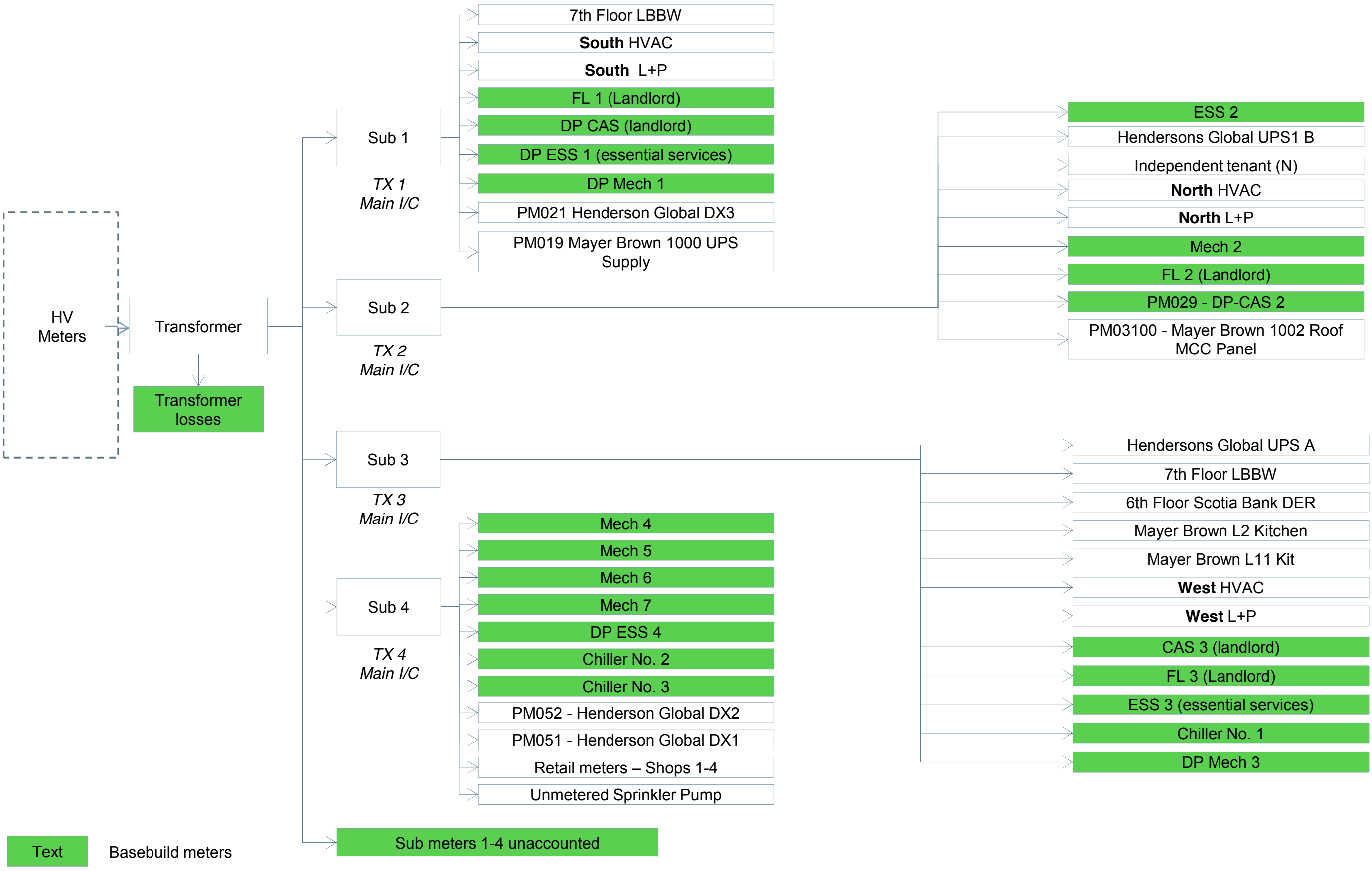


Figure 31 Outline meter tree

Technology Strategy Board
Driving Innovation

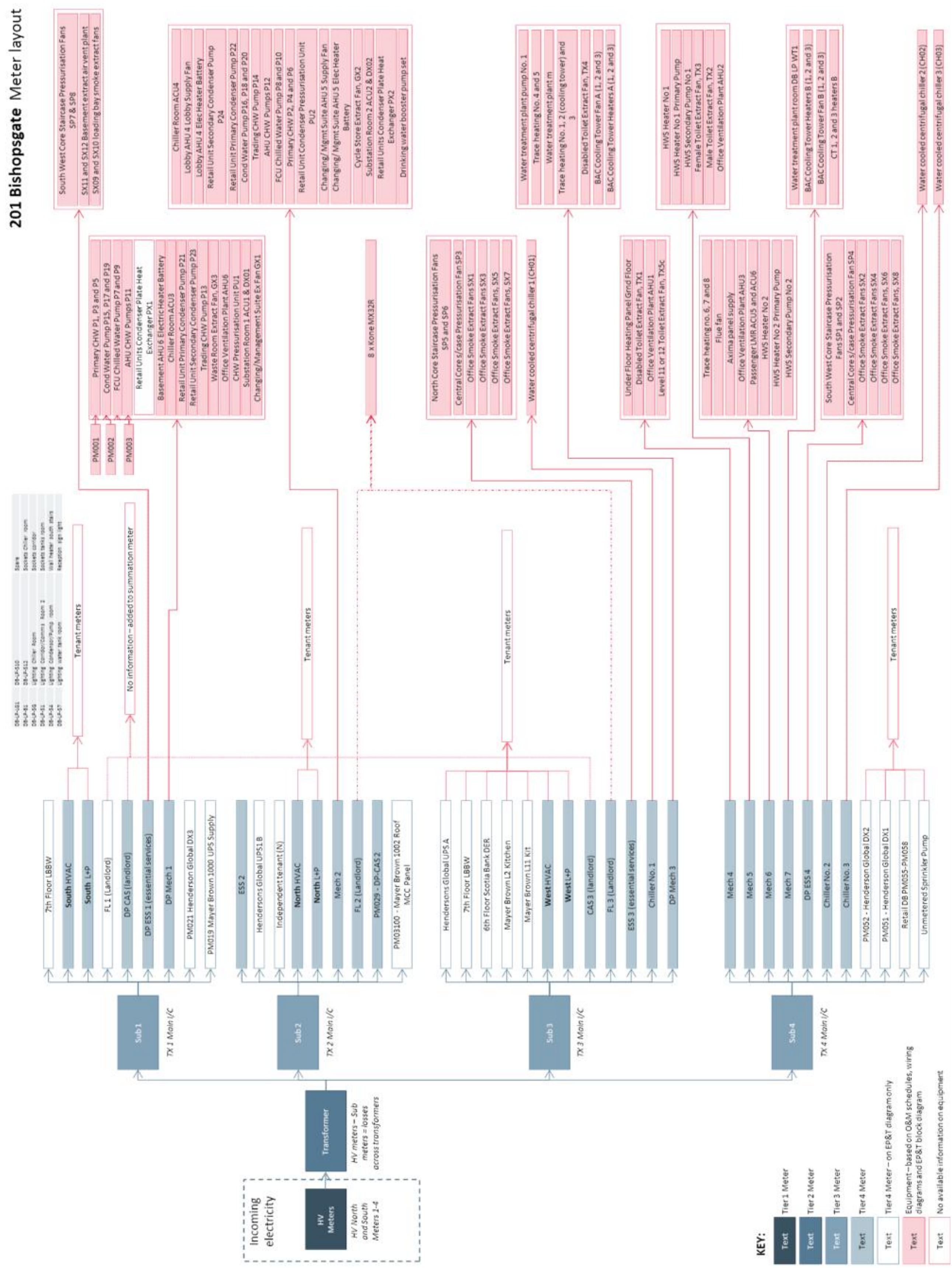


Figure 32 Simplified meter layout produced by Verco

1.2 Summary of building parameters

Item	Parameter	Specific	Value
Acoustic	Average Noise Criteria	Office, Levels Ground,	40 NR
	Services Installations	Office, Levels 1- 12	38 NR
		Toilets	45 NR
Dimensional	Floor to Ceiling Height - refer to attached SOM drawing L-A-251	Basement to Lower Ground	5.050 m (Varies)
		Lower Ground to Upper Ground	2.550 m (Varies)
		Upper Ground to Level 1	8.350 m (Varies)
		Office Floors 1 - 2	3.000 m
		Office Floors 2 - 3	3.000 m
		Office Levels 3 - 11	2.750 m Typical
		Office Levels 11 - 12	2.750 m
		Level 12 to Roof	4.395 m
	Raised Floor	Office/ Trading Levels 1 & 2	300 mm
		Office Levels 3 - 12	150 mm
	Planning Grid	Office levels 1- 12	1.50 m
Electrical	Cat A Fit-Out	Floor Box Spacing	10 m²/unit
		Office Light Level	400 Lux avg
		Smoke Sensor	In accordance with codes
		Voice Alarm Speaker Spacing	In accordance with codes
		Typical Luminaires	To industry standard
	Electrical Loading	Office Small Power	25 W/m²
		Office Lighting	12 W/m²
		Supplementary Small Power available in on-floor riser.	20 W/m²
		Future small power switch gear.	15 W/m²
		Trading Floor small power	70 W/m²
		Trading Floor lighting	12 W/m²
		Trading Floor supplementary small power available at main switchgear	80 W/m²
	Landlord's Essential Services Standby System	Generator Capacity	Min 600 KVA
	Tenant's Standby Power System	Area provided for Generators	Space provision

Figure 33 Extract from Base Build Definition document showing a summary of key building parameters

Lifts	Firefighting	Number	2 no.
		Size	630 kg
		Speed	1.6 m/s
	Goods	Number	2 no.
		Size	3000 kg
		Speed	1.6 m/s
	Passenger (1 No. lift serves as firefighting lift)	Number	8 no.
		Size	26 persons
			2000 kg
		Speed	2.5 m/s
	Passenger Lift Performance	Peak 5 minute handling capacity	15% population
		Average waiting interval	<30 secs

Figure 34 Extract from Base Build Definition document showing a summary of key building parameters

Item	Parameter	Specific	Value
Population Density	Means of escape	Office Floors, 1 & 2	7 m^2/person
		Office Floors, 3 - 12	10m^2/person
	Lifts	Office Floors	14 m^2/person (enhanced by DHC)
	Escalators	Office Floors 1-2	7 m^2/person
	Mechanical	Office Cooling + Outside Air Quantity	10 m^2/person
		Floors 1-2	7 m^2/person
	Toilet Fixtures	Count - Offices	10 m^2/person
		Male to Female Ratio - Offices	60:60
Mechanical / plumbing	Category A Fit-Out	Central FCU Spacing	75 m^2/unit
		Perimeter FCU Spacing	6mx6m
		Sprinkler Spacing	To code
	Cooling Power Load Densities	Office - Lighting	12 W/m^2
		Office - Small Power	25 W/m^2
		Supplemental Cooling	16 W/m^2
		Cooling Capacity Future Flexibilty	10 W/m^2
		Floors 1-2 Lighting	12 W/m^2
		Floors 1-2 Small Power	70 W/m^2
		Floors 1-2 supplementary in plant + risers.	80 W/m^2
	Extract Rates	Toilet Rooms	10 ac/hour
	Inside Temperature	Summer Design (Note that blinds are included in solar gain assessment)	23.5ºC
		Winter Design	21ºC, control range ± 1.5ºC
	Outside Temperature	Summer Design	29ºC db
			22ºC wb
		Winter Design	-4 ºC db
		Cooling Tower design maximum ambient	23 ºC wb
	Outside Air Volume	Design Air Temperature	16 lps/person (12ºC at peak Summer, 16ºC at peak Winter)
	Thermal Performance	Curtain Wall	1.6m^2K (g-value:0.43)
		Roofing System	0.25 W/m^2 K

Figure 35 Extract from Base Build Definition document showing a summary of key building parameters

Structural	Imposed	Roof	1.5 kN/m^2
		Level 7 Terrace	3.5 kN/m^2
		Office	3.5 kN/m^2
		Toilets	2.5 kN/m^2
		Typical Floor Plant Areas	6 kN/m^2
		Plant Rooms and open plant area	7.5 kN/m^2
		Storage/ filing - Office and general	7.5 kN/m^2
		Public Areas, Lobbies	5 kN/m^2
		Retail	4 kN/m^2
		Parking Areas	2.5 kN/m^2
		Stairs	4.0 kN/m^2
		Loading Bay	12 kN/m^2
		Partitions (office and retail areas only)	1 kN/m^2
Summary Power Provisions	Office Total		72 W/m^2
	Office Future Provision		35 W/m^2
	Trading Total		162 W/m^2
	Trading Future Provision		80 W/m^2

Figure 36 Extract from Base Build Definition document showing a summary of key building parameters

10.5 EP&T recommendations

Broadgate Estates (the FM organisation) and EP&T (the metering and M&T contractors) hold monthly Monitoring, Analysis and Reporting Service (MARS) meetings in order to gain a better understanding of the recent issues with the building's operation and those picked up by EP&T. The format of the MARS meetings is a conference call between EP&T's technical support team and Broadgate Estates FM team. The meeting is typically structured around issues and actions logged in EP&T's monitoring and reporting system. The status of each issue and corresponding action is methodically discussed.

EP&T began their engagement with 201 Bishopsgate in 2010 with a contract for 3 years. They have far exceeded their initial guaranteed savings.

Key points of interest include:

- Plant operating times were a major issue early on in the building's occupation. These have now been fine-tuned. However, one of the recurrent themes during the meeting is issues relating to the BMS. These issues appear generally to relate to inappropriate time clock or demand settings for equipment, particularly out of hours plant operation. For example, control loops have been amended for the heater battery in AHU2 which was providing excessive heat.

- A major issue already identified is that occupier's BMS can call for HVAC equipment at any time, over-riding the central BMS, and often these demands are considered unnecessary. The reason for the facility is to enable flexible working. Broadgate Estates have now modified the BMS to limit this facility, and have had discussions with the occupiers on the impact on energy usage. This change is has resulted in a significant reduction in building energy consumption. Monthly Out of Hours Request Logs are now sent to EP&T by Broadgate Estates (BE) so that EP&T can review the energy usage and ensure that plant energy consumption is consistent with operational requirements, and there was extensive discussion around this topic.

- Out of Hours (OOH) allocation of energy costs to tenants is based on lighting and small power energy consumption, as well as a proportion of an early plant replacement charge. For tenants not using OOH plant services, they are credited with a corresponding proportion of the latter charge.

- The heating in the reception area is an issue – it is provided by electric underfloor heating which is not working effectively in providing heat to the receptionists. In addition, the disabled door is used a lot instead of the revolving door, which is creating draughts. Door seals were thought not to be considered suitable in terms of their appearance when the entrance lobby was designed, and so could not be integrated into the door frame. Therefore, these air gaps are also contributing to the air infiltration.

- There have been ongoing issues with a low temperature differential in the refrigerant circuit on all the chillers, and also with the control valves – this issue is being resolved.

EP&T also issue monthly MARS reports which summarise identified discrepancies/anomalies in sub-meter energy consumption and log notes between EP&T and the client to try to identify a solution. Verco have reviewed the last six months' worth of logs and noted some of the key issues, as well as their corresponding savings – these are listed below.

- An inconsistency was identified in AHU3 daily energy demand, stopping and starting throughout the night. AHU3 supplies the lift lobbies, and occupiers' floor area including toilets. It is understood from the client that the occupiers' BMS can override the central BMS. The out of hours demands are monitored and occupiers are informed on a weekly basis. An unknown change was made to the system which removed this issue, with an estimated annual saving of around 23MWh.

- Inconsistencies in operation were identified for AHU1 and 2. Again, it is understood from the client that the occupiers' BMS can override the central BMS. EP&T suggested that the AHUs might be coming on erroneously as the plant is coming on during the night, and that there could be an issue with the BMS. EP&T also suggested taking away the BMS plant control from any problematic occupiers. A change in control schedules was implemented, resulting in weekly loads dropping substantially, as shown in the graph below, with an estimated annual saving of 128MWh.

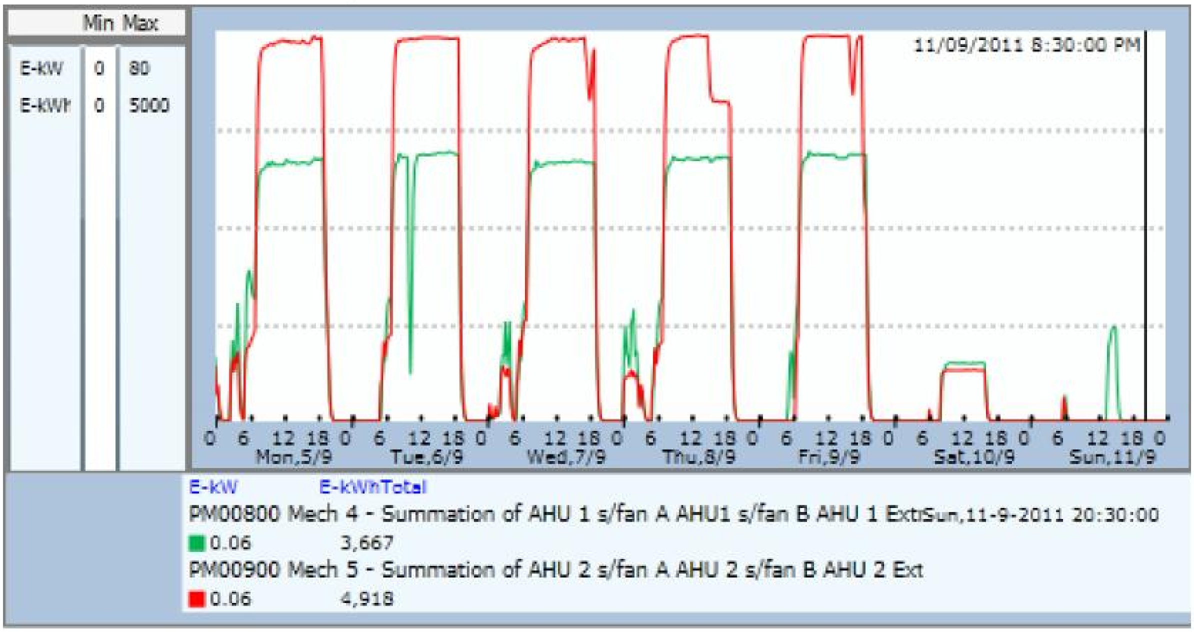


Figure 37 AHU fan energy consumption

- The chilled water system pumps were observed to be operating constantly. The client reported that the occupiers' BMS had locked the pumps in the 'on' position, so this demand was removed, with an estimated annual saving of 278MWh.
- The chillers were observed to be operating all weekend. They are time controlled for the normal operating periods of building, but the occupiers have the ability to switch the chillers on outside normal working hours, thus explaining the odd running periods. As a result, the chiller operation is currently under review to determine whether the occupier control facility can be removed. There is a potential annual saving of 341MWh.
- Distribution board Mech 5, which serves some AHUs and a domestic hot water heater, showed a high base load. This was investigated, and the time clock for the DHW heater adjusted and the BMS control loops for the AHUs adjusted to ensure heater batteries were not operational during warm weather. An estimated 97MWh annual saving was achieved.
- The FCU pumps were identified as operating out of hours. This was thought to be due to the occupiers' BMS signals and was investigated further.
- A high base load was identified on distribution board Mech 3 of 3.2kW. This was investigated and found to be partly due to a faulty BMS outstation which controls the timeclock for a toilet extract fan. Investigations are continuing to try to determine what other equipment could be contributing to the high base load. Total annual savings of around 29MWh are estimated to be achievable.
- Motion-controlled lighting was installed in back-of-house areas to reduce energy consumption, but the lifts still appear to be consuming a significant amount of energy at weekends.

- Chilled water pumps on Mech 1 were observed to be operating continuously. These pumps are either time clock controlled, or via an occupier demand signal, consuming an additional 3,000kWh in one week. The client implemented control changes and very high annual savings of 460MWh were estimated to have been achieved.

- The underfloor heating in the reception area was observed to be operating during the summer. This issue was rectified, with an estimated 37MWh saved annually.

- The cooling towers were operating unnecessarily during out of hours periods – this was found to be due to demands from the occupiers BMS, giving a saving of 49MWh.