Castle Hill Primary School

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	450035
Project lead and author	ECD Architects
Report date	2014
InnovateUK Evaluator	Robert Cohen (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Schools (primary)	Kingston-upon-Thames	Traditional	See below
Floor area	**Storeys**	**EPC / DEC**	**BREEAM rating**
817 m^2 and 302 m^2	Various	N/A	Very good

Purpose of evaluation

The subjects of the evaluation were the two additions to the Castle Hill site: a classroom extension and a new build dining hall. The classroom extension of 817 m^2 and the dining hall of 302 m^2 were completed in May 2010 and April 2011 respectively. The BPE project reports on the application of Soft Landings. While Soft Landings activities were adopted at inception, briefing, and post-occupancy stages, further involvement by both design and construction teams were thought necessary. Changes that occurred during the design and construction may have had a detrimental effect on the building's energy performance.

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

CIBSE TM22 was used separately for the extensions of the junior block and dining hall to assess the in use energy performance of these two parts of the site. Dining hall electricity use: 73.8 kWh/m^2 per annum; thermal (gas): 272.9 kWh/m^2 per annum. Gas use was 4.5 times higher than predicted and close to double the CIBSE *TM46* benchmark. Junior block electricity use: 28 kWh/m^2 per annum; thermal (gas): 95.7 kWh/m^2 per annum. Separating energy consumption through sub-metering was problematic, with difficulties for the BPE team in understanding the existing building as well as obtaining accurate and useful data.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	44 of 68, and 36 of 41	65% and 88% respectively

Two surveys were carried out, in 2012 and 2014. By the time of the second BUS survey the school had already carried out certain feasible improvements. Staff members who did not spend the majority of their time working in the new buildings were excluded from the second survey. Significant differences were not observed between the 2012 and 2014 surveys, with the exceptions of improvements in perceived productivity scores, and reduced satisfaction with temperature and air quality.

About this document:

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

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

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

Contents

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.

This report has been produced as part of the TSB Building Performance Evaluation project, to summarise the activities of a two year assessment of Castle Hill Primary School, Kingston upon Thames.

The subjects of this Building Performance evaluation are the two latest additions to the Castle Hill Site; a classroom extension and a new build Dining Hall. Both were designed by ECD Architects for the Royal Borough of Kingston Local Authority, and constructed by Thomas Sinden Contractors. M&E consultants were David Miles and Partners.

The Classroom Extension of **817m^2** and the new Dining Hall building of **302m^2** were completed in May 2010, and April 2011 respectively. The new buildings were designed with U Values of **0.15W/m^{2}K**, and a predicted air tightness of **10m^3/m^{2}h**, using a combination of timber frame, brick and concrete block cavity wall construction.

The heating is provided by a gas boiler system, connected to under floor heating. Natural ventilation cowls were installed to the classrooms and dining hall, with an MVHR system to the WC areas.

Key findings:

Air tightness varies significantly from the design stage estimate of **10m^3/m^{2}hr**, with the Dining Hall achieving a value of **11.85m^3/m^{2}hr** (worse) and the Nursery Extension a value of **8.49m^3/m^{2}hr (better)**. As the buildings were assessed under Part L2a and Part L2b (2006) of the Building Regulations, no target was required to be met. However, the implication of a much higher air leakage would reflect the higher than predicted heat requirement, and consequently higher energy consumption.

The **Thermography Survey** revealed 3 areas in the building fabric where the temperature was above the threshold of the requirements set out in **BRE IP17/01** and **BS EN 13187:1999**, which have been identified as areas where the layer of insulation and air tightness are not continuous **[Appendices 4-5]**. The survey found numerous areas within the existing building, where insulation and air tightness were compromised. In addition, the proportion of heat loss through the existing windows was identified as significant, and thermal bridging was identified within the structural elements. The **Building User Survey** revealed that the users experienced thermal comfort issues, particularly during the winter. An unexpected result was that the users' experienced thermal discomfort when moving from the new extension, which was felt to be warm, to the existing building, where the temperature was perceived to be significantly lower.

Separating energy consumption through **Sub Metering** has been particularly problematic, with difficulties for the BPE team in understanding the existing building, as well as ensuring accurate and useful data. This has been a major concern for the robustness of the evaluation.

University College London's (UCL) environmental reports assessed the potential for **Overheating,** and poor **Indoor Air Quality**. These assessments were based upon the Building Bulletin 101: Ventilation of School Buildings.

In accordance with the BB101 Criteria, the UCL Overheating Report predictions state that there is no overheating in the classrooms, with the exception of Classroom S2C1. The occupant's perception is that the new build is warmer than the existing and it is also compared to other surveyed buildings in the BUS data set.

The UCL IAQ research concluded that the ventilation strategy provided a satisfactory indoor environment according to BB101 guidelines during both seasons. However, the daily average concentrations of CO_2 were found to be above 1000 ppm during spring. Increasing evidence in studies of other school classrooms shows that high CO_2 concentrations may be related to increased prevalence of SBS symptoms and reduced academic performance. The natural ventilation strategy however has led to a number of reports of poor comfort, as the incoming air from passive stack systems is very cold. By comparison the MVHR systems in the WC have not had any reported problems.

Soft Landings activities were adopted at Inception, Briefing, and Post Occupancy stages, however to ensure an efficient and well used building, further involvement by both design and construction teams could have be allowed for. Changes that occurred during the design and construction may have had a detrimental effect on the building's energy performance.

For more a more detailed overview of the findings please refer to **Sections 8 and 9**

Table 1.1 Key building information

Unique reference number	**BPE 450035**
Name of Project	Castle Hill Primary School Dining Block and Nursery Extension
Address	Castle Hill Primary School Buckland Road Chessington Surrey
Post Code	KT9 1JE
Procurement method	Traditional Contract **(JCT SBC 2005)**
Occupation Date	**Junior Block** 4th May 2010**, Dining Block** April 2011
Project Team	Architects **ECD** Project Managers **Keegans** Contractors **Thomas Sinden** Client **Kingston upon Thames Council**
Contact Details	**ECD Architects** 020 7939 7500
TSB Evaluator name and details	Frank Ainscow; Interfacing/ Robert Cohen; Verco Global
Floor Area	**Junior Block** 817.04m^2 **Dining Block** 301.65m^2
Construction Type	Timber Frame and Masonry

Occupancy Pattern	**Junior Block** School building **Dining Block** Canteen
Energy Calculations	**Junior Block** EPC C Rated **Dining Block** EPC A Rated BREEAM Very Good 56.01%, **(Design Stage Certificate)**
Occupancy Survey	BUS Questionnaire survey, 65% response rate
Carbon Buzz / EST cross reference/ link	TBC
url of project team	ECD Architects **www.ecda.co.uk** Keegans **http://kgans.co.uk/** Thomas Sinden **http://www.thomas-sinden.co.uk** Royal Borough of Kingston upon Thames **http://www.kingston.gov.uk/**
Key Features	Natural Ventilation; Super Insulated; Photovoltaics; Timber Frame; Heat Recovery; Recycled and Low Embodied Energy Materials; BREEAM Very Good (Design stage only).

	Predicted	Actual
Air Permeability	10 m^3/m^2h	**Junior Block** 8.49 m^3/m^2h **Dining Block** 11.85 m^3/m^2h
Floor	0.15 W/m^2h	No testing as part of study
Walls	0.15 W/m^2h	
Roof	0.15 W/m^2h	
Delivered Energy Gas	**Junior Block** 37kWh/m^2 Heating 10kWh/m^2 Hot Water 47kWh/m^2 Total **Dining Block** 24kWh/m^2 Heating 36kWh/m^2 Hot Water 60kWh/m^2 Tota	**Junior Block** 95.4kWh/m^2 Total **Dining Block** 170.6kWh/m^2 Heating 45.8kWh/m^2 Hot Water 15.5kWh/m^2 Cooking **Whole Site (incl. Existing)** (DEC) 113kWh/m^2
Electrical Consumption	**Junior Block** 21kWh/m^2 regulated 34kWh/m^2 total **Dining Block** 14kWh/m^2 regulated 91kWh/m^2 total	**Junior Block** 28kWh/m^2 total **Dining Block** 73.8kWh/m^2 total **Whole Site (incl. Existing)** (DEC) 36kWh/m^2

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 Building Description

Building Type
The Site of both buildings is at the end of a residential street located to the South (Dining) and East (Junior Block) of the existing school. The nursery extension provides 9 new classrooms with breakout spaces, whilst the Dining Block has a large hall, servery and plant room. Both have WC blocks for the users.

Building Form
The Junior Block Extension is a curved extrusion, built with timber frame, and brick and block cavity walls.

The Dining Block provides a large double height space with a Dutch Barn style roof comprising of glulam beams with block infill.

Daylight Strategy
The daylight strategy was investigated in depth, using the Bartlett School of Architecture's Heliodon and Artificial sky. This led to design decisions regarding the positioning of the louvred windows and the angle of the brise soleils. The daylight factor for both areas was designed to be high enough that artificial lighting would not be required during the summer term.

Transport links, cycling facilities
The School is located close to Chessington North train station, within 1 mile of the A3 motorway. Cycling facilities are provided as part of the School's sustainable transport policy, which takes advantage of the extensive cycling network of Kingston.

Construction contract type
The construction contract was the JCT Standard Building Contract 2005, administered by Keegans Project Managers.

2.2 Design, Construction and Handover Review

The discussion in this section focuses on the first three stages of the Castle Hill construction process, as they relate to the Soft Landings Framework (BSRIA, 2009). The remaining two stages will be discussed in Section 5 of this report.

1 Inception and briefing
2 Design development and review
3 Pre-handover
4 Initial aftercare
5 Aftercare in years 1 to 3

Information for the analysis was obtained from the following sources:

- Design Team Minutes
- Site Visit Minutes
- Interviews with key personnel from the Design Team
- Design drawings
- Correspondence between Client and Design Team
- Planning Approval Documents, including Design and Access Statement

Soft Landings Stage 1: Inception and Briefing

The procurement route for the Castle Hill Project was traditional, via a framework agreement with the Royal Borough of Kingston upon Thames and Keegans Construction and Property Consultants. As the project budget was over £1million, the Client was required to conduct a mini-competition, for which Keegans appointed ECD (Architects) and DMP (Mechanical and Electrical Consultants) at an early stage (RIBA Stages A and B).

The outcome of the competition was based on quality and cost basis (60%/40%), for which the Keegans / ECD / DMP team was successful. This, according to the project manager, is in part the result of the architects' concept of a 'fabric first' approach to meet the 60% reduction in CO_2 emissions. Soft landings could have been introduced at this point in the project, though as the brief did not call for this, the design team did not pursue this route.

For future projects, the design team could promote the Soft Landings approach at this stage to improve the usability of the buildings. The Soft Landings framework states that the costs for adopting the measures at Stage 1-3 should be negligible, with a small increase in costs after occupancy.

Project roles and responsibilities were assigned early on in the project, as the competition team was kept for RIBA Stage C onwards. The Main Contractor was selected as part of the tender process at Stage H.

The task of energy modeling was performed by DMP, who had recently become certified for SBEM calculations. Early on in the design stage, ECD and DMP discussed other school projects where sub metering and energy savings were made (Elfred High School, report prepared by Flintshire County Council). No stage L (BPE) activities were allowed for in the contract for this project, however.

Aftercare duties were not assigned, except for a defects liability period within the JCT SBC Contract.

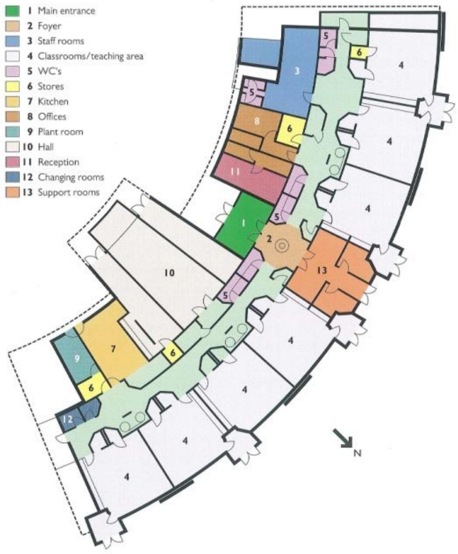
Within the Soft Landings Framework, there is a requirement to obtain and understand the future occupant expectations.

At the initial client meeting, the key stakeholders were identified as follows:

- Pupils
- Parents and Guardians
- Teachers
- Governors
- Local residents and community

- Local authority (Planning and Building Control)

Previous projects and precedents were discussed, in a “lessons learnt” section of these meetings. One key factor identified at this stage by the client was products, such as extract fans in the existing building being difficult to maintain and source new parts. This was relayed to the M+E engineer for their specification.



	KWh/m²/yr		kgCO₂/m²/yr*		
	Electricity	Gas	Electricity	Gas[1]	Combined
Kingsmead Consumption 2005	72	103	29	20	49
Kingsmead photovoltaic generation 2005**	4	-	-	-	-
Top 25 percent of primary schools[2]	25	113	11	22	33

*Assuming 0.19 $kgCO_2$/kWh gas, 0.43 $kgCO_2$/kWh electricity
**Estimated from 4 months' data February to May 2005
[1]Gas use adjusted for local temperature
[2]Twenty fifth percentile for energy consumption recorded in DfES (2004) Energy and Water Benchmarks for Maintained Schools in England 2002-2203

Figure 2.1: Kingsmead School, White Design; one project used as a precedent to describe ECD’s design aspirations. The case study demonstrated energy consumption in use from 2005.

On 05/02/09, a public exhibition and consultation event was held, where feedback from parents, governors and pupils was collated. Visioning workshops were held with key stakeholders before the final sign-off of the Tender Documents. The consultation revealed some conflicting requirements, which were difficult to satisfy for all stakeholders. For instance, the school expressed a preference for a single storey building, due to cost and access to external space, whilst some parents and governors thought the building took too much space on the site.

In total, 12 meetings engaging the users and key stakeholders were held during the design stages. The design team saw this as above and beyond the client’s requirements and was particularly enthusiastic about its involvement in the project. Potentially, this user engagement could have continued throughout the construction and into the initial aftercare stages, following the soft landings framework procedures.

Summary of *Soft Landings* Stage 1:

- A considerable amount of unstructured feedback from existing users was obtained as part of the brief development, Stage A/B.

- The M+E Engineer was appointed early in the process, and discussed building performance in depth with both the Architect and the Client.

- Soft Landings could have been discussed at this stage, and aftercare duties assigned to ensure a building that performs effectively for the users.

Figure 2.2: Exhibition invite and image from one of the Consultation events. These events were used to develop the brief further, and to allow the major stakeholders an opportunity to input into the design.

Soft Landings Stage 2: Design, Development and Construction

Desk studies and reviews of existing Post Occupancy Evaluations were carried out at RIBA Stages A-B. The Design Team discussed an Energy Audit compiled by Flintshire County Council, which looked at Elfred High School in 2007. This report highlighted energy saving opportunities to the existing building fabric, electrical and heating systems, and mentioned renewable sources of energy to be investigated after. This 'fabric first' approach was, in the Project Manager's opinion, one reason why the commission was won.
The potential for refurbishing the existing school was investigated at a high level, but it was deemed too expensive in initial capital expenditure, once the new extension was included.

Internal design reviews were undertaken in accordance with the accredited Quality Assurance procedure. Site meetings were held monthly as per the contract requirements, where issues were discussed, though no independent reality checking procedures were adopted, such as BSRIA Pitstopping. The responsibility for design reviews was taken by the Project Manager, Keegans, as the Client's Agent.

Energy modeling was undertaken by DMP, for compliance purposes only, using HevaComp v. 24 52 3. Through the design process, the Architects wished to solve building performance issues, such as overheating, which proved to be difficult and time consuming for the M+E Engineers, as the software was not designed for quick assessments and adjustments.

The process involved the Architects producing a Stage C scheme for the M+E Engineers, who modeled the building to check compliance with Part L. U Value calculations were performed in house at ECD, based on construction details. The building performance then influenced the size of the PV array that was required to meet both the 60% CO2 reduction required by the brief, and achieving BREEAM Very Good (which was a Planning Condition).

Overheating was predicted by DMP (10.03.09 SM) to occur in classrooms. The SBEM report highlights this overheating risk; modeling software inflexibility meant that time was spent by both M+E and Architects to understand the limitations of HevaComp. These were: sensible gains considered and not latent heat; occupation by children and not adults.

The Architects undertook a sunlight analysis at UCL's Heliodon, to prove that the louvre design would reduce glare sufficiently, in order to avoid uncomfortable conditions internally. Although this was a detailed exercise, it would have been more accurate to model the louvre blades in software such as IES or TAS, to have a robust and compliant model, rather than adjusting internal heat gains manually in Hevacomp. In accordance with the CIBSE Guide TM37 a lower metabolic rate for children was assumed, as Hevacomp is set to default for adults' metabolic rates only.

Once the tender documents were confirmed by the client, no further energy analysis was carried out, even though an extra classroom was added to the contract during construction, with knock on effects for the accuracy of the prediction.

As part of the commission, there was no distinct stage for checking commissioning records, except for the regulatory Building Control submission. Commissioning and any required re-commissioning was contracted to DMP, though limited to mechanical and electrical systems (mechanical ventilation; BMS; PV Array; and refrigeration).

As the Dining Block fell under the 2006 Part L2a Approved Document, no air pressure test was required. It was under the compliance limit of $500m^2$, therefore for the purposes of certification a default air permeability of $15m^3/hr/m^2$ was applied to the SBEM model The Nursery was an extension, so was regulated by Approved Document Part L2b and therefore no air test was required.

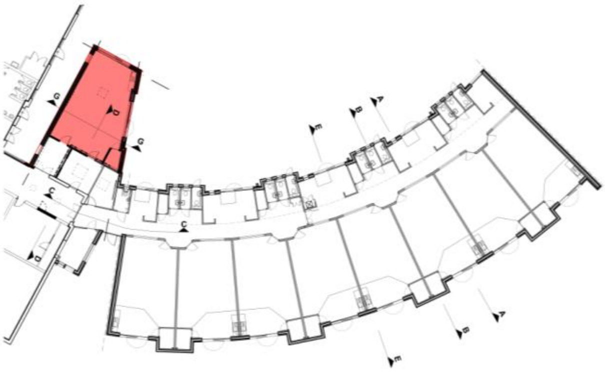


Figure 2.3: Additional 56m2 Classroom highlighted in red. This addition created difficult junctions with the classroom roof, as illustrated in the Figure to the right, as well as an increase in floor area, heat and electrical demands.

Summary of *Soft Landings* Stage 2:

- Extensive options for form and position of the new buildings were investigated.
- The Hevacomp SBEM model used was not dynamic, which makes it less suitable for naturally ventilated buildings (ref: Breathing Buildings). Level 5 model (‘complex’ buildings) would have been more appropriate for accurately predicting overheating and indoor air quality.
- The energy model was not always updated when key design changes occurred (additional classroom; changes to natural ventilation cowl specification).
- The location of the new building was limited due to existing temporary accommodation in the ‘ideal’ place.
- Curves in building were developed as options for client and chosen at Stage C.
- The additional $56m^2$ ‘Bulge Classroom’ was added during Stage K (Construction). The energy model was not updated to consider this increase in floor area and energy demand. This would have a significant effect on the EPC and the energy consumption for this part of the building, though on a per m2 basis the results are still comparable. The M+E design for this section was given less thought and as a result UFH manifolds were installed in this classroom, resulting in spaces that overheat frequently, according to user feedback.
- Value engineering led to an adjusted specification of the PV, Solar Thermal installations and Natural Ventilation cowls. However, the VE did not affect the building fabric.

- Architects spotted missing insulation whilst on site, but air tightness was not always considered. See separate Thermography Report and Air Permeability tests for further details.

- The curved roof and faceted walls resulted in difficulties in build-ability, which led to a less airtight building. These details should be reviewed in future projects.

Soft Landings **Stage 3: Pre Handover**

The head and caretaker of the school were given a full day as handover training, running through the Operations and Maintenance manual and Building Management System (BMS). The BMS Supplier, who also installed the sub meters to monitor energy consumption, provided one year of support for the school in using the BMS.

The responsibility for the Building User Guide was placed with the Design Team, with input from the Main Contractor. The final guide was written by ECD Architects and issued to the school as part of the BREEAM process. It consists of the minimum requirements as described in the BREEAM Manual credit Man04, and focuses on building services with little illustration, or explanations in plain English.

The Operations and Maintenance Manual was produced by Thomas Sinden, as part of the contract. This detailed the ‘As Built’ drawings, instructions for all the building systems and material specification for cleaning and replacements, where required. The manual covered similar material as the Building User Guide, at a more technical level of detail. The ownership was transferred to the school when practical completion was certified and the reviewing process is the responsibility of the end users.

Although the requirements were met for the BMS, BUG and O+M Manual, in future projects it would be beneficial to the client for these to be more user friendly, illustrated for the lay person and displaying only the relevant information. This was outside of the contract for this project, but would be part of the Soft Landings framework services if adopted in future projects.

Summary of *Soft Landings* Stage 3:

- Although a Design Stage Assessment was completed, the BREEAM process was not completed.

- The Building User Guide has a lack of detail, though some consultation and O+M Manuals were produced. One day of training was given for the caretaker and head of the school by the contractor. This is not considered sufficient.

- An issue was identified with UFH manifolds running through the ‘bulge’ classroom before reaching the controls. This results in this classroom overheating even when the system is switched off and also leads to an increase in gas consumption.

- As part of the TSB Building Performance Evaluation Competition, some Soft Landings activities were completed. ECD Architects drove this activity and it has led to learning outcomes for the company which are being fed back to the design team and client.

2.3 Building Walkthrough notes

On 5th November 2013 ECD carried out a walkthrough of Castle Hill Primary School, focusing on the Junior Block (Extension C) and Dining Hall, in order to provide an updated assessment of the building, over two years after initial occupation. The school bursar and the school caretaker accompanied ECD during the visit. Their roles at Castle Hill encompass the operation, maintenance and management of the school buildings and services, and they have been key points of contact for the project team during the Post Occupancy period.

Figure 2.4: Plan of Castle Hill Primary school, indicating the new Dining Hall and the Junior Block Extension C. Coloured overlay highlights the areas of the building and grounds that were toured during the walkthrough.

The event started with a meeting in the school office, to discuss the TSB guidance documentation and to answer general questions, followed by a tour of the buildings **[Route highlighted in Figure 2.4**].
During the tour ECD were also able to speak to other members of staff in order to ask questions on their experience of specific features of the buildings. The visit was conducted out of teaching hours in order for the team to be able to inspect classrooms and other areas of the building that would not have been available during school hours and so that photographs could be taken. Further correspondence with the school was necessary to elaborate on certain findings.

The remainder of this section will discuss the general user experiences of the Dining Hall and the Junior Block (Extension C), as reported by members of staff during the walkthrough. Given the non-uniform characteristics of the buildings across the site and the complexity of the M&E strategy required to meet the various heating demands, a considerable portion of this walkthrough was allocated to documenting the user's understanding of services within the various buildings. These systems will be discussed in more detail later in Section 3.

Overview: Dining Hall Block

The Dining Hall Block is a thermally independent structure located directly opposite the entrance to the main school building and accessed by means of an external covered walkway.

The block has a gross internal floor area of 302 m^2, of which 158m^2 is a double height vaulted dining space to the Southern side of the building, supported by a run of arched glue-laminated beams (Glulam) oriented along a North-South axis **[Figure 2.5]**.

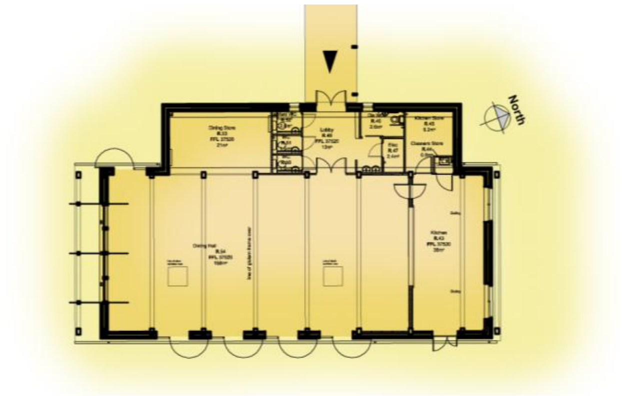


Figure 2.5: Ground Floor Plan of Dining Hall Block

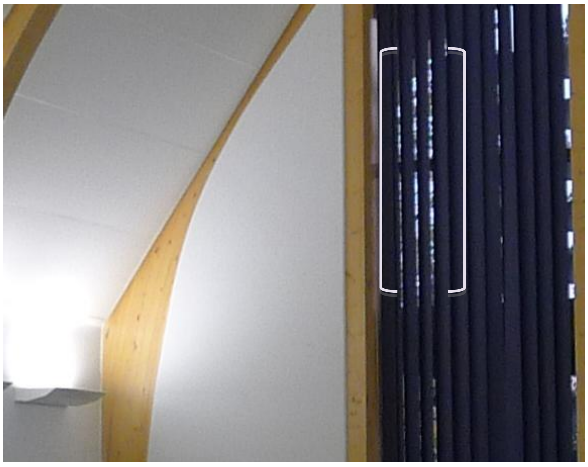
The North of the block is split into two levels, with a 38m^2 kitchen on the ground floor, and a plant room of identical size and proportion on the mezzanine floor above. The remaining area comprises of an entrance lobby, 3No. WCs and 1No. Accessible WC, plus storage areas, all located within a single storey annex to the West side of the main vaulted structure.

Daylight to the main space is provided by a large 'picture' window to the South with smaller opening doors along the East façade. Additional illumination is provided by pairs of 'up-lighters' situated at equidistant centres between the glue-laminated beams **[Figure 2.6]**. Ventilation is provided by means of Passive stack ventilators, which are operated automatically by CO_2 Sensors. Further discussion of the services within this space can be found later the report **[Ref Section 3]**.

Walkthrough notes: Dining Hall Block

- The Dining Hall has been carefully detailed and the on-site finish is generally of high standard. The 'Dutch Barn' Glulam arches with matching window frames give the building a soft, uplifting appearance, which complements its use as a space for primary school children.

Figure 2.6: Photograph of the main Dining space, looking South toward the picture window.



- The school enjoys using the space, which is light, open and thermally comfortable. It is also used for P.E. classes and drama in addition to its primary function as a dining space, thanks to the large storage area which can accommodate the tables and chairs when not in use.

- The staff reported that the hall is slightly too small to be used effectively for 'whole school' assemblies, which are currently split between junior and infants. Was the building to have been built a second time, this additional provision of floor space is something that they would have liked to allow for.

- The solar louvres to the South glazing block out the majority of direct sunshine effectively and help prevent overheating, but they do not prevent glare at all times. As a result, there is a short period in the morning and in the afternoon when either the left or right hand curtain is drawn to prevent glare during periods of direct sunlight **[Figure 2.7]**.

- There were no signs of condensation or mould around the window panes or frames although some cracking of the paintwork to one of the window reveals was spotted on the East of the main space **[Figure 2.8].** It was unclear whether it was historic damage (perhaps caused by incorrect application of the paintwork), or whether this signified a more significant fault in the window junction.

- The Dining Hall Block has been fitted with firefighting equipment, emergency exit signage and Perspex-covered information sheets, which are neatly fitted and appear to be regularly maintained.

Figure 2.8: Cracked paintwork was observed to the reveal of one of the East facing windows

- The plant space above the kitchen is accessed using a ladder via a doorway installed above the main serving hatch at the first floor level. Although it was originally intended by the design team that the ladder would hook into discrete eyelets mounted to the wall, the team were informed at a late stage in the design process that the doorway must be fitted with a safety access platform, with a latching gate that can be closed behind the user **[Figure 2.9]**. Whilst H&S is clearly of primary importance, there is an argument to suggest that the risk posed here could have been mediated in a less cumbersome manner.

- The visual intrusion of the access platform has been exacerbated by the later addition of an overhead projector. It appears that the installer has used a part intended for wall mounting, and so approx. 1-2 metres is redundant. This could have been solved by cutting down the bracket or sourcing a different mount.

Figure 2.9: A bulky service access platform and over-head projector overhang the servery window

Figure 2.7: On each side of the South facing picture window, direct sunlight is able to penetrate at certain times of the day, via a strip of unprotected glazing.

Overview: Junior Block (Extension C)

The Junior Block extension has a Gross Internal Area of 817m^2 and is situated to the North of the main building. It is connected to the main corridor through the area of Extension B formerly occupied by the speech therapy room [**Figure 2.10** highlights the layout of this area before it was re-modelled].

The main body of extension C comprises of 8No. identical classrooms arranged in handed pairs and served by dedicated WCs located in 'blocks' opposite each classroom door. The WC blocks are interspersed by break out spaces, through which the rear –West - playground is accessed.

The smaller section of Junior Block Extension C, adjoining the main building, houses the Deputy Head's office, Accessible WC, speech therapy room and SEN office. An additional irregular shaped teaching space, referred to colloquially as the 'bulge' classroom, was added to the West of this section at a later stage in the design & construction process.

Figure 2.10- Plan of Junior Block (extension C). The room layout of main building (extension B) is shown as it was prior to the addition of the Junior Block. Note that the 'Speech therapy' room has been relocated.

The Indoor Air Quality report revealed that, in percentage terms, staff had higher levels of satisfaction with the new extension than with the existing building for the majority of the 28 comfort criteria covered by the BUS methodology used for the analysis **[Figure 2.11]**. Summer, winter and overall comfort levels were all among the responses where the new extension scored higher, which can be taken as a useful indication that the thermal envelope of the new building is performing effectively.

When taken in context of the entire school building, the better performance of the new building did bring unforeseen consequences. One user reported that as a result of perceived differences of temperature when moving between the new extension to the old building, they had to carry a cardigan with them at all times.

Whilst this adaptation measure must certainly be an inconvenience for the user, it should be viewed not as an argument against high performance construction, but that the existing building is in need of additional refurbishment to bring its comfort standards in line. The experience of the users will be documented in more detail at later stages of the report **[Ref Section 4]**.

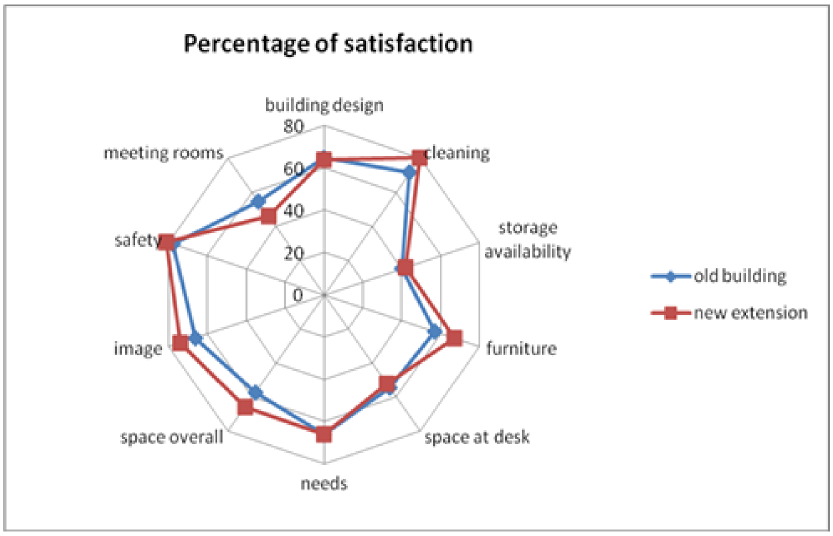


Figure 2.11- Extract from the UCL Indoor Air Quality Report.

Walkthrough notes: Junior Block

- The Junior Block extension was in occupation by September 2010 and so by the date of the walkthrough had been in use for a little over 3 years. During this time, the timber cladding has started to naturally weather to a silver grey and this process has already evened out the differences in shade that were initially visible between upper and lower façades during construction **[Figure 2.12]** . The silvering of the timber has been most accelerated at the base of the lower façade, where the overhanging roof provides the least amount of protection from the weather. The staff seemed aware that the material would weather naturally, although they did question whether this particular pattern was normal. It was explained that in time the weathering effect will even out across the façade.


Figure 2.12: Photographs of West façade, taken Nov 13 during walkthrough (left), & Aug 2010 during construction (right)

- The zinc roof appears to be in good condition and gives a sleek appearance to the building, which is enhanced further by the gentle curve of the building's plan form. The clean appearance of the eaves line has been achieved with a bespoke gutter detail, with a small zinc up-stand set back around 800mm from the eaves that disperses water into concealed rain water pipes. The 800mm strip of roofing in front of the gutter does not have any outlet other than the drip edge detail at the eaves and so during times of heavy rain, it was noted that there is a considerable flow from the roof edge. Additional gutter problems were noted to the roof of the 'bulge' classroom and adjacent to one RWP on the Dining Hall. These issues will be investigated further during the remainder of the study.

- The external lighting was already on at 16:20, when the 5th Nov 13 official hours of darkness (for vehicle lights) did not begin until 16:56 **[Figure 2.13].** It is proposed that the control setting should be investigated further as an outcome of this report.

Figure 2.13: External lighting for the Junior Block extension was on outside the hours of darkness.

2.4 Conclusions and key findings for this section

The Dining Hall has been carefully detailed and the on-site finish is generally to a high standard, although there are examples of cracking and blistering paint. The 'Dutch Barn' wooden arches with matching window frames give the building a soft, uplifting appearance, which complements its use as a space for primary school children. The school like using the space, although in hindsight would have preferred for it to be slightly bigger.

The metal louvres to the South facing glazing detract somewhat from the external appearance. They are clunky in form and sit uncomfortably within the elegant framing of the Dutch barn gable. More importantly, they are not quite wide enough to fully carry out their function. The original design concept for the louvres was for a wider system that filled the full width of the arch [this is indicated in the sketch illustration of the Dining Hall shown in **Figure 2.2**] and would have provided a more suitable design solution to the problem of glare and overheating.

The Junior Block extension with its gentle sweeping curve has a sleek appearance and creates an intimate feeling of space within the playground that it helps to enclose. The building is weathering naturally, and the silvering timber in complimented by the dark grey tones of the zinc roof. There are however signs of peeling and cracking soffit boards outside, and peeling paint inside, suggesting a problem in the specification of finishing materials or poor on site application. Ironmongery and door furniture have broken in a number of locations, suggesting unsuitability for high traffic environments with children.

The design team paid considerable attention to creating bespoke, concealed gutters and RWPs, which give an uncluttered appearance to the building. Unfortunately, the school have reported a number for problems with drainage, both at the Junior Block extension and Dining Hall, suggesting this design was not detailed carefully enough.

Overall however, the buildings appear light bright and pleasant spaces to work in, and the school appear happy overall to be happy with the new buildings. Were it possible to rectify the defects with the drainage and finishing, there would be little to fault the general design of these spaces.

The following wider messages have been drawn from the project stages to building handover, with specific relation to Soft Landings activities.

Soft Landings Stage 1: Inception and Briefing

1. The Soft Landings approach should be adopted at the earliest possible stage and the whole process should be adhered to throughout the building conception and hand over. Picking and choosing elements from the Soft Landings Framework does not provide sufficient benefit to the users.

2. Future occupants of the building should be engaged with the throughout the process.

Soft Landings Stage 2: Design, Development and Construction

1. The ability to use energy modeling software as a design tool may assist in delivering low energy buildings, but time and expertise must be allowed for this.

2. Air-tightness design should be considered early, with sections and plans showing the airtightness strategy.

3. Supervision of the Contractor with regards to air tightness, particularly with traditional procurement, is imperative to ensure test results meet design predictions.

4. Value Engineering should be approached with caution, with more emphasis placed upon the effect that it will have on building performance and usability (for example; the natural ventilation strategy, PV array, additional classrooms).

5. The BREEAM process started later than ideal in this process; ideally the design stage assessment should be completed at Stage D. It is a poor outcome for the project that the BREEAM certification was not completed.

Soft Landings Stage 3: Pre Handover

1. Sub metering needs to be planned and, if cost savings are required, it should be clear what has been value engineered out and, for the team to ensure that all energy implications are accounted for.

2. Continued support for occupants would reduce confusion over controls, as suggested in the Soft Landings Framework. Having someone on site during the first few weeks has been shown to greatly increase the users' understanding of the building.

3. Building User Guides should be clearly illustrated and written with the occupants in mind; jargon and complex information can lead to confusion.

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

Overview: services
The Castle Hill design brief stipulated a BREEAM Very Good rating. A key requirement is that the building must achieve a 60% reduction in CO_2 emissions against a 2002 benchmark. The design team's strategy for achieving this was 45% from enhanced fabric and services and 15% from on-site renewable provision.

- Lighting is controlled by daylight and PIR sensors to rooms that receive natural daylight and by PIR sensors to rooms that do not have access to natural daylight and/or are used intermittently.
- The classrooms and Dining Hall are naturally ventilated using 'Midtherm' stack ventilators controlled by CO_2 sensors. When CO_2 levels are at acceptable levels they are designed to shut, in order to prevent unnecessary ventilation. They are also designed to provide secure night cooling in the summer months.
- WCs are ventilated with heat recovery units to pre-heat fresh air using waste heat from extracted air.
- The buildings are predominately heated by under floor heating from gas condensing boilers.
- To meet the on-site renewables target of 15% a 24.42kWp (176m^2) photovoltaic array was included as part of the works, which was installed on the existing building in order to optimise orientation. A display panel is located in the reception area showing the output of the array.

Overview: Space heating and DHW

The space heating and DHW systems for the whole school are distributed between 3No Plant rooms. Plant room 1 and 2 are located at either end of the main building and plant room 3 was added as part of the construction works for the Dining Hall Block.

The DHW demand for the Dining Hall is met by a gas fired Dorchester Condensing DR-FC Evo 46kW boiler located in the mezzanine level plant room above the kitchen. The Dining Hall has a separate metered gas supply for this boiler, and also to supply the gas fired hobs used for cooking.

The space heating demand for the Dining Hall Block is met by 2No. gas fired Broag Remeha Quinta 85kW boilers, which were installed in plant room 1. Heat is piped via an underground heating trench from the main building to the Dining Hall, where it then feeds into a series of manifolds, supplying an array of different heat emitters:

- The main Dining Hall space, the lobby area, Accessible WC and the stores have under floor heating loops, with additional wall mounted radiators below the South facing picture windows in the hall. The systems are responsive, and able to provide sufficient heating to the spaces.
- The kitchen is heated by an air heater battery, with 2No. additional wall mounted panel radiators.
- The WCs are heated by high level pipe loops.

The space heating and DHW demand in Junior Block (Extension C) is met by 2No. gas fired Broag Remeha Quinta 85kW boilers, located in Plant room 2. The space heating output is delivered via by underfloor heating loops to the classrooms, offices, breakout areas and Accessible WC. Heat output to the remaining WCs is delivered via high level heating loop pipes. The underfloor heating systems are responsive, and able to provide sufficient heating to the spaces

The DHW for the Junior Block extension, after having been brought to temperature by the boiler, is stored in a 160l Hamworthy Powerstock Calorifier in plant room 2. The appliance contains a 100W heating coil to maintain the temperature in the cylinder during periods of reduced demand.

The heating for the existing school building was controlled by a JEL Micro 2000 control system. During the works, a new control panel was installed by Smith and Byford linking the existing controls to the Building Management System, and also to control the new heating circuits. The school have a contract with Smith and Byford for the ongoing maintenance of the system.

In recognition of the fact the thermal envelope of the Junior Block is connected to the main building, and as the works carried out as part of the extension included alterations to the services of the existing building certain observations for the main building have also been included in the remaining sections of this report.

Overview: Ventilation

The Junior Block extension and Dining Hall use a mixed mode system of natural and mechanical ventilation strategies. The main teaching and hall space spaces incorporate Midtherm Windvent passive stack ventilators, to provide a fresh air supply. The exhausts are controlled via a CO_2 sensor with manual override (Figure xx). The classrooms have 2.6 m^2 of operable windows to the East facade, although the high level clerestory West facing glazing is fixed.

The WCs in all areas are ventilated by Vent-Axia MVHR units. One unit meets the supply and extract requirements for each grouped block of three WCs.

Figure 3.1: Trickle vents in the Junior Block classrooms

The IAQ study by UCL noted that teachers kept the doors closed during most part of the occupied period to avoid noise disruptions from the corridor and the playground. The design of the windows incorporates trickle vents **[Figure 3.1]** for minimum fresh air supply; however researchers noted that the occupants were unaware of the use.

Figure 3.2: Window design and operable area in the Junior Block Extension

Figure 3.3: Mechanical exhaust with manual override in the Junior Block Extension

Overview: Energy metering

In order to satisfy the BREEAM Ene 2 criteria for the target of Very Good, the Castle hill team were required to install a sub metering system to monitor the 'substantial energy uses' within the building. The requirement was met using pulsed type meters installed by Smith & Byford and connected via the school's existing IT network to a dedicated BMS PC and monitor screen. The screen was installed in the main reception, with software provide to enable the users to track their energy usage within the building.

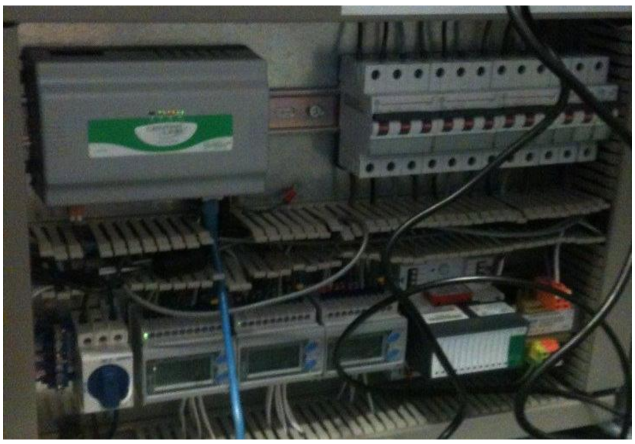


Figure 3.4: Pulsed type meters in the plant room provide a record of energy consumption, although labelling appeared incomplete during the building walkthrough.

The system takes data readings of gas, electricity and hot water usage every 15 minutes, and was provided with an ADSL connection to enable remote access. The metering strategy is split between mechanical sub metering for the gas supplies and electrical sub metering.

For cost reasons, sub meters were not installed the Existing school building. The metering was installed with the primary purpose of meeting the BREEAM credits and the existing school did not form a part of the BREEAM assessment.

Mechanical metering

Metered data for each of the school's three gas supplies are collected remotely by the Utility company, which enables it to bill using actual readings. The BPE project team has been able to gain access to this data (with permission of the school) via an energy brokerage group that manages the school's supplies.

The Dining Hall, the Junior Block Extension and main building all share their supplies, so it is not possible to use utility data alone to separate out the energy usage for the new buildings. Mechanical sub metering with three pulsed gas sub meters was installed to monitor the consumption of the new buildings.

Pulsed type sub meters take separate readings of m^3 gas for heating and hot water in the Dining Hall, and combined readings for heating and hot water in the Junior Block Extension. Cooking gas is calculated separately, as a subtraction of Hot water usage from the utility supply to the Dining Hall. The boilers which provide piped heating for the Dining Hall are located in plant room 1 within the main building, so the sub meter for the Dining Hall heating is also located here.

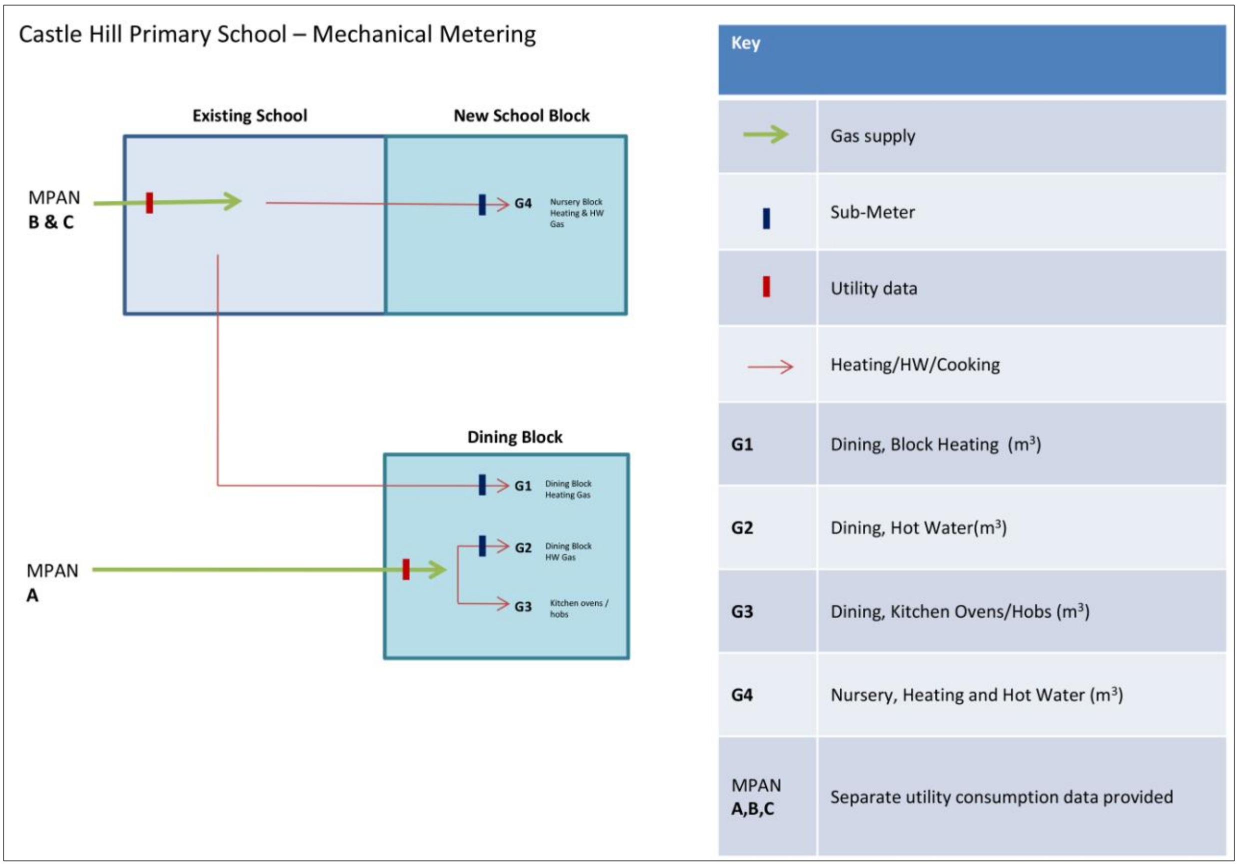


Figure 3.5: Sub meter tree diagram for the gas and heating at Castle hill

Electrical metering

There are two electrical supplies to the site, the first of which serves the combined demands of the main building and Junior Block extension, and the second of which supplies the Dining Block. This arrangement is slightly more straightforward than the gas metering, as the whole of the Dining Block usage can be attributed to a single supply. The Junior Block extension is nonetheless reliant upon electrical sub meters to apportion loads correctly to this area of the building.

One notable weakness in the sub metering strategy across the various supplies is the reliance on manual calculation to determine residual ‘unregulated’ loads. An example of this can be seen in the Dining Hall, where neither the kitchen electrical, nor kitchen gas supplies have a dedicated sub meter. In theory, this does not cause a problem; consumption is the residual amount left after subtracting the consumption of other sub metered loads from the utility supply meter. In practice, if there is a problem with either the utility meter or any of the sub meters, it is not possible to cross reference one with another to check for correlation. There is always, in effect, a hypothetical ‘missing meter’ which prevents this cross check from happening.

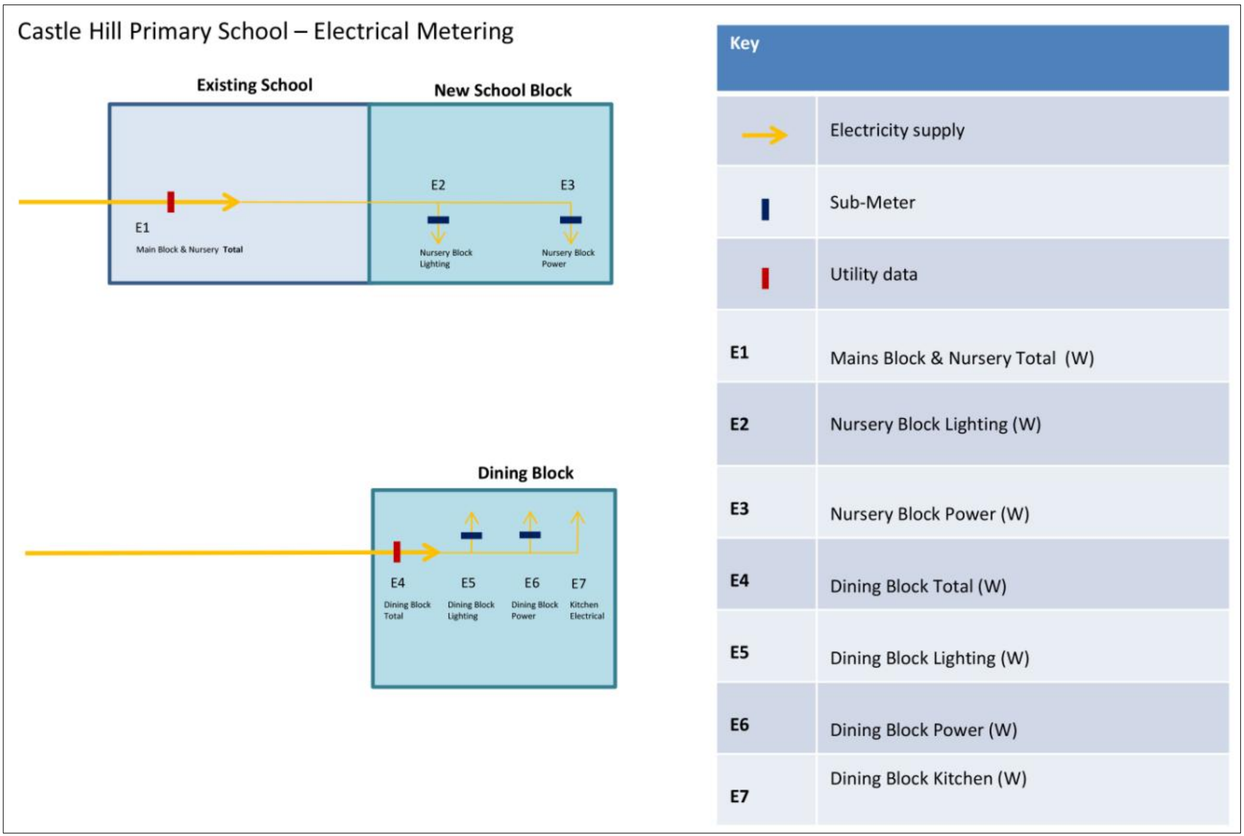


Figure 3.6: Sub meter tree diagram for the electricity supplies at Castle hill

The missing meter conundrum has the effect of reducing the level of confidence that any client or energy assessor can place on their energy metering equipment. They become reliant on claims on manufacturer/installer claims that metering is installed correctly.

3.2 Conclusions and key findings for this section

The metering strategy at Castle Hill has been designed to be cost optimal, in order to meet minimum requirements and has not been tailored to assist the school in understanding its energy usage. The metering was paid for by the client as part of the building contract in order to gain BREEAM certification, but did not in fact request it overtly as part of the brief. Between the project team, BMS installer, and client, it appears that there was not one single party that took sufficient responsibility for ensuring that the system was commissioned correctly or that the data was recorded accurately. The errors in the system had not been spotted at commissioning stage by the installer, the project team or the client, and it became encumbent on the BPE team to resolve the problem, though it was unfortunately only picked up later on in the study. By this point the system was out of warranty, and the BPE team did not have a direct contractual link with the metering company to enable any remedies to be made to the system. This point serves to stress the importance of timely commissioning checks.

Whether or not buildings are assessed for their 'total' energy consumption in the future, unregulated loads will form an increasingly significant fraction of building energy use as fabric improvements continue. Good metering is dependent upon specific wiring arrangements and is difficult to retrofit at a later date. Making the provision for better metering strategies of new buildings of today will facilitate the future challenges of building owners. An additional level of joined up thinking is required, and is notably lacking in the current approach.

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. Figures, images and data could be included in this section where it supports the background to developing a view of causes and effects.

4.1 BUS Survey

The Building Use Studies (BUS) Survey is a tool developed by the Usable Buildings Trust and is a method for obtaining professional-level feedback data from occupants in a quick and thorough manner. The questionnaire has been used in more than 600 buildings in post occupancy evaluations and the database draws from 380 buildings in 17 countries. From this database, benchmarks are derived to allow comparisons between different buildings and their perceived building performances.

The results in this section are taken from two separate surveys at the start and end of the BPE monitoring period. The survey responses were collected on site using official BUS forms, and subsequently processed by Arup, in order to compare the building's performance to the benchmarking database.

BUS 2012 overview:

The first survey was carried out in 2012 by researchers at UCL, concurrently with their Indoor Air Quality study for the new buildings. This survey was carried out within new areas and existing areas of the school concurrently and was used to make correlations between the two within the IAQ report. The UCL IAQ report drew useful conclusions but did not include formal data processing from Arup. In January 2013, the data from the 2012 survey was sent to Arup for formal processing, the results of which were the subject of further analysed by the BPE team.

The first survey was given to 68 staff at the Primary School and 44 were completed, giving a 65% response rate. This is lower than the 'Best Practice' response rate of 80% for buildings with 30-500 staff (Leaman, Stevenson; 2009). Of the 44 collected surveys, 19 were from staff working mainly in the new extension, with 21 in the existing classrooms and 8 administration staff. A number of respondents missed a page in the survey, and therefore some questions have a lower response rate. The further analysis separated the new extension from the existing classrooms and administration staff.

BUS 2014 overview:
A building walkthrough was conducted by the BPE team in November 2013 in order to gather first hand evidence of the building in operation and record additional qualitative observations of performance from staff. The BPE team used these findings in conjunction with other studies, such as the UCL IAQ/overheating reports, to make a series of recommendations that the school could implement to improve its energy use. These recommendations were recorded in the 'feasible improvements' plan.

After the building walkthrough, a second BUS survey was conducted by the BPE team in June 2014. The date was chosen toward the end of the two year BPE monitoring period, in order that any differences could be noted in the building's performance resulting from the 'feasible improvements plan.

By the time of the BUS survey, the school had already carried out certain feasible improvements, for example agreeing a new contract with the sub meter installation and maintenance company and testing of the PV array. However, by the point of the survey, the school had not yet proceeded with additional cost items such as re-commissioning of the ventilation system. As such, there were no alterations to the building environment controls which would have affected the user experience of the spaces as recorded by the BUS.

The survey was given by ECD in June 2014 to 41 staff at the Primary School, of which 36 were completed, giving an 88% response rate. This is above the 'Best Practice' response rate of 80% for buildings with 30-500 staff (Leaman, Stevenson; 2009).
On receipt of the survey, the staff were advised that their responses should be focused only on their experience of the Junior Block Extension and New Dining Hall areas, i.e. only the areas covered by the TSB study. Staff members who did not spend the majority of their time working in the new buildings were excluded from the survey, in order to better focus on the outcomes and in order to prevent any confusion made between different school areas when completing the form.

A large number of staff chose not to identify themselves or their department on the survey form, however it is known that there were respondents from every department, namely: teaching and support staff, administration, catering and facilities management.

UCL Analysis of 2012 survey

This section is summarised from the BUS findings within the UCL IAQ report ***[Appendix 2]****, which compares BUS responses for the Junior Block extension with the Existing school building. All results relate to the occupancy period (Spring 2012).*

The study looked at subjective BUS responses from staff and children. Out of 48 targeted school personnel a total of 30 completed and returned the questionnaire resulting to a response rate of 63%. The majority of school personnel were women and this was reflected in the respondents, who were all females but one.

Table 4.1: information on school personnel responded in the survey

	Old building		**New Extension**	
Gender	11 females	0 males	18 females	1 male
Age	9 over 30	2 under 30	14 over 30	5 under 30
Average Days per week in building	4		4 - 5	
Average Hours per day in building	7.8		8.3	
Journey to work	15 minutes		17 minutes	
Main mode of travel	car as a driver		car as a driver	

A monitoring survey of physical, chemical and microbial parameters together with an occupants' survey was performed in Castle Hill Junior Block Extension and the adjacent Existing Building. Indoor Environmental conditions and occupants' subjective responses in the two schools were compared.

According to school children, a satisfactory school environment was related to acceptable IAQ and thermal comfort. IAQ was found to be positively correlated to thermal comfort and had a moderate negative correlation to stuffy air and odours. Therefore odours in the classroom contribute directly to the dissatisfaction of children with the school environment. Satisfaction with the school environment was also related to personal factors such as how friendly the school was and negatively related to stressful working conditions. A friendly school had a positive correlation with thermal comfort and lighting levels, and a negative relationship with noise levels. Noise levels, poor thermal comfort conditions, perception of stuffy air and odours were also contributing to a stressful school environment.

The direct access to the playground provided purge ventilation during the breaks preventing the build-up of pollutants; however it might have significant energy implications. The strategy employed to provide fresh air supply with low inlet and extraction from a high ceiling is an excellent approach for maintaining good IAQ. A disadvantage of the mechanical exhaust included the relative complexity of the use by the occupants.

Teachers were not aware of the use of the mechanical exhaust due to inadequate briefing. Moreover, the controls were located away from the teacher's desk possibly discouraging the use.

The high concentrations of CO2 noticed in the spring season in the Junior Block classrooms indicate that an inadequate setting in the operation of the high level exhausts was applied. The efficiency of the exhaust system was tested with smoke tube tests in the non-heating season. It might be worth designing operable windows at the high level instead because the teachers are more familiar with their manual operation.

Satisfaction overall

Satisfaction in the new building was higher for most of the investigated factors **[Figure 4.1]**. Satisfaction among school personnel in both schools was higher for safety and cleaning varying between 70% and 80%, while in both schools they were less satisfied with the storage and meeting rooms' availability.

The overall satisfaction with the building design presented a mean of 4.5 in the scale from 1 to 7 (7 being the most satisfied) in the primary and nursery school **[Figure 4.2]**. Re-occurring comments in the questionnaires included the length of the building and the lack of storage space and space for intervention groups.

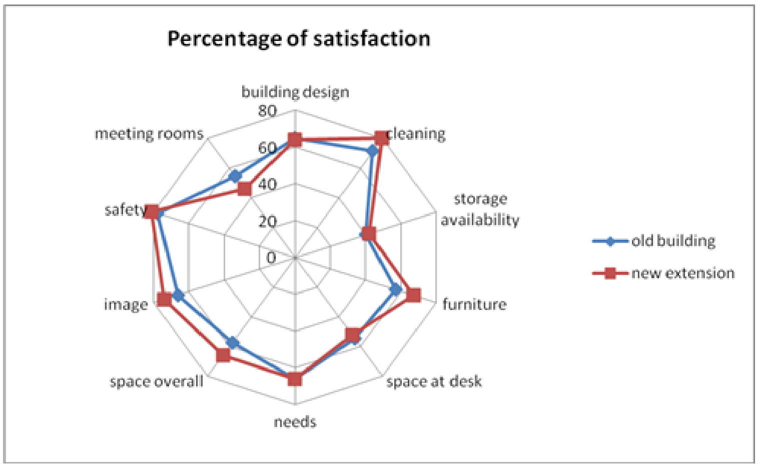


Figure 4.1: satisfaction levels in the primary and nursery school buildings

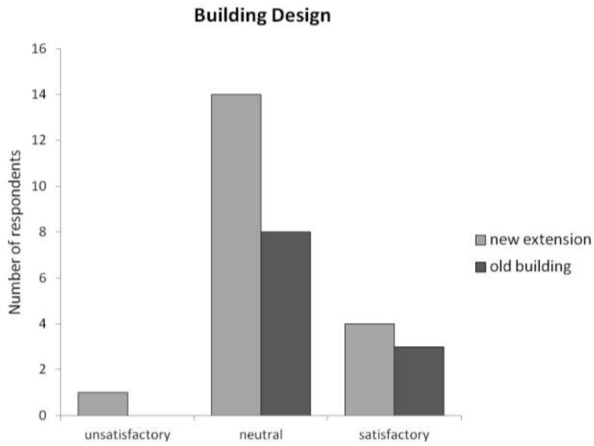


Figure 4.2: satisfaction of staff with the building design

Satisfaction of school children with the school was similar to school personnel scoring on average 6.82 out of 10, with higher satisfaction expressed during the non-heating season. Satisfaction ratings between classrooms were similar.

Satisfaction with Indoor Environmental Quality (IEQ)

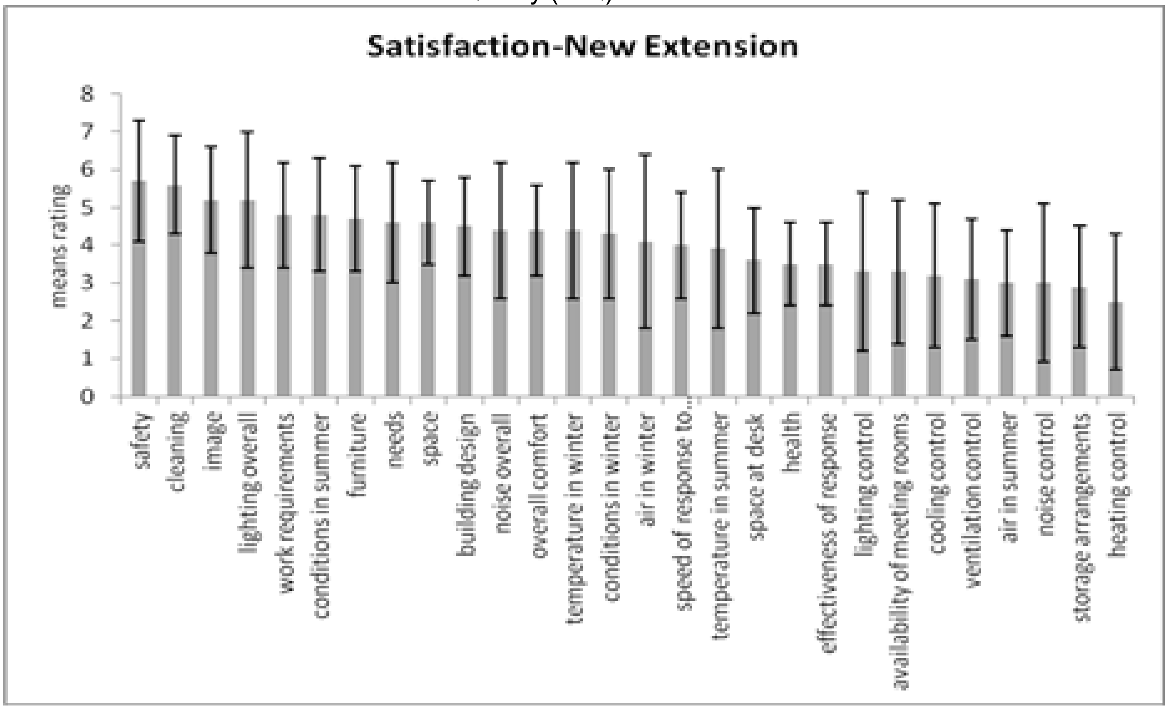


Figure 4.3: Mean rating and standard deviation of school personnel satisfaction with the Junior Block extension

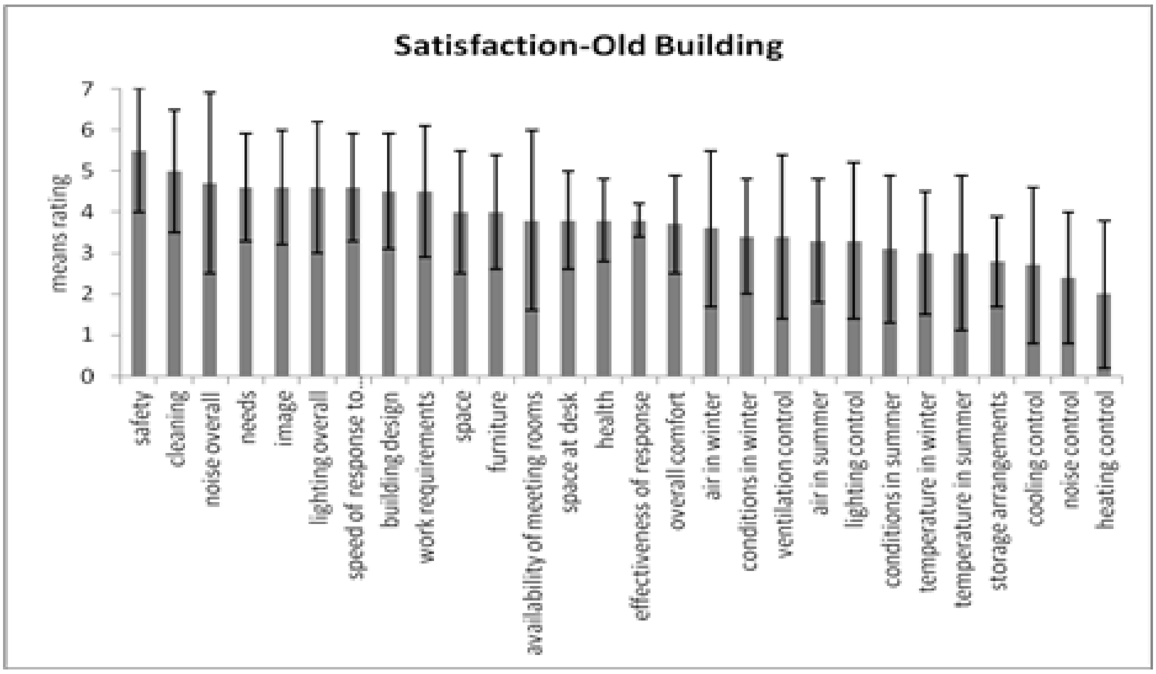


Figure 4.4: Mean rating and standard deviation of school personnel satisfaction with the Existing Building

The mean rating and standard deviation of all the variables examined under occupants' satisfaction for both buildings revealed that they felt more satisfied with the safety and cleaning of the building and less satisfied with the fact that they did not have control of the heating system. Moreover, they were more satisfied by the conditions during winter, including temperature and air quality, than during summer at both buildings.

Satisfaction with lighting was rated higher than any other environmental parameter in both seasons by school children. Students also felt satisfied with indoor and outdoor air quality in both seasons. Winter IAQ and lighting were rated higher than spring conditions. Students were satisfied with thermal comfort in both seasons, however they appeared less satisfied with odours and stuffiness in the classroom.

ECD analysis of 2012 and 2014 data

This section analyses the Arup benchmarked results of the 2012 and 2014 surveys, in order to compare the formal BUS analysis for the buildings at Castle Hill with other buildings in the Arup database. The analysis in this section begins with a discussion of each summary variable as collated in January 2012 and 2014. **[Figure 4.5-6]** Full Arup analysis of data and comments can be found later in the report. **[Appendices 7-10]**

Summary (Overall Variables) 2012

Figure 4.5 summarises the 'overall' comfort variables from the BUS analysis. It should be noted that the summary overall variables in the figure are an average of all areas of school, including the existing building and new constructions. The results are broken down by area during the remainder of this section.

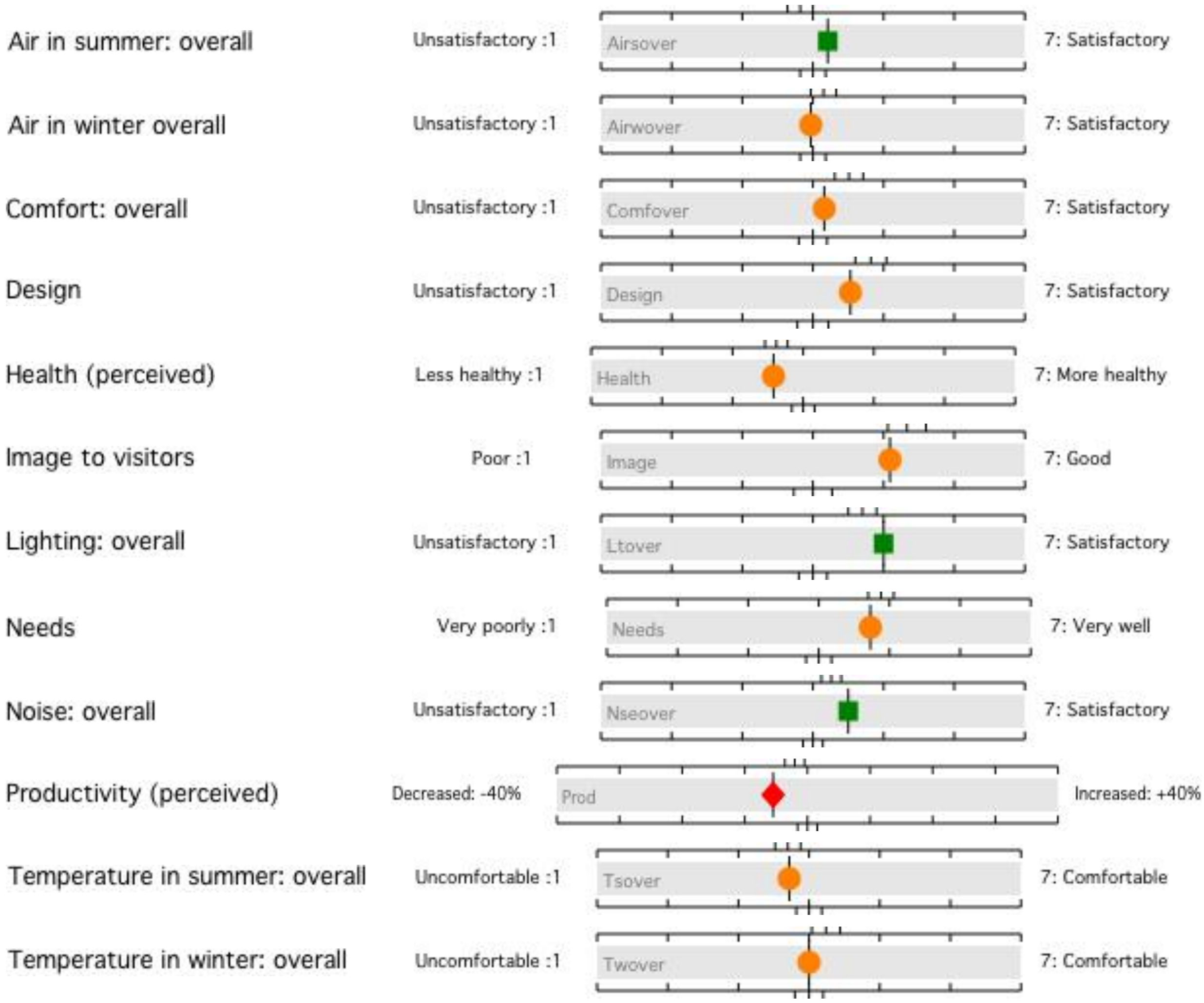


Figure 4.5: BUS 2012 summary of occupant survey, for existing and new classrooms showing key results and coding, following a traffic light system (green meaning positive, amber average, and red negative).

As seen from above the air quality in the summer, lighting and noise are all perceived as good, scoring in the 3rd or 4th quintile and scoring well against the other surveyed buildings. Productivity (perceived) is scored very low, however, with 60% of other buildings surveyed perceived as more likely to increase user productivity but this could also be the fact that the overall project is taken into account (Existing-New).

Summary (Overall Variables) 2014

The 2014 summaries **[Figure 4.6]** include only the new classrooms and Dining Hall. Of the 12 the majority (8) are shown as Amber, indicating an average result when compared against other surveyed buildings in the database. Of the remaining 4 summaries, 2 are shown as green, ‘Image to visitors’ and ‘Lighting’, indicating that these variables are rated positively. Scores for these variables are in the 3rd and 5th quintile respectively. The final 2 variables are shown in red indicating that these variables are rated negatively, ‘Air in summer’ and ‘Temperature in summer’. 67% of other buildings surveyed in the database are perceived as having higher summer air quality, and 70% of other buildings as having more comfortable summer temperatures.

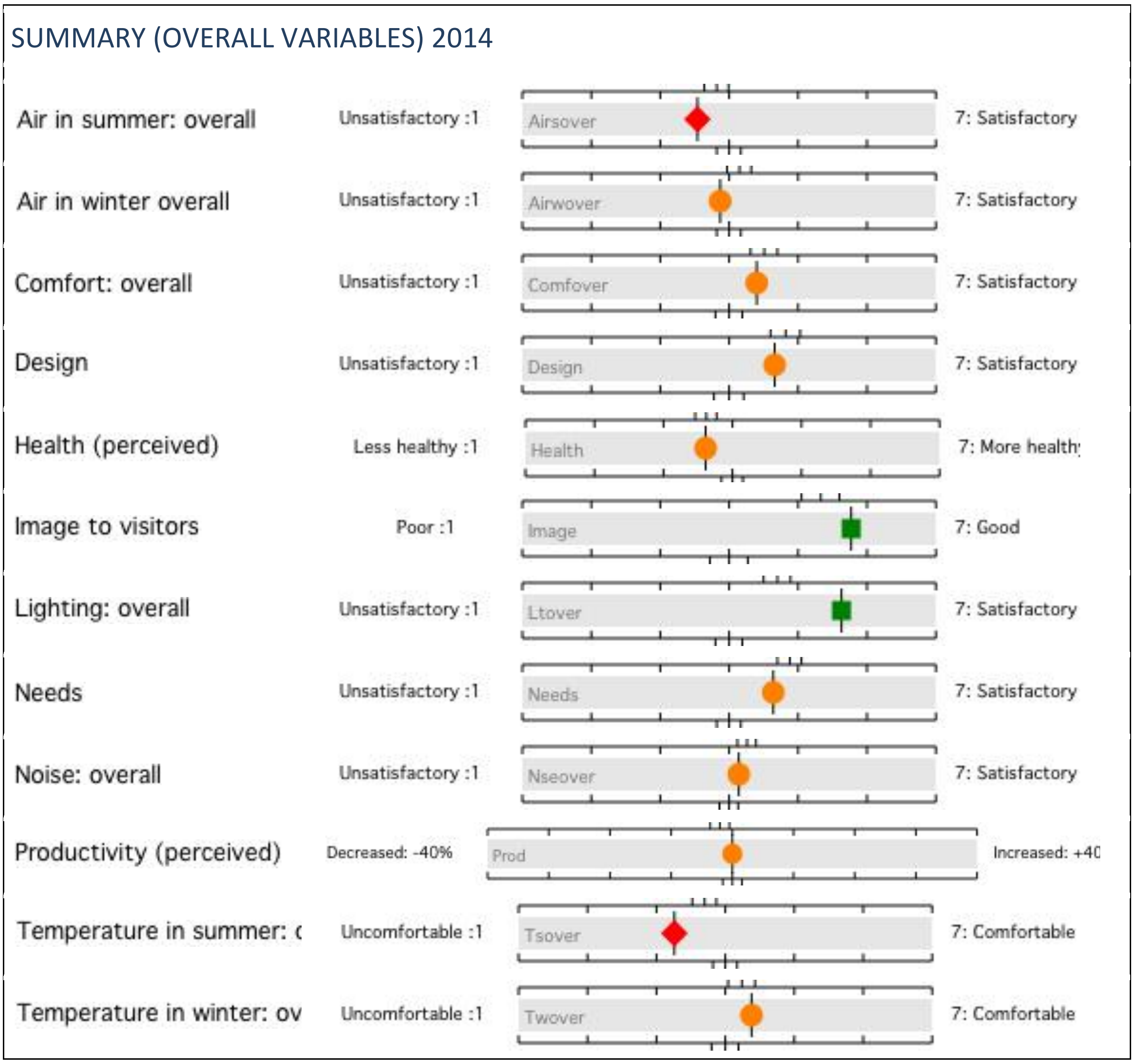


Figure 4.6: BUS 2012 summary of occupant survey for new classrooms, showing key results and coding, following a traffic light system (green meaning positive, amber average, and red negative).

Perceived Comfort Levels

Further to the summary results above, the data was separated between the Existing Classrooms, Administration rooms and New Nursery Classrooms, to analyse the responses in more detail. As has been noted, the 2014 BUS focused only on the new areas of the school subject to the TSB BPE analysis.

During both summer and winter, the users of the existing building are moderately comfortable compared to the Arup benchmark. The new Classrooms are less comfortable during the winter. This has been seen in naturally ventilated schools, (Fitzgerald; 2012) with overheating and inadequate ventilation in winter.

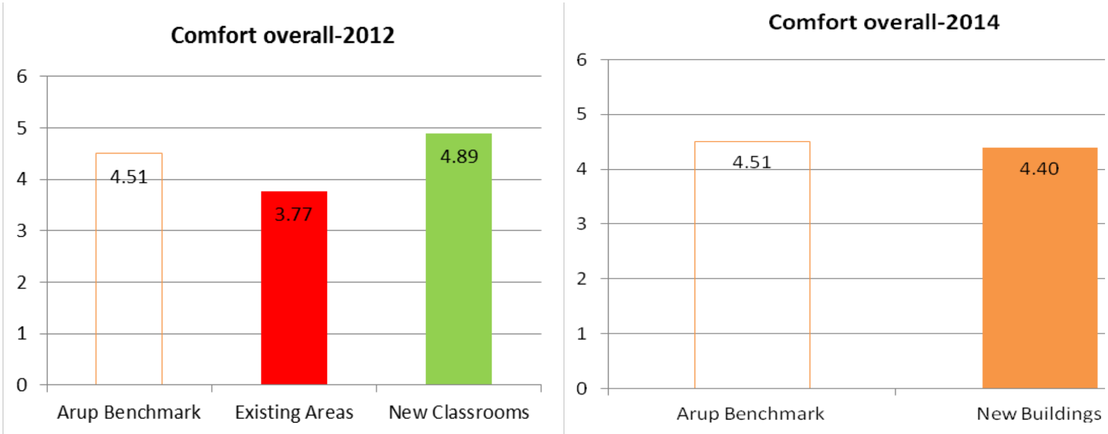
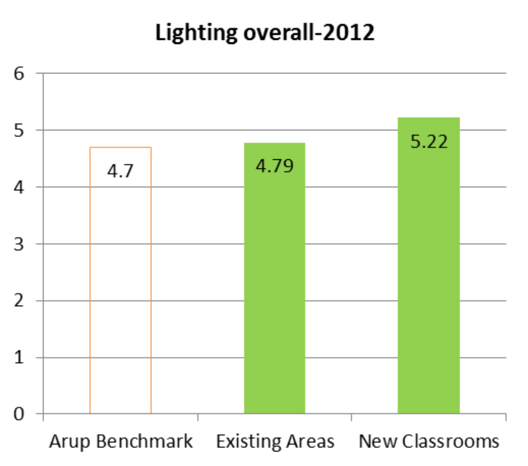


Figure 4.7: Comparison of Perceived Comfort levels during summer and winter,

Lighting

Lighting was of particular interest to the Design team, as some effort was made to ensure a good quality of light was achieved and solar gains were reduced. A study by UCL was commissioned at Design stage, with the Heliodon and artificial Sky used for modelling. The results show that, except for the comments mentioned later in this report, the overall lighting design was well received by the users.

On both surveys the overall lighting was received well with a slight rise in 2014 as see from **Figure 4.9**. In both the 2012 and 2014 surveys glare from the sun and sky were commented on as negative aspects of the building, but, despite these comments, the users described the lighting as satisfactory overall. It should be noted that the lighting score for the new classrooms was better in 2014 than in 2012 and both scores were better than the existing buildings and the Arup benchmark. It is possible that the improvement between 2012 - 14 is a result of additional understanding of lighting controls on the part of the users. The caretaker noted during the building walkthrough that the lighting controls had not been fully understood when the building was first occupied, but that through informal training, the users became better informed. Whilst the improving score for 2014 is therefore a positive indicator that staff are happy with the lighting, it is also likely that statistical variations in sampling also played a factor.



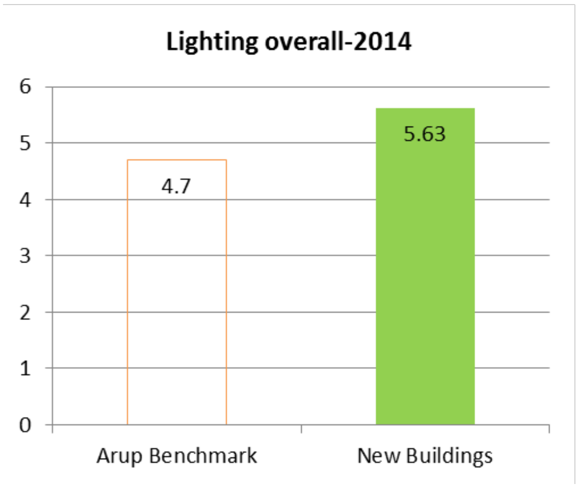
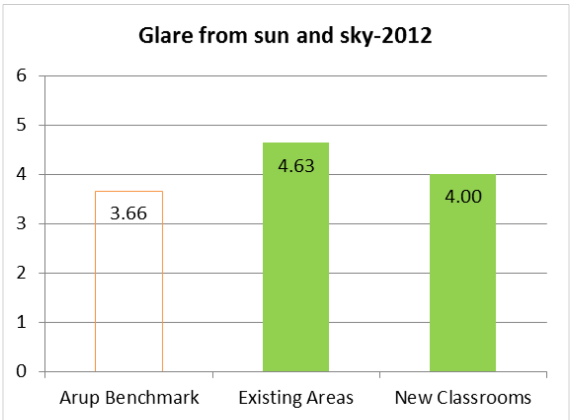
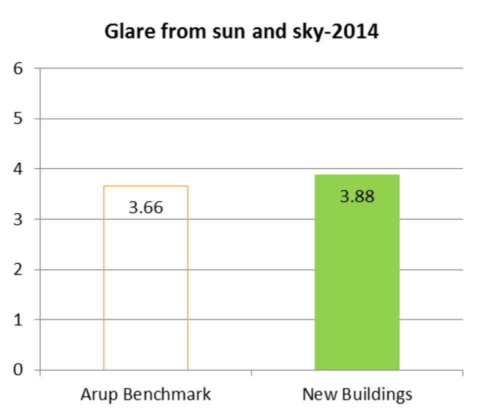
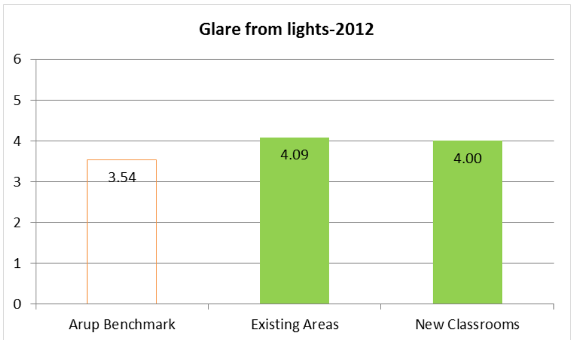


Figure 4.8: Charts showing satisfaction with lighting across all spaces







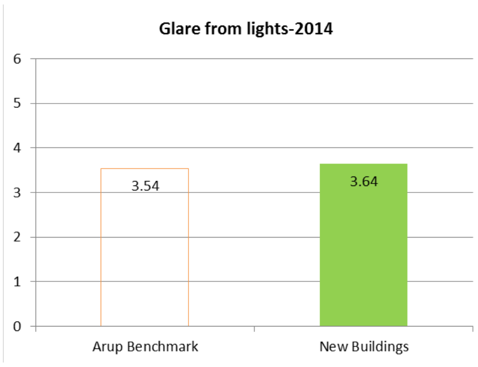


Figure 4.9: Glare from Sun and Sky, and artificial light

Air Quality

There was a marked difference between the two surveys when it came to the overall scoring for air quality.

In 2012 the overall the satisfaction levels were above the average both in winter and summer. Nevertheless, satisfaction levels were lower within the specific air dryness and air stuffiness categories.

In 2014, overall, the occupants deemed the air quality closer to the 'unsatisfactory' mark, than the 'satisfactory'. In winter similar results were obtained for air quality, though the overall satisfaction was slightly better. It is possible that the poor air quality results are related to problems with drainage, which - as has been noted elsewhere in the report - often result in smells from some of the classroom sinks.

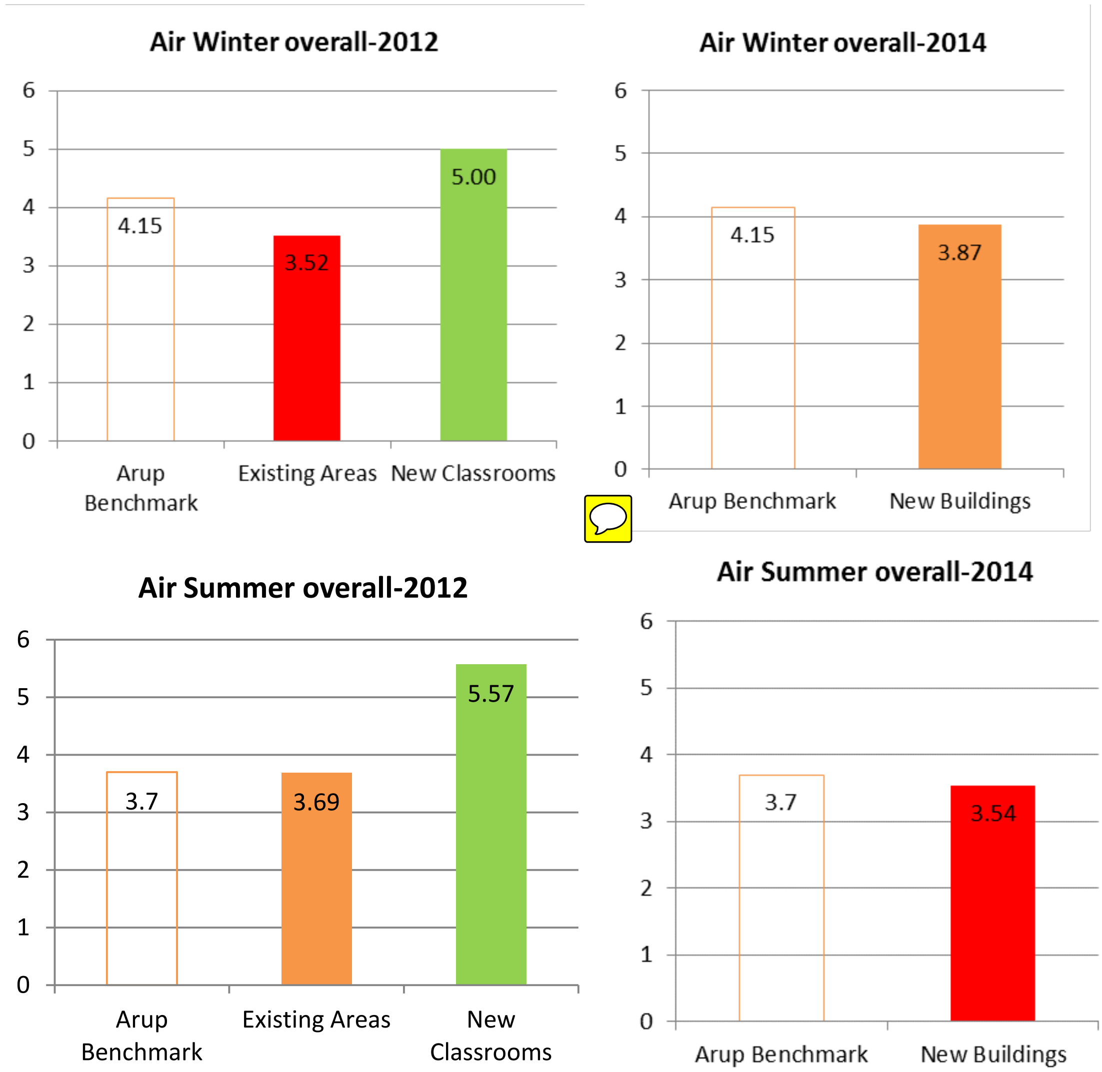


Figure 4.10: Perception of Air Quality overall during summer and winter

Temperature

The temperature satisfaction levels appear to have dropped significantly between the 2012 and 2014 surveys. The 2012 results for the new classrooms were substantially better than the existing areas in the school and the Arup benchmark in both winter and summer overall temperatures. By 2014, the new classroom temperatures in the winter were still perceived as better than the existing areas, and the Arup benchmark, but now only by a small margin. It is unclear what may have caused the differences here, although it is possible that the problem is linked to the cold down-draughts from vents in the classrooms [discussed further in

Section 7]. Despite these concerns, it is encouraging that the new buildings are still considered more comfortable than either of the comparisons.

The temperature in the summer results on the other hand, demonstrate a much more significant drop in perceived comfort between 2012 and 2014. Whilst the 2012 result for the new classrooms was better than either the Arup benchmark or the existing school, by 2014 its result was the poorest. It is possible that the results were influenced by the especially hot summer of 2012, one of the ten hottest UK summers on record. Changes of staff or sampling differences may have also been a factor in the change of opinion. The wide degree of variation between the two data samples indicate changing opinions of the comfort in the building and suggest that further BUS studies in subsequent years may be appropriate.

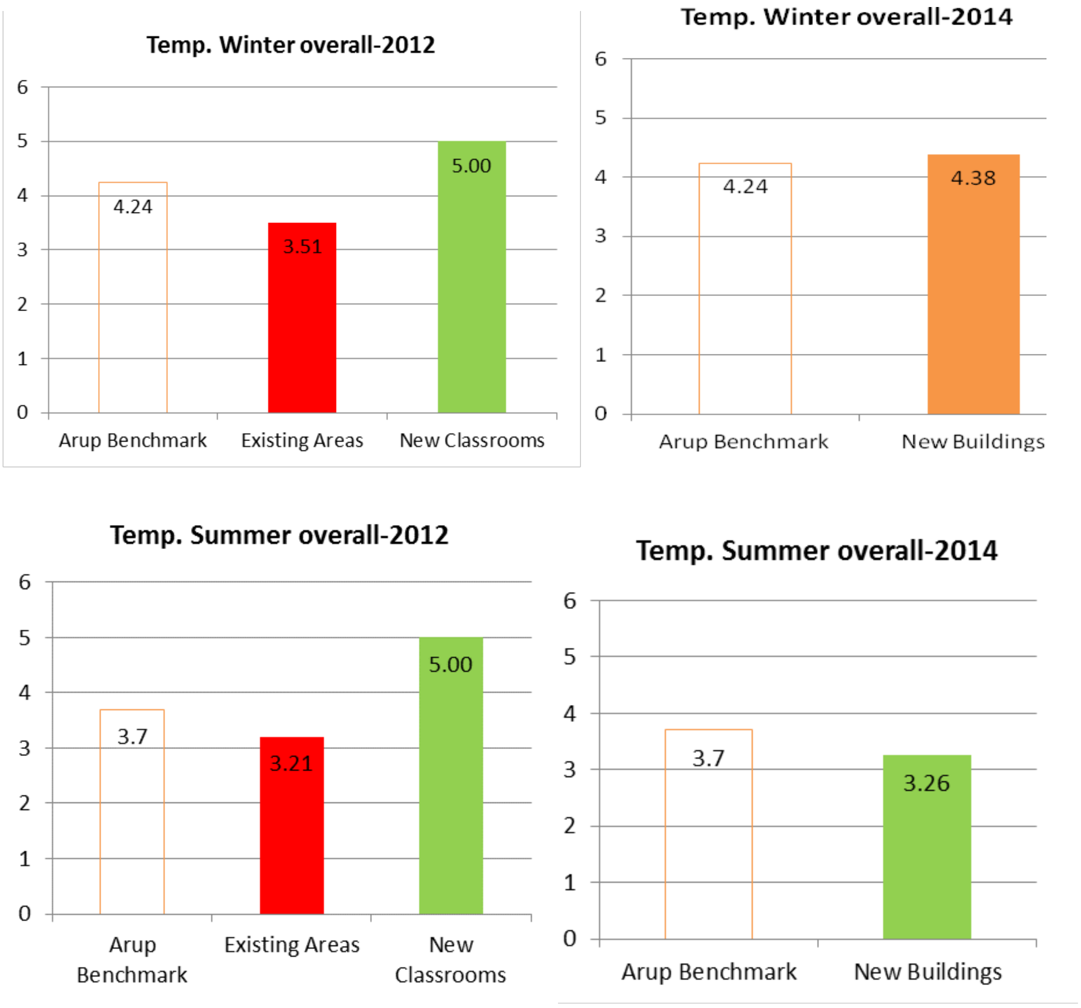


Figure 4.11: Figures showing separated data demonstrating temperature satisfaction levels in both summer and winter.

Noise

The noise satisfaction level seems to have fallen from the 2012 survey to the 2014 survey to the point where it is almost not possible to differentiate between the new and existing areas of the school. It is difficult to see what differences could have occurred in the building fabric between 2012 and 2014 that could have caused such a significant change in attitude. It is more probable in this instance that the changes are a result of a difference in the usage or management of the space.

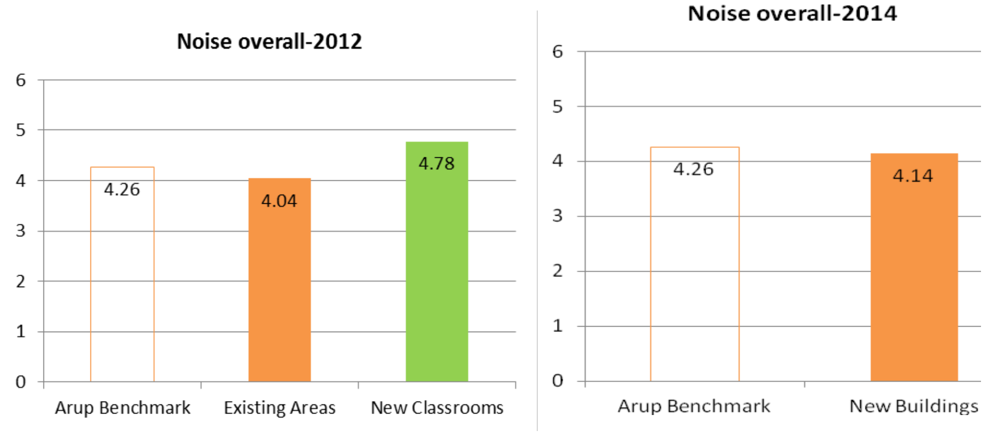


Figure 4.12: Noise satisfaction responses level.

Productivity

Perceived productivity for the whole building was measured as -5% in 2012, which is significantly lower than the Arup Benchmark. When the responses are separated, it can be seen that the existing building led to a less productive workspace than the new building, but both are still lower than the average, and would be situated in the 2nd lowest quintile of buildings surveyed.

Productivity in 2014 seems to have improved significantly from 2012 to the point where it surpasses the Arup benchmark in the existing school as measured in 2012. It is an encouraging result for the school, and perhaps one which might not have been expected, given that a number of the indicators for comfort have fallen in score over the same period. It may be that other factors outside the building, perhaps social or economic have influenced the users' judgement of productivity.

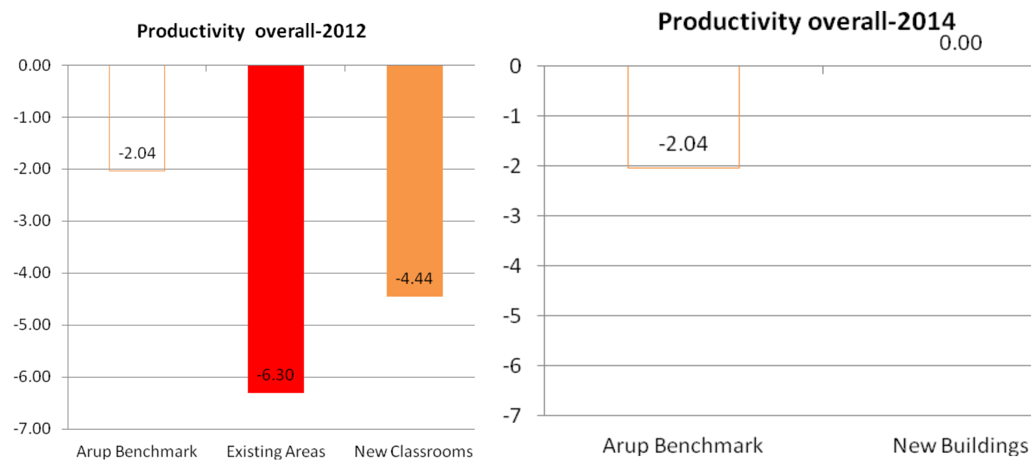


Figure 4.13: Perceived productivity responses level.

Health

From the 2014 survey the satisfaction levels on the health impacts of the new building are higher than the 2012 and almost equal to the benchmarks. The results are relatively stable over the two surveys, suggesting that the opinions of staff have remained reliably consistent for all newly constructed parts of the building.

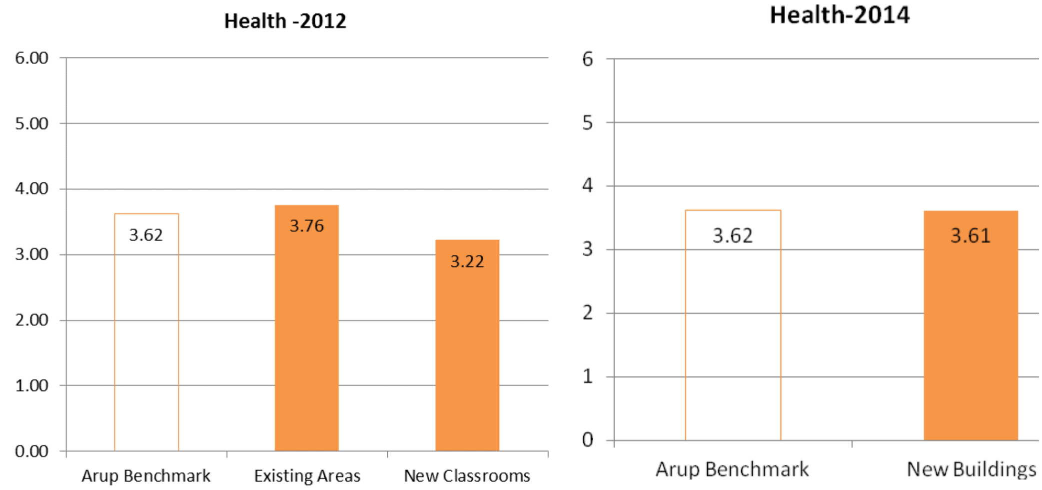


Figure 4.14: Health effects responses.

Design and Image

Satisfaction from the design in 2014 appears to be slightly lower than the 2012 levels and still lower than the benchmark. However, in a slightly conflicting message, users also responded to note that the new classrooms portray a positive image for the school to visitors, higher than for existing areas and higher than the Arup benchmark. The 'image to visitors' category was rated higher in 2014 for the new buildings. This suggests that the design of the Dining Hall has a particularly positive aspect on visitors.

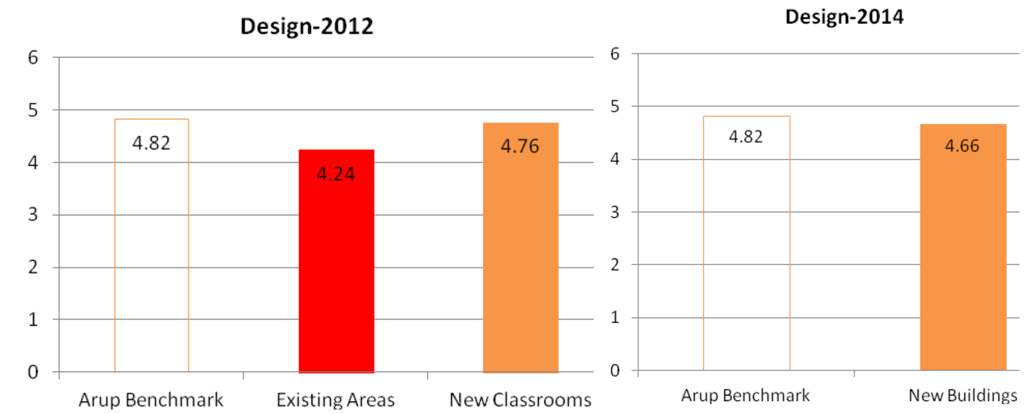


Figure 4.15: Design satisfaction level.

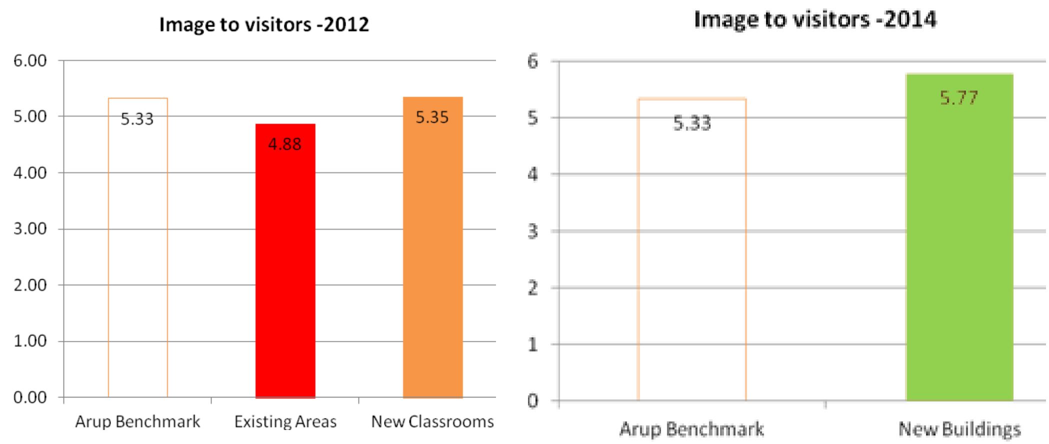


Figure 4.16: Image to visitors.

Survey Comments from 2012 survey

*Refer to **[Appendix 8]** for all qualitative survey answers.*

The survey collected qualitative feedback from the staff. The key comments recorded were related to:

1. Space – Storage, specialist areas, or first aid spaces
2. Temperature – hot and cold, and variations between areas
3. Design – length of extension, light
4. Health – perceived air quality, headaches and asthma

1. Space
The feeling of space was mentioned as a positive. However, storage and meeting rooms were identified as potentially lacking in the school. This could be noted for future projects, to allow for extra space in the Client's Brief, though this would of course have an impact on costs.

> *"Cramped office space, cannot keep all my work to hand. Because of shape of building can take some time to find other people."*

> *"Lack of working space. Wasting time trying to find somewhere to work with individuals."*

2. Temperature
One user commented that there is too much heating in winter and others described having to change clothing between areas of the School.

> *"Building can be very hot in summer and stuffy and very cold in winter unless additional electric heaters are used."*

> *"Continually carrying cardigan to go on/off in various areas of school. I have to dress in layers of thin clothing next to sun even in very cold winter."*

3. Design
Many of the comments mentioned the length of the building, and distance between spaces leading to wasted time moving between them. This will be fed back to the design team, although it should be noted that the position of the extension was investigated thoroughly at an early stage of the design.

> *"The building is modern although it could have been much bigger. More rooms would have helped in other areas of learning i.e. art room."*

> *"Too long - my time and children's time wasted from one end to other."*

4. Health
Some staff members mentioned headaches and one mentioning asthma and chest infections: both are potential indicators of poor air quality. Though the CO2 levels measured by UCL never exceeded the maximum levels, the study was only able to monitor air quality for a short period of time in relation to the full year. CO2 levels may have been higher at points outside the study and though CO2 is a good proxy of air quality, it is also possible that other factors could be the cause for these complaints. Given that the BUS survey indicated that the school was in line with the benchmark (with a score of 4) this is an interesting result, and suggests that these individual responses are not strongly correlated with the general trend.

> *"If it becomes too warm then it creates headaches and tiredness"*

> *"Because of heat, wear summer type clothes all year."*

Survey Comments from 2014 survey

*Refer to **[Appendix 10]** for all qualitative survey answers.*

The survey collected qualitative feedback from the staff. The key comments recorded were related to:

5. Space – Storage, meeting room areas and learning spaces in corridors
6. Temperature – temperatures in summer and heating control
7. Design – shape and size of rooms
8. Health – perceived air quality, headaches and asthma

5. Space

The feeling of space was mixed between respondents. Space was noted as a positive factor in comments from 4 of the respondents, although a further 7 noted that the building was too small, and a final 1 gave both positive and negative comments. Storage was identified as potentially lacking in the school, with 7 of the 9 comments received indicating that these were limited or insufficient. Meeting room spaces were also felt to be lacking, with 3 comments received relating to limited meeting room space.

> *"Very little storage for equipment and stationary."*
>
> *"[Works well response] Having available space outside the classroom to teach smaller groups."*
>
> *"Cramped areas - too small to accommodate number of chairs and tables, difficult to circulate classroom effectively."*

6. Temperature

Comments tended to be focused on summer temperatures, or control of winter temperatures. One mentioned lack of control of temperature in winter. During the building Walkthrough it was noted that there had been a fault with the under floor heating, which remained on constantly in the bulge classroom after installation. This problem has now been resolved.

> *"It's a sun trap or very uncomfortable in the summer."*
>
> *"Generally the classroom is stuffy and too warm. Measures to cool classroom down, e.g. vents are ineffective."*
>
> *"Heating unable to be turned off sometimes."*

7. Design

Many of the comments related to the shape and size of the building. Some liked the pitched ceilings, and the attraction of the design whilst others thought that the classrooms were an odd shape and too small. The learning spaces in the corridors also drew mixed responses, with some liking the flexibility they offered and others implying that they were too noisy and it would have been better to have dedicated spaces for learning.

> "The design is visually attractive but too small."
>
> More attention to "look" than consideration for use e.g. computer infrastructure cupboard taken out of teaching space to make the corridor look pretty.
>
> "Like the high pitched ceiling of the classroom."

8. Health

Two staff members mentioned asthma, which is a potential indicator of poor air quality. Though the CO2 levels measured by UCL never exceeded the maximum levels, other pollutants could be a contributory cause for this. A further staff member mentioned temperature extremes as a cause of health concerns. These issues will be raised with the school for H&S reasons.

"In the past year I had developed asthma."

"Temperature extremes."

4.2 Conclusion and key findings for this section

Conclusions from the 2012 results

The analysis by Arup shows that:

1. Air quality in summer is perceived as slightly humid and smelly, with some draughts. The occupants, however, deemed it good overall. In winter similar results were obtained, though an average satisfactory result was given.
2. The users felt they had little control over the heating and ventilation controls.
3. The lighting was seen as a positive feature of the building, though glare and artificial lighting were negatively received.
4. Noise levels seem to have been a problem, though again overall satisfaction was high.
5. The users' productivity is perceived to be much better in the 2014 survey than the 2012 survey in the building.
6. Temperature in summer varies and can be uncomfortable and hot. In winter, the conditions can be too cold and again vary during the day.

Further interpretation of the results into separate areas shows that:

1. The occupants commented on the temperature being particularly warm in the new extension and colder in the existing building. This led to one occupant changing clothing accordingly.
2. The lighting was good in all areas of the building.
3. The lack of draughts in the new build suggests fewer thermal bridges and a more air tight building.

The comments revealed that the members of staff feel the building is generally a pleasant space to work in, though a number of variables were rated as satisfactory or poor, suggesting that significant improvements could be made to the design.

More storage and cooler spaces in summer would have been beneficial. Given that glare from the sun was also mentioned as a significant concern, improved external shading would have made a more comfortable environment in both of these areas. Some experienced symptoms related to poor air quality, such as headaches and asthma, which would appear to corroborate the mixed results of the UCL IAQ report. Many comments (23 out of 144) mentioned the temperature. There were a number of complaints with the natural ventilation vents, which appear to be an ineffective solution for a number of users.

Conclusions from the comparison of 2012-2014 results

Significant differences were not observed between the 2012 and 2014 surveys, with the notable exceptions of productivity improvements, worsening of temperature and air quality **[Figure 4.5]**. This could possibly be related to sampling differences, with a larger number of entries in the 2012 survey than the 2014. The differences could also be related to the fact that for the 2014 survey, staff were asked to focus their attentions solely on the new areas of the building, i.e. Junior Block and Dining Hall. A number of staff were not asked to carry out a survey in 2014, as it became apparent that they did not spend enough of their time there to be able to give it a reliable assessment. It may be that the differences in staff completing the survey were significant enough to create noticeable differences in certain results.

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 Operation and Management

The discussion in this section focuses on the final two stages of the Castle Hill construction process, as they relate to the Soft Landings Framework (BSRIA, 2009). The first three stages are discussed in **Section 2** of this report.

1 Inception and briefing
2 Design development and review
3 Pre-handover
4 Initial aftercare
5 Aftercare in years 1 to 3

The school appears to have a good on-going relationship with the project team ECD/Keegans, who have assisted with a number of enquiries post-handover. One recent example is the faulty wiring connection found in the Photovoltaic system, where the project team were able to put the school in contact with the most suitable person at EvoEnergy who could expedite their enquiry. It has been confirmed that this particular problem has now been fixed and the school are enjoying the benefit of the panels.

The school have a complete set of O&M manuals. They use these as a reference to find the relevant company/service provider for a particular system, or if visiting service engineers ask for any of the schematic drawing. The school do not use the information frequently and so it is stored with their archives. The staff commented that other that the 'useful contacts page' there is nothing in the document that they found to be particularly helpful in day to day management, as "it is too big and cumbersome". Staff instead rely on their own series of notes and a list of phone numbers of the relevant companies/suppliers.

The design team provided the school with a 'Building User guide' in addition to the O&M manuals, which was written clearly in non-technical language, and with information split according to user type, e.g. 'General User' and 'Facilities Manager' **[See extract in Figure 5.1].** As a number of key pieces of information included within the Building User guide seemed unfamiliar to the staff at the walkthrough, it is likely that for whichever reason this guide has not made its way through to the end users as was intended. As an outcome of this report, it is proposed that additional training should be put in place to re-familiarise the staff with its contents and to discuss how the information could have be better conveyed.

It was recorded in the Design, Construction and Handover report that the school were given one day's training on the use of the building and its systems by the contractor. During the building walkthrough, the staff recalled that the induction was more of a 'whizz through', with the majority of the time spent in the plant room. As the building was not finished at the time of the induction, there was much that the training did not cover and they feel that the non-technical members of staff would have benefitted from additional time spent with them.

2.0	**Index**
2.1	1.0 introduction 2.0 index 3.0 building services information 4.0 emergency information 5.0 energy & environmental strategy 6.0 water use 7.0 transport facilities 8.0 materials & waste policy 9.0 re-fit/re-arrangement considerations 10.0 reporting provision 11.0 training 12.0 links & references 13.0 general
3.0	**Building Services Information**
3.1	General User
3.1.1	Heating – the dining block & junior block are both heated by gas boilers serving underfloor heating to the majority of rooms with some radiators to small rooms (wc's, stores). The boilers are located in the basement plant room in the existing building (dining block boilers) and the ground floor plant room by the reception classrooms (junior block boilers). Radiators have thermostatic valves that can be adjusted if required. Underfloor heating areas have wall-mounted thermostats that can be adjusted to suit. It should be noted that underfloor heating takes longer to respond than radiators, so the effect of altering the thermostat will not be felt immediately. Classrooms and hall should not need to be set higher than 20 degrees in all but the coldest periods. Radiators should not be covered or blocked as this will affect their performance. Cooling – there are no cooling systems provided, the buildings have been designed to not require these. Ventilation – there are two types of ventilation: 1. Toilets have mechanical ventilation that is automatically activated by someone entering the room, and will automatically switch off sometime after the room is vacated. 2. Classrooms and dining hall are ventilated by automatic natural ventilation units mounted in the ceiling. These will automatically open when the rooms get too hot or too stuffy, and then will close once the room has cooled down or feels fresher. There are wall-mounted sensors in

Figure 5.1: Extract from the Building User Guide, written in 'Plain English', produced by the project team at ECD/Keegans

The school do not have a formal process for logging problems. The caretaker is usually the first port of call for any issues and if it is an issue that he can resolve he will do so. For more complicated issues, the school will make a call out. As the building is now out of Defects Rectification period, this is not always the original supplier/installer, they look for companies who will provide the best service for the lowest price. The school have on-going maintenance agreements with several companies, for example for the cleaning of the ventilation grilles and fans. It appears that this particular maintenance contract does not include responsibility for re-calibration/commissioning of the settings.

The operation of the heating system is controlled by a Building Management System (BMS), installed and maintained by an external company, Smith and Byford. A 'BMS monitor' in the reception should theoretically enable users to keep track of their energy usage, but the system has proved unreliable and of limited effectiveness when in use. Further discussions around the technical issues arising from the above can be found in **Section 7**.

Energy bills are collected remotely by the school's utility companies; actual readings are taken for both gas and electricity. Gas data are collected on a monthly basis, and electricity data are collected on a half hourly basis. The energy bills are managed by an external energy buying group called L.A.S.E.R.

The above arrangement, though efficient in terms of accuracy and cost, by necessity separates the users from taking energy readings and processing their energy bills, which could lead to a degree of separation between the users and the energy consumption in the building.

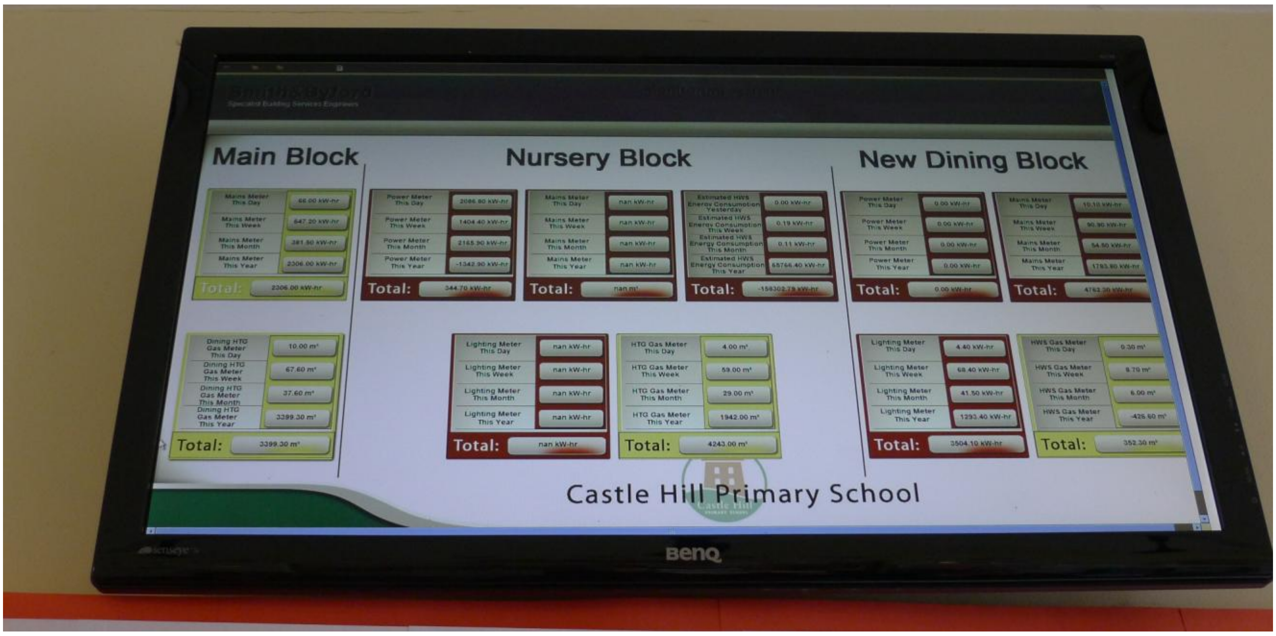


Figure 5.2: The energy display in the school reception provides building performance data to users, but is rarely in working order. The information is laid out in a format that is difficult for non-technical users and children to interpret.

5.2 Conclusions and key findings for this section

The good ongoing relationship between the school and the design team has facilitated an informal communication channel, which allows the client to be able to seek assistance on the project where it is not possible to obtain this information readily from the O&M.

It should however be noted that during the BPE study that L.A.S.E.R. have been very responsive in collating and summarising utility data in electronic .CSV format. This data is arguably more accessible than traditional paper billing, and has the potential to be much more informative – for example breaking down electricity use by time period, or comparing year on year. If regular reports, such as this, were set up and discussed with the staff at the school, this would enable them to get a much clearer picture of their overall energy use.

The BMS system, as with the energy bills, adds a further degree of separation between the facilities management staff and the operation of the building. Though in theory a BMS should be able to allow control of certain settings on site, in the arrangement at Castle Hill the staff are required to call out an engineer whenever a problem arises, even for small matters. Though the staff report that the S&B engineers who do arrive are knowledgeable, the school are forced to wait for engineer appointments to become available, plus further delays for subsequent appointments, when the initial visit does not resolve the issue. This has reportedly been the case on several occasions.

The first year's support and data connection that came with the energy metering equipment has proved to be of limited use to the school, as with the energy display in reception. The data that was compiled for the school during this time was not checked for accuracy, with the result that a number of charts and data readouts are displaying erroneous data. After the first year's subscription came to a close, the school were not contacted to arrange a repeat contract and the data was left uncollected until the problem was spotted by a member of the BPE team.

It should be noted that since the involvement of the BPE team the school has renegotiated its contract with S&B, and the company have been more proactive in setting up meetings and getting to the bottom of problems. One of the requests that has recently been agreed is a detailed summary report to be sent to the school each month, which in addition to the BPE findings will help them to manage their ongoing usage, The problems that have been discussed in this section were unearthed only as direct result of the BPE study. The design team would certainly not have had the time or resource allocation to be able to carry out such a detailed investigation. Findings such as the above are valuable to building users, who may not have technical understanding. A key recommendation is that POE should form a mandatory part of building procurement.

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 in 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

The TM22 Building Evaluation tool was used separately for the extensions of the Junior Block and Dining Hall to assess the in use energy performance of these two parts of the site.

The meter tree in **Figure 6.1-2** below was produced by the BPE team as a guide to understand the energy supply in the buildings as well as describing the data collected whether from utility, sub meter or the combination of both.

Data Collection
The data collection of the energy use in the Dining Hall as well in the Junior Block extension each had significant interruptions due to the incorrect calibration and/or mechanical dis-function of certain sub meters. To reach as close as possible to a realistic representation of energy use a series of normalisation steps were taken that will be discussed below in detail.

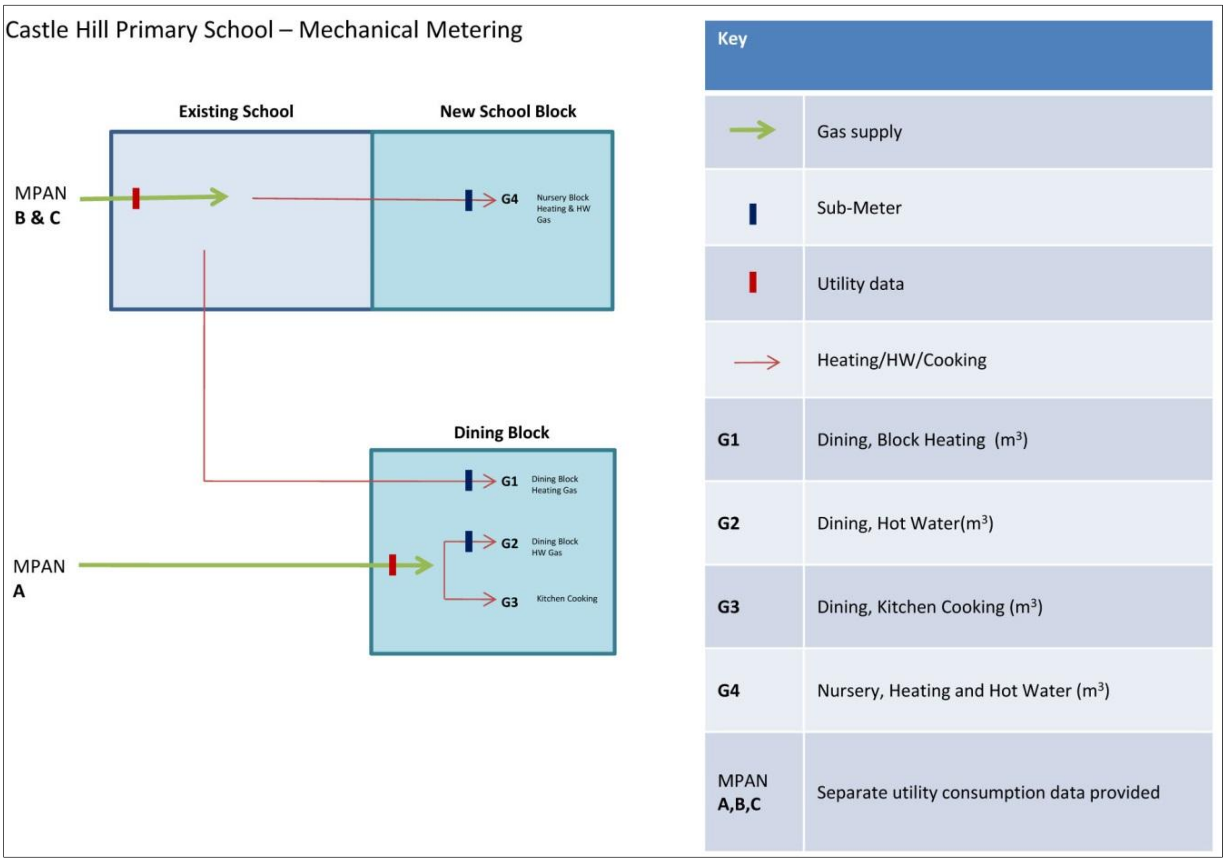


Figure 6.1 Gas meter tree diagram

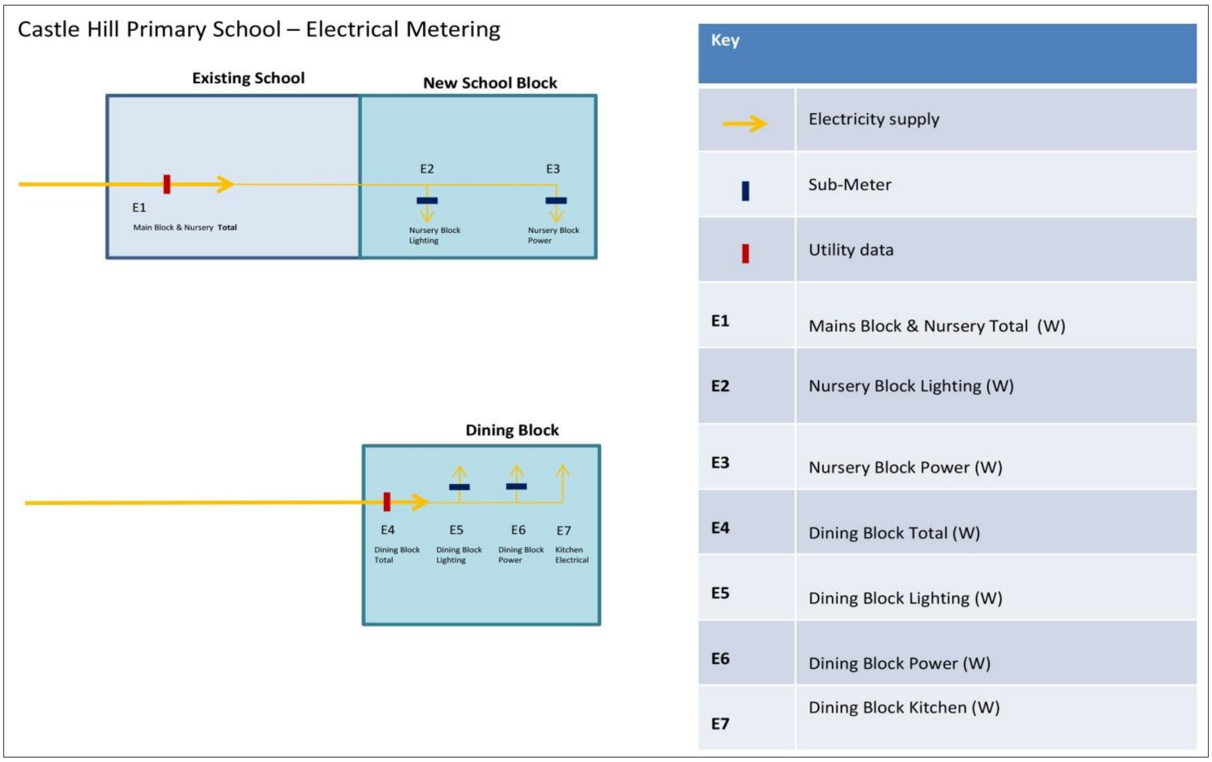


Figure 6.2 Electricity meter tree diagram

6.1 Dining Hall Block

The Dining Hall Block is a large double height space with a GIA of 302m^2 which is comprised of 158m^2 double height vaulted dining space, a 38m^2 kitchen on the ground floor, a plant room of identical size and proportion on the mezzanine floor above, 3No. WCs, 1No. accessible WC and storage areas.
As seen below from the TM22 Building Energy Summary Data (Table 6. 1) the total measured energy consumption comes to 22,292 kWh/year for electricity and 82,426kWh/year for gas.

Energy summary: Dining Hall

The electricity consumption was predicted to be 91 kWh/m^2 in total where of that 14kWh/m^2 contributed to "regulated" energy use. For the gas demand, the predicted figures were 24 kWh/m^2 for heating and 36 kWh/m^2 for hot water. These figures were placed in the TM22 as "user benchmarks" and a clearer comparison with predicted vs. actual energy consumption can be seen in **Figure 6.1**.
It should be noted that DEC data were not available for each of the new buildings but rather the total (Existing & New extensions) so to avoid confusion they were not included in the TM22 evaluation.

The actual energy consumption from utility and sub meter data collected was 73.8kWh/m2 for electricity use and 272.9 kWh/m2 for gas with carbon emissions of 40.6kgCO2/m2 and 52.9kgCO2/m2 respectively **[Table 6.2].** The gas use was 4.5 times higher than predicted and close to double the TM46 benchmark. The electricity use on the other hand came to an approximate 17% less than expected but still around 45% higher than the TM46 benchmark.

Table 6.1 BUILDING ENERGY SUMMARY

Energy, carbon and cost summary	Units	Electricity	Fuels	Thermal
Non-renewable fuel or electricity supplied to site	kWh/annum	22,292	82,426	0
Separable energy uses	kWh/annum	0	0	0
Renewable energy used on site	kWh/annum	0	0	0
Renewable energy exported	kWh/annum	0	0	0
Output from CHP used in building	kWh/annum	0		0
Exported CHP	kWh/annum	0		0

Table 6.2 SIMPLE ASSESSMENT

Absolute values	Energy supplied (kWh)		Carbon dioxide emissions (kg CO_2)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	82,426	22,292	15,991	12,261	28,251
Exported CHP	0		0		

Unit values	Energy supplied (kWh/m^2 GIA)		Carbon dioxide emissions (kg CO_2/m^2 GIA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	272.9	73.8	52.9	40.6	93.5
Exported CHP	0.0		0.0		
Raw TM46	150.0	40.0	29.1	22.0	51.1
User Specified	60.0	91.0	11.6	50.1	61.7
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0

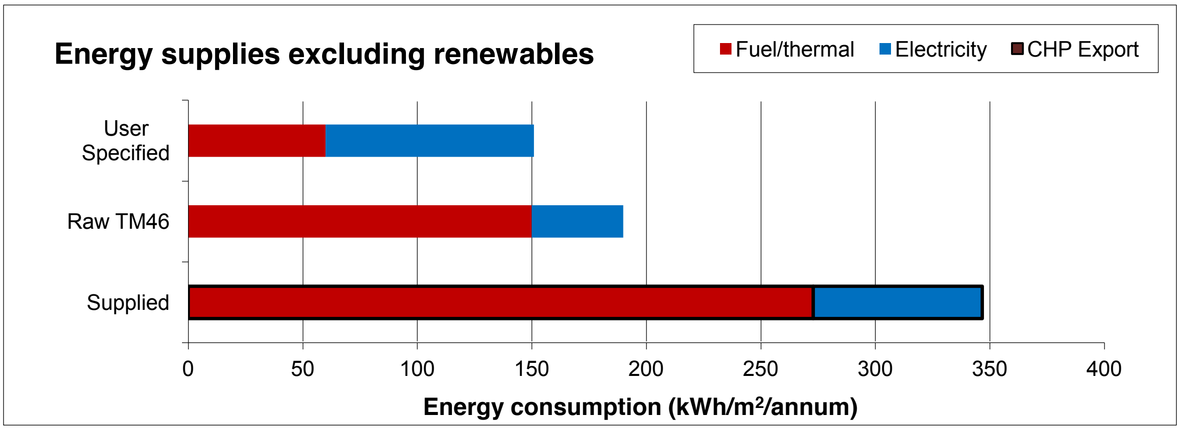


Figure 6.1 Energy Supplies excluding renewables

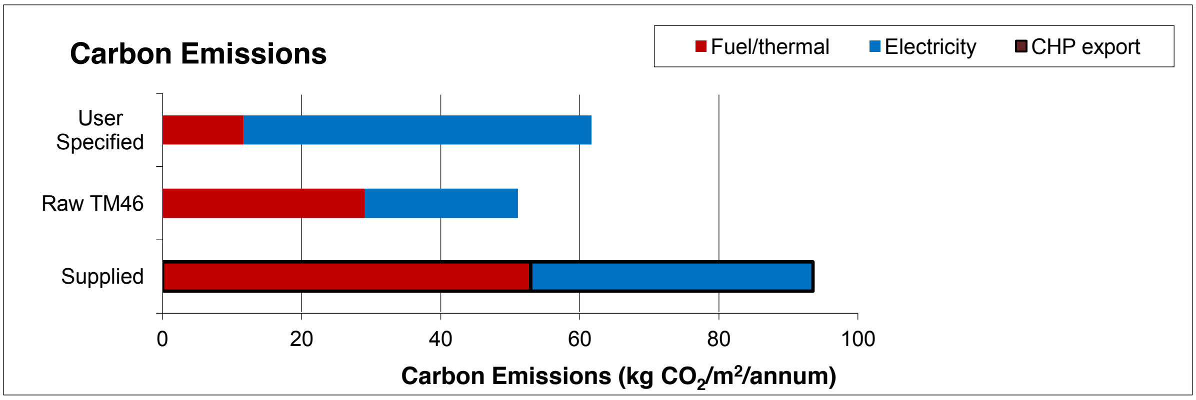


Figure 6.2 Carbon Emissions

Table 6.3 Energy use breakdown

	Heat demand (kWh/m2/year)		Electricity demand (kWh/m2/year)		Additional metrics for electricity demand				
System	**Design (kWh/m2 /year)**	**In-Use (kWh/m2 /year)**	**Design electricity (kWh/m2 /year)**	**In-use electricity (kWh/m2 /year)**	**In-use electricity (kWh/year)**	**In-use % of total**	**In-Use Full load W/m2**	**System hours/ year**	**Utilisation**
Space Heating	0.0	170.6	0.0	2.1	626	2.9%	7.9	261	3.0%
Hot water	0.0	45.8	0.0	0.0	0	0.0%	0.0	0	0.0%
Fans	0.0	0.0	0.0	5.7	1,734	7.9%	3.2	1,772	20.2%
Controls	0.0	0.0	0.0	0.3	88	0.4%	0.0	8,760	100.0 %
Lighting (Internal)	0.0	0.0	0.0	7.5	2,265	10.4%	14.5	516	5.9%
Lighting (External)	0.0	0.0	0.0	7.4	2,248	10.3%	2.3	3,249	37.1%
Small Power	0.0	0.0	0.0	3.1	925	4.2%	11.7	262	3.0%
Catering - Central	0.0	15.5	0.0	38.4	11,603	53.0%	85.3	451	5.1%
Cooled Storage	0.0	0.0	0.0	7.9	2,391	10.9%	0.9	8,760	100.0 %
Total	**0.0**	**232.0**	**0.0**	**72.4**	**21,879**	100.0%	**125.9**		
Metered building energy use		232.0		73.8	22,292				
Variance TM22 versus metered total		0.0		-1.4	-413		**Building GIA:**	302	
Variance TM22 versus metered total		0%		-2%	-2%				

Dining Hall consumption assessment: Gas

At first glance **[Table 6.2]** the biggest contrast can be seen in the predicted vs. Actual gas consumption, a difference of almost double the TM46 benchmark and 4.5 times greater than the amount predicted at design stage. This benchmark data should nonetheless be considered with slight caution, noting that the TM46 energy benchmark refers to “Schools and seasonal public buildings” in general where only the Dining Hall of the building is reviewed here. As a result, **Figure 6.3** from the TM22 could be potentially misleading.

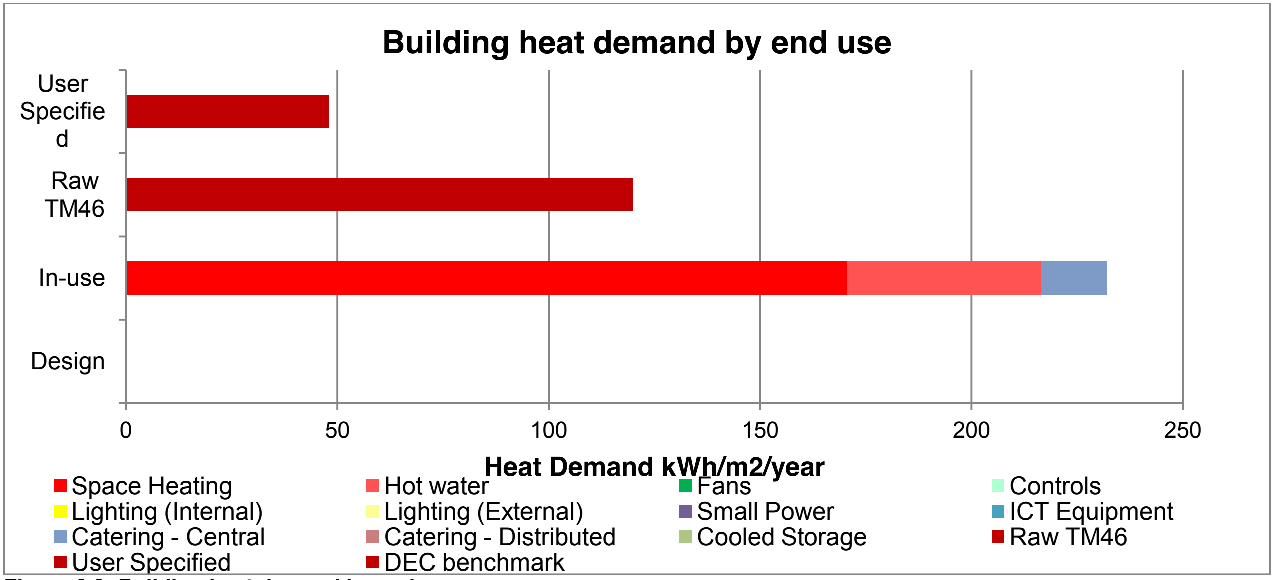


Figure 6.3: Building heat demand by end use

Data Collection
The gas consumption data were derived from the monitored period of June 2012 to June 2013. It was the closest time period with consistent readings of a year’s data that could be used for assessment, since certain data sets in other months were missing or were sporadically consistent due to technical errors on the part of the sub metering contractor.

As seen from **Figure 6.1** there are two main supplies of gas, one to the existing school that also supplies the New Junior Block(MPAN B&C **Figure 6.1**) and one for the Dining Hall (MPAN A). The Dining Hall has a separate main supply that feeds the hot water and cooking but the space heating is connected to the Existing Building’s boiler. The only consumption load that does not have a sub meter is the kitchen cooking and so this consumption figure was derived by simply subtracting from the main supply total (MPAN A) the sub meter reading of the hot water gas supply.

Space Heating
The biggest consumption of gas relates to space heating, with 170.6 kWh/m^2 **[Table 6.3]** and there are possibly two main justifications for this. The first one relates to the fact that the Dining Hall is a double height space and it is not possibly represented accurately by the GIA of 302m2; it would take longer to warm up in comparison to a building with similar GIA but lower ceiling height. The second is possibly contributed to by the heat losses from the piping connection since, as can be seen from the meter tree **[Figure 6.1],** the heating in the Dining Hall is supplied from a boiler in the Existing Block. One notable factor affecting the energy performance of the building is its intermittent occupancy. Large number of people use the space for short periods of time, but in the intermediate periods the space is empty, and therefore it has a lower internal heat gain than other parts of the building. As the occupancy is transient this also affects the amount of time that doors are kept open, which impacts further on the space heating demand. Other contributory factors could be the kitchen feedback loop as noted in **Section 7**, the large proportion of external doors, or its poor air-permeability score.

Hot Water
The actual hot water consumption of 45.8kWh/m2 is higher, although not incomparable to the predicted 36 kWh/m2.

Cooking-Gas
The gas consumption related to cooking was measured to be 15.5kWh/m2, which makes up of 6% of the total gas consumption of the building.

Consumption assessment-Electricity

At first glance **[Table 6.2]** it can be seen that the total actual electricity consumption 73.8kWh/m2 was lower than the predicted 91kWh/m2. Nevertheless, it is still higher than the TM46 benchmark of 40kWh/m2. Once more it should be noted that the TM46 energy benchmark, refers to "Schools and seasonal public buildings" in general, where here only the Dining Hall of the building is reviewed. So the Figure 6.4 from the TM22 could be misleading.

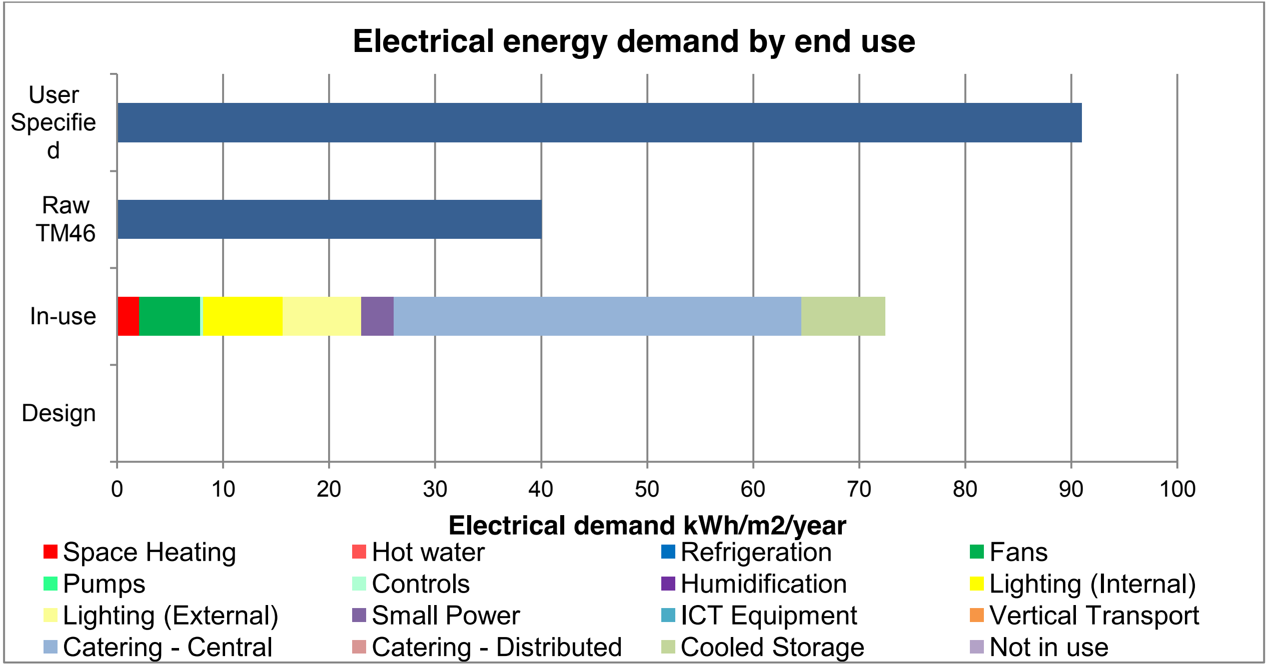


Figure 6.4: Electrical energy demand by end use

Data Collection
As can be seen from **Figure 6.2,** utility data existed for the total kWh supply to the Dining Hall and sub meters for lighting and power, but not for kitchen usage. To obtain this figure, a basic calculation was made by adding E5 (Lighting Sub meter) and E6 (Power Sub meter) and subtracting from E4 (Dining Block total, Utility). Due to technical difficulties explained in Section 7, the period of the data collected from the lighting and power sub meters was from 09 June 2014 to 14 September 2014. To have close to a complete year's data, the rest of the missing entries were extrapolated as can be seen in **Table 6.4**, which shows an example snapshot of power and lighting data calculation/entries.

Table 6.4 Extrapolated data for power and lighting sub meters.

Row Labels	Count of date		
Inset day	2		
School holidays	40		
Term time	56		
Grand Total	**98**		
Row Labels	**Count of date**	**Average of Total**	
Inset day	2	6.85	
School holidays	40	4.71	
Term time	56	11.04107143	
Grand Total	**98**	**8.371428571**	
Row Labels	**Count of date**	**Sum of Total**	
Inset day	2	13.7	
School holidays	40	188.4	
Term time	56	618.3	
Grand Total	**98**	**820.4**	
	School term dates in 2013-14		
	Count of dates	Extrapolated electricity use (kWh)	
Inset days	4	27.40	
Holiday dates	107	503.97	
Term dates	254	2804.43	
Total	365	**3335.80**	
TM22 Input	3 month data s	**Extrapolated to 12 montl**	Percentage
Weekend	**150.9**	**613.57**	18.39%
Core week	**442.6**	**1799.64**	53.95%
Non core week	**226.9**	**922.59**	27.66%
Total	**820.4**	**3335.80**	100.00%

Row Labels	Count of date		
Inset day	2		
School holidays	40		
Term time	56		
Grand Total	**98**		
Row Labels	**Count of date**	**Average of Total**	
Inset day	2	22.3	
School holidays	40	4.075	
Term time	56	15.3625	
Grand Total	**98**	**10.89693878**	
Row Labels	**Count of date**	**Sum of Total**	
Inset day	2	44.6	
School holidays	40	163	
Term time	56	860.3	
Grand Total	**98**	**1067.9**	
	School term dates in 2013-14		
	Count of dates	Extrapolated electricity use (kWh)	
Inset days	4	89.2	
Holiday dates	107	436.025	
Term dates	254	3902.075	
Total	**365**	**4427.3**	
TM22 Input	**3 month data set (**	**Extrapolated to 1**	**Percentage**
Weekend	**94.1**	**390.12**	8.81%
Core week	**707.3**	**2932.32**	66.23%
Non core week	**266.5**	**1104.86**	24.96%
Total	**1067.9**	**4427.3**	100.00%

Electricity

The electrical loads in the Dining Hall comprise artificial lighting fixtures, external and internal, extract fans and MVHR, and finally kitchen equipment for food preparation, display and cleaning. There are minimal loads for small power. As can be seen from **Table 6.2** and **Figure 6.4**, and as might be expected, the highest consumption comes from the kitchen equipment, which is responsible for the 68% of the total.

A small but significant amount of energy, approximately 1200W or 12% of the average peak load **[Table 6.4, Figure 6.5-6]** is used when the building is not in use, with a significant 46% of the Dining Hall total (Non-core hours and weekends). As noted in the TM22 Guidelines, it is reasonable to expect such a high figure with non-domestic buildings that are mostly occupied of around 10 hours in weekdays (50 a week) and especially with schools where longer holidays apply. There is some evidence as well from the half hourly data **[Figure 6.5-6]** that a significant amount of energy is used between 18:30 to 20:00, outside the normal operational hours. This can be attributed to the fact that the Dining Hall space is occasionally used for evening events. As the base load is used primarily for cold storage there is little that the school could do to improve the result.

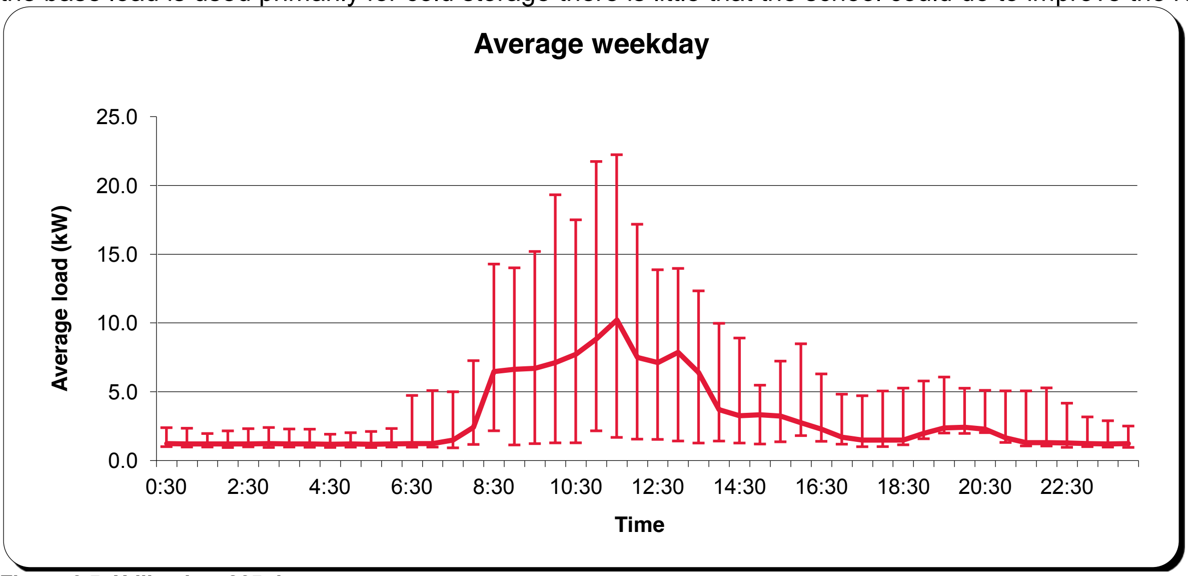


Figure 6.5. Utility data 365 days

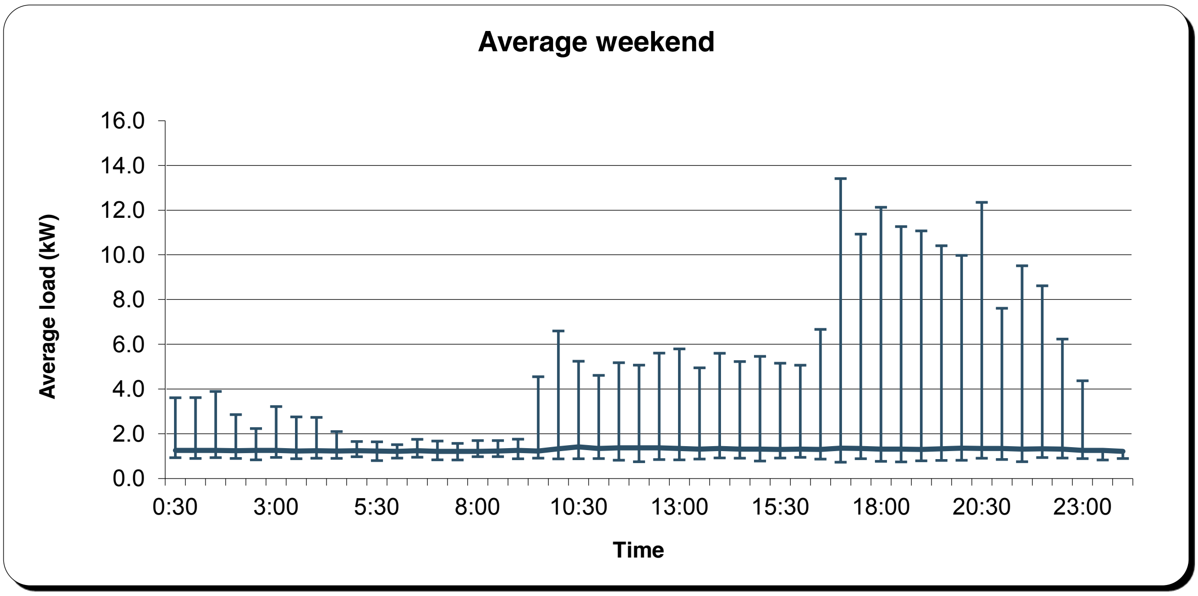


Figure 6.6 Utility data 365 days

In use vs. metered

The total in use vs. metered consumption for the Dining Hall was comparable with a -2% difference of 413kWh/year and 1.4 kWh/m^2 over calculated from actual use **[Table 6.5]**.

Lighting sub meter

The lighting consumption came fairly close in relation to in use against metered. The differences between core and non-core hours **[Figure 6.7]** can possibly be explained by the manual variations of control of the lights according to weather and daylight conditions to achieve comfortable light levels.

Dining Power sub meter

The loads that were allocated to the Dining Power sub meter include extract fans/MVHR, Dimplex fan heating (Kitchen), an electrical insect-o-cutor and warm air hand dryers for the WCs. The total in use vs. metered was comparable, with only a minimal difference of 20kWh. The variances between core and non-core hours **[Figure 6.8]** can potentially be explained by the manual controls and variations in user profile from surveyed operational hours.

Kitchen (Residual)

The Kitchen Power was calculated by subtracting the utility data from the lighting/power sub meter readings. In use vs. metered differences were greater than the two sub metered, a Figure of 519kWh. This can potentially be explained by the fact that the equipment uses are very energy intensive; diverging by only half to one hour per day from the in-use entries can easily accumulate great differences.

Base loads

The base load of lighting is 14.5 W/m^2 and is within the general benchmarks (CIBSE Guide F) of 15-20 W/m2. The highest base load, as might be expected, falls to the kitchen equipment with a load of 85.3W/m^2. These compare with a utility measured base load of 40W/m^2

Table 6.5 Dining electricity meter reconciliation

		Total	
Sub meter	**Description**	**Metered**	**In-use (reconciled)**
No sub meter	No sub meter-Kitchen	14,529	14,010
E01	Dining Lighting BMS Output	4,427	4,513
E02	Dining Power BMS Output	3,336	3,356
TOTAL		**22,292**	**21,879**

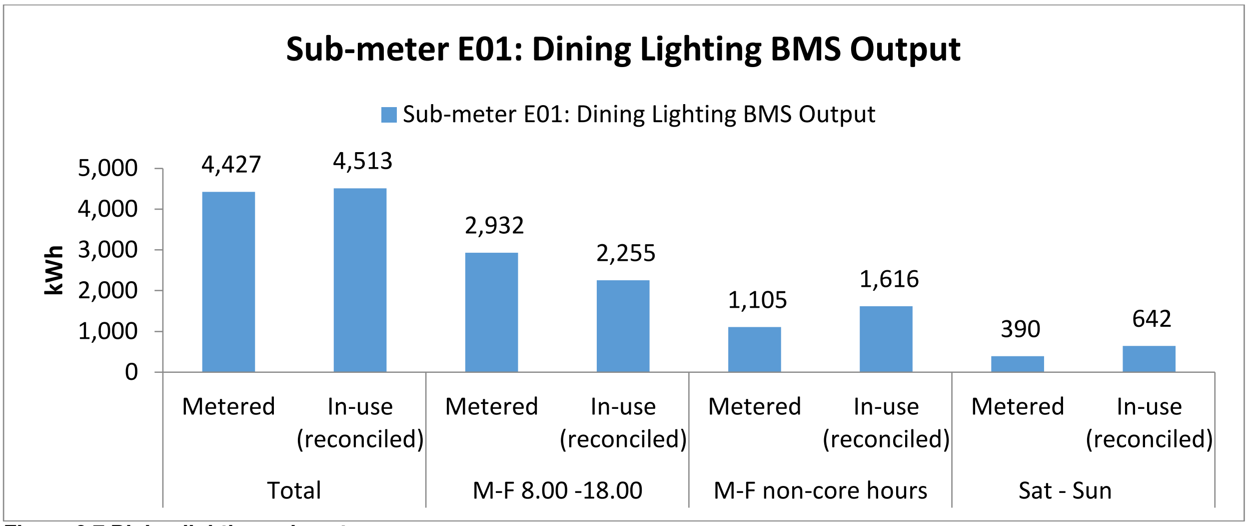


Figure 6.7 Dining lighting sub meter

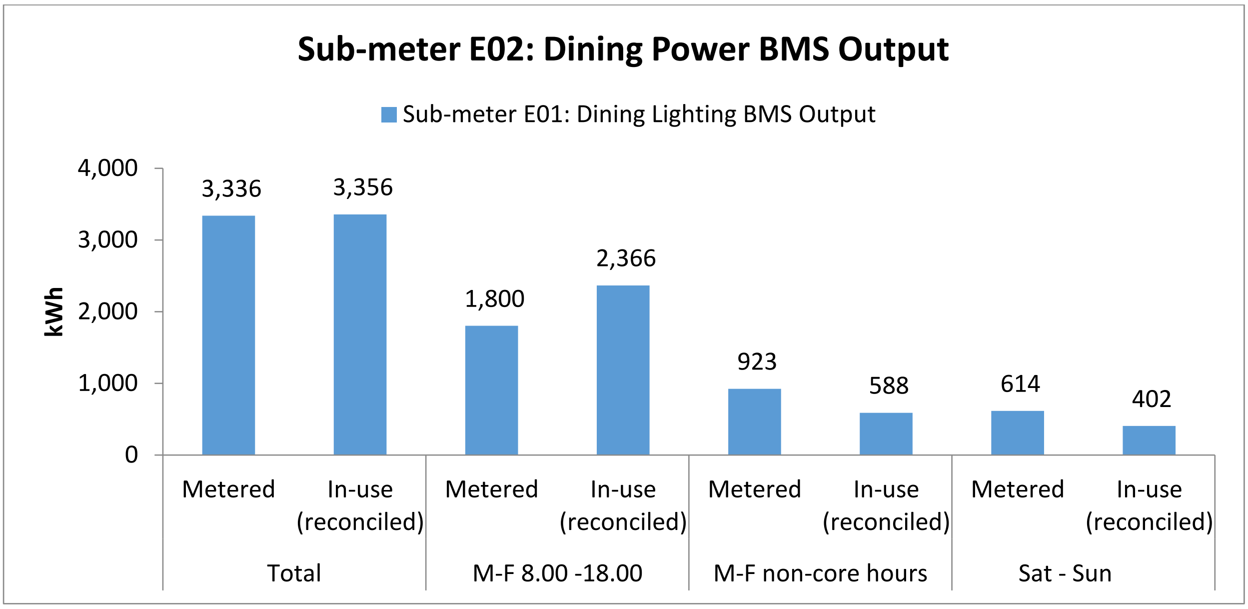


Figure 6.8 Dining Power sub meter

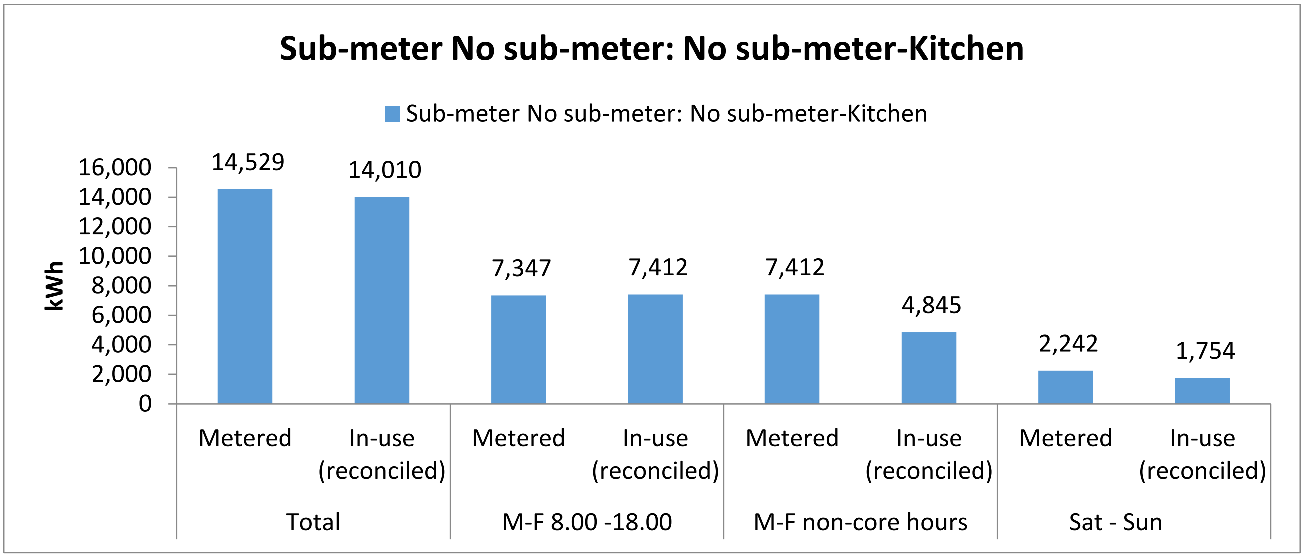


Figure 6.9 Residual Power Dining Hall

Table 6.5 ENERGY DEMAND (kWh/m²/year)

	Additional metrics for electricity demand				
System	**In-use electricity (kWh/year)**	**In-use % of total**	**In-Use Full load W/m2**	**System hours/year**	**Utilisation**
Space Heating	626	2.9%	7.9	261	3.0%
Hot water	0	0.0%	0.0	0	0.0%
Fans	1,734	7.9%	3.2	1,772	20.2%
Controls	88	0.4%	0.0	8,760	100.0%
Lighting (Internal)	2,265	10.4%	14.5	516	5.9%
Lighting (External)	2,248	10.3%	2.3	3,249	37.1%
Small Power	925	4.2%	11.7	262	3.0%
Catering - Central	11,603	53.0%	**85.3**	451	5.1%
Cooled Storage	2,391	10.9%	0.9	8,760	100.0%
Total	**21,879**	100.0%	**125.9**		

Summary, Dining Hall

The actual energy consumption from the utility and sub meter data collected was 22,292 kWh/year for the electricity and 82,426 kWh/year for gas, which equates to 73.8kWh/m2 and 272.9 8kWh/m2 respectively.

The electricity consumption was predicted to be 91 kWh/m^2 in total, of which 14kWh/m^2 could be attributed to "regulated" energy use. For the gas demand, the predicted design figures were 24 kWh/m^2 for heating and 36 kWh/m^2 for hot water.

The actual electricity consumption resulted in 40.6kgCO2/m^2 of carbon emissions, which was 10kgCO2/m^2 less than predicted but 18kgCO2/m^2 higher than the TM46 benchmark **[Table 6.2].**

The gas consumption, unfortunately, was four times higher than predicted and raised the total carbon emissions to 93.5kgCO2/m2 which are close to double than the TM46 benchmark. This could be attributed to a number of factors, including the double space height of the Dining Hall, energy losses from the piping, a poor air permeability score and the kitchen extract feedback loop discussed in section 7.

6.2 Junior Block

Junior Block overview

The Junior Block extension has a Gross Internal Area of 817m2, and is situated to the North of the main building. It comprises of 8 identical classrooms, 5 flexible group spaces, the Deputy Head's office, speech therapy room, SEN office and 13 WCs. As can be seen below from the TM22 Building Energy Summary Data **[Table 6.6],** the total measured energy consumption comes to 22,890 kWh/year for electricity and 78,186kWh/year for gas.

Energy summary-Junior Block

The design stage electricity consumption was predicted to be 34 kWh/m^2 in total, where of that 21kWh/m^2 contributed to "regulated" energy use. For the gas demand, the predicted figures were 37 kWh/m^2 for heating and 10 kWh/m^2 for hot water. These figures were placed in the TM22 as "user benchmarks" and a comparison with predicted vs. actual energy consumption can be seen in Figure 6.10.

It should be noted that DEC data were not available for each of the new buildings but rather the total of the whole site (Existing & New extensions). To avoid confusion, they were not included in the TM22 evaluation.

The actual energy consumption from the utility and sub meter data collected was 28kWh/m^2 for the electricity use and 95.7 kWh/m^2 for the gas which converts to 15.4 kgCO_2/m^2 and 18.6 kgCO_2/m^2 respectively.
The electricity consumption is 18% less than what was expected and approximately 30% lower than the TM 46 benchmark. The gas on the other hand came to be double the amount predicted, but it was still around 40% lower than the TM46 benchmark.

Table 6.6 BUILDING ENERGY SUMMARY

Energy, carbon and cost summary	Units	Electricity	Fuels	Thermal
Non-renewable fuel or electricity supplied to site	kWh/annum	22,890	78,186	0
Separable energy uses	kWh/annum	0	0	0
Renewable energy used on site	kWh/annum	0	0	0
Renewable energy exported	kWh/annum	0	0	0
Output from CHP used in building	kWh/annum	0		0
Exported CHP	kWh/annum	0		0

Table 6.7SIMPLE ASSESSMENT

Absolute values	Energy supplied (kWh)		Carbon dioxide emissions (kg CO_2)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	78,186	22,890	15,168	12,590	27,758
Exported CHP	0		0		

Unit values	Energy supplied (kWh/m^2 GIA)		Carbon dioxide emissions (kg CO_2/m^2 GIA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	**95.7**	**28.0**	**18.6**	**15.4**	**34.0**
Exported CHP	0.0		0.0		
Raw TM46	**150.0**	**40.0**	**29.1**	**22.0**	**51.1**
User Specified	**47.0**	**34.0**	**9.1**	**18.7**	**27.8**
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0

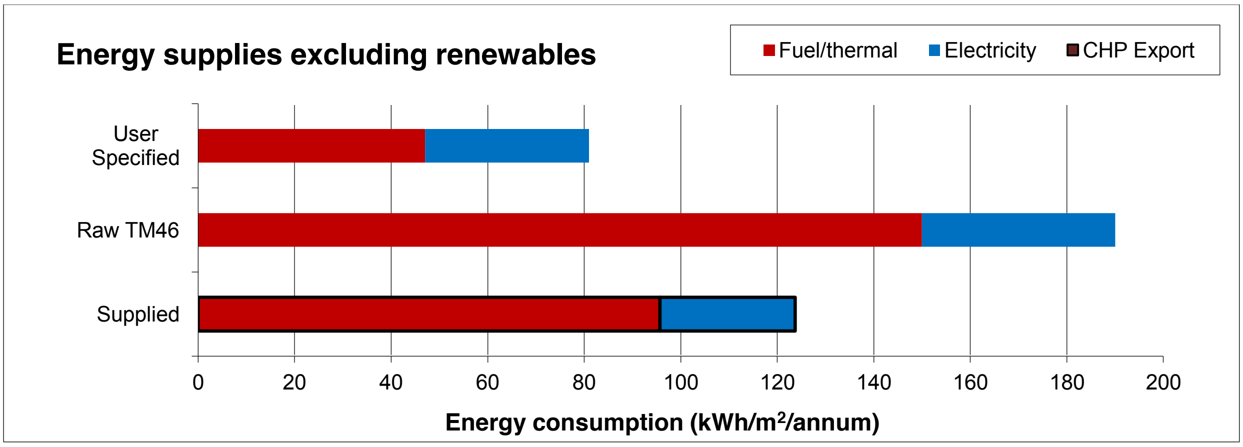


Figure 6.10: Energy Supplies excluding renewables

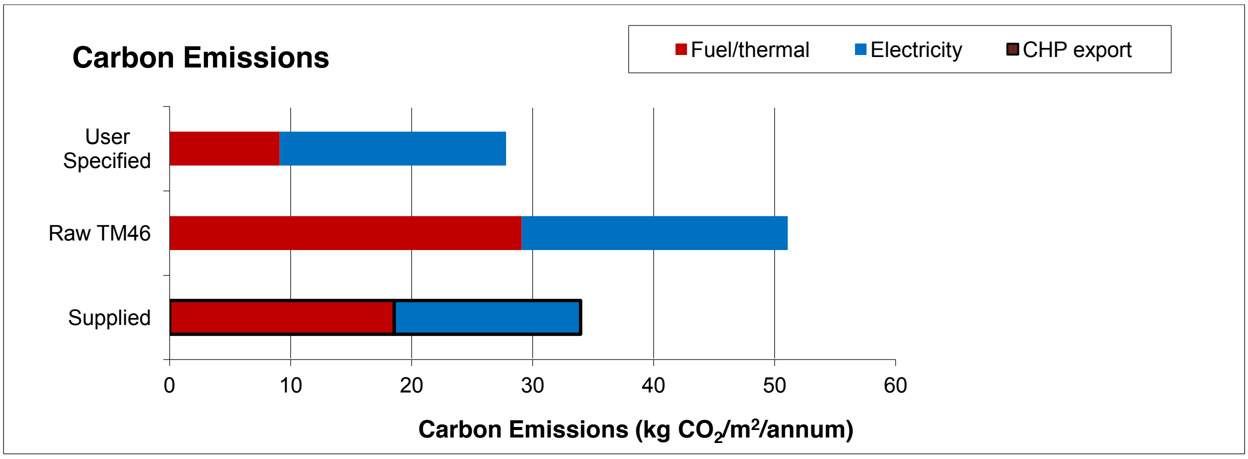


Figure 6.11: Carbon emissions

Table 6.8 Energy Demand breakdown

ENERGY DEMAND (kWh/m^2/year)

	Heat demand (kWh/m2/year)	Electricity demand (kWh/m2/year)		Additional metrics for electricity demand			
System	**In-Use (kWh/m2/year)**	**In-use electricity (kWh/m2/year)**	**In-use electricity (kWh/year)**	**In-use % of total**	**In-Use Full load W/m2**	**System hours/year**	**Utilisation**
Space Heating	46.5	0.0	0	0.0%	0.0	0	0.0%
Hot water	34.8	0.0	0	0.0%	0.0	0	0.0%
Fans	0.0	5.4	4,426	20.5%	0.8	7,075	80.8%
Controls	0.0	0.1	88	0.4%	0.0	8,760	100.0%
Lighting (Internal)	0.0	9.2	7,490	34.8%	6.2	1,473	16.8%
Lighting (External)	0.0	4.5	3,667	17.0%	0.7	6,153	70.2%
Small Power	0.0	7.2	5,882	27.3%	12.6	573	6.5%
Total	**81.3**	**26.4**	**21,553**	100.0%	**20.3**		
Metered building energy use	81.3	28.0	22,890				
Variance TM22 versus metered total	0.0	-1.6	-1,337		**Building GIA:**	817	
Variance TM22 versus metered	0%	-6%	-6%				

total			

Junior Block consumption assessment-Gas

The overall gas consumption was 50% greater than predicted at design stage, as can be seen in Table 6.7 and Figure 6.12. Nevertheless, it is still ~30 % lower than the TM46 Benchmark.

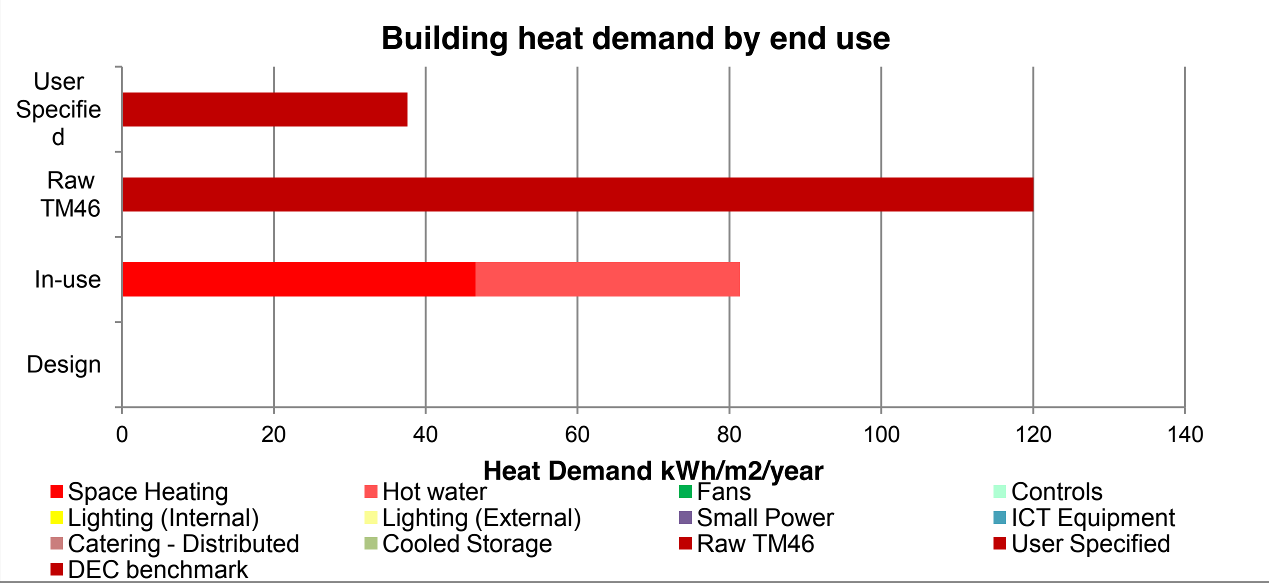


Figure 6.12: Building heat demand by end use

Data Collection
The gas consumption data chosen for the analysis spans over the period of April 2012 to April 2013. Of all the sub meter data, this period provided the most consistent readings for a year's data that could be used for assessment – other months contained data records that were more sporadically consistent. As can be seen from **Figure 6.1,** there is a main supply for both of the buildings (Existing-Junior) and a sub meter for the total gas use of the Junior Block.

Heating & Hot Water
Due to the lack of sub meters for final use, a precise in depth review of heating and hot water was not possible. Nevertheless, with the available overall consumption and the knowledge of the term and holiday dates the difference of hot water and space heating was estimated by reviewing the gas consumption during the summer dates where the heating was zero. The gas consumption during this period was solely contributing to hot water use. This data were then extrapolated to the rest of the year and the remaining gas consumption was assigned to space heating. The conclusions showed that the heat demand for space heating is 46.5 kWh/m^2 and 34.8 kWh/m^2 for hot water. The space heating is ~25% higher than predicted and similarly the hot water ~3.5 times higher. This could in part be explained through the use of the building outside "school-hours" and during holiday dates by community groups.

Junior Block consumption assessment-Electricity
At first glance **[Table 6.7]** it can be seen that the total actual electricity consumption 28kWh/m^2 was 18% less than the predicted amount at 37kWh/m^2 and ~30%lower than the TM46 Benchmark.

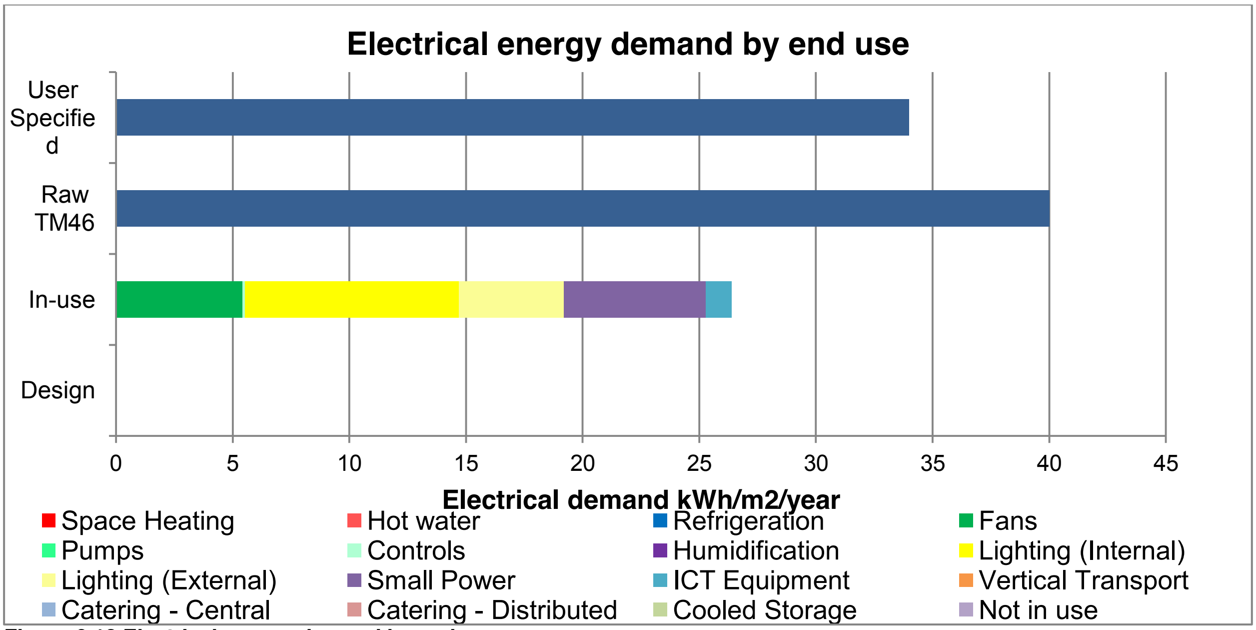


Figure 6.13 Electrical energy demand by end use

Data Collection

As can be seen from **Figure 6.2** utility data exist for the total kWh supply of Existing/Junior Block and separate sub meters for Junior Block power and lighting. Only the sub meters were used in the assessment, as the utility data would be useful only in estimating the total site energy usage. Due to technical difficulties on the part of the metering company, the period for the data collected from the sub meters for lighting and power was between 09 June 2014 and 14 September 2014. To have close to a complete year's data the rest of the missing entries were extrapolated as seen in **Table 6.9**, showing an example snapshot of power and lighting data calculation/entries.

Row Labels	Count of date
Inset day	2
School holidays	40
Term time	56
Grand Total	**98**

Row Labels	Count of date	Average of Total
Inset day	2	27.05
School holidays	40	21.9125
Term time	56	34.65357143
Grand Total	**98**	**29.29795918**

Row Labels	Count of date	Sum of Total
Inset day	2	54.1
School holidays	40	876.5
Term time	56	1940.6
Grand Total	**98**	**2871.2**

	School term dates in 2013-14	
	Count of dates	Extrapolated electricity use (kWh)
Inset days	4	108.2
Holiday dates	107	2344.6375
Term dates	254	8802.007143
Total	**365**	**11254.84464**

TM22 Input	3 month data	Extrapolated to 12 r	Percentage
Weekend	662	2594.98	23.06%
Core week	1224.9	4801.50	42.66%
Non core week	984.3	3858.37	34.28%
Total	2871.2	11254.84464	100.00%

Row Labels	Count of date
Inset day	2
School holidays	40
Term time	56
Grand Total	**98**

Row Labels	Count of date	Average of Total
Inset day	2	24.6
School holidays	40	13.1325
Term time	56	39.88928571
Grand Total	**98**	**28.65612245**

Row Labels	Count of date	Sum of Total
Inset day	2	49.2
School holidays	40	525.3
Term time	56	2233.8
Grand Total	**98**	**2808.3**

	School term dates in 2013-14	
	Count of dates	Extrapolated electricity use (kWh)
Inset days	4	98.40
Holiday dates	107	1405.18
Term dates	254	10131.88
Total	**365**	**11635.46**

TM22 Input	3 month data	Extrapolated	Percentage
Weekend	276.9	1147.26	9.86%
Core week	1913.4	7927.67	68.13%
Non core week	618	2560.52	22.01%
Total	2808.3	11635.46	100.00%

Table 6.9. Extrapolated data power and lighting

Electricity
The lighting and Small power equipment, as might be expected, were found to be responsible for the highest electricity consumption in the Junior Block (Table 6.8 & Figure 6.13). The MVHR consumption comes next, with 24/7 operation. It should be noted that the energy used in MVHR systems will typically result in much greater savings in energy as a result of reduced ventilation heat losses. For MVHR systems to be effective, an air-permeability target of less than $3m^3/h.\ m^2$ @ 50Pa, whereas for the Junior Block (and worse Dining Hall) the air permeability is much greater.

A substantial amount of energy **[Table 6.9]** is used when the building is not in occupation, with a significant 57% of the Junior Block total (Non-core hours and weekends). TM22 Guidelines note that such a Figure is reasonable for non-domestic buildings that are mostly occupied of around 10 hours in weekdays (50 a week) and especially with schools where longer holidays apply.

Below a series of data charts are presented **[Figure 6.14 to 6.17],** using the half hourly data module to give an estimation of the electricity use through core and non-core hours. It should be advised that the charts are based on 3 months of data, and are therefore less representative than if a full year's data were available.

Figures 6.14-5 are associated with power use and as might be expected there is evident high consumption during core-hours of the week day. During the non-core hours and weekend, the consumption can be attributed in part to the stand-by power of the Small power equipment and the running of the MVHR units.

Figures 6.16-7 are associated with lighting and it is apparent that their usage extends further than the core-hours. The constant energy load through the night time is contributed to primarily by the external/security lights.

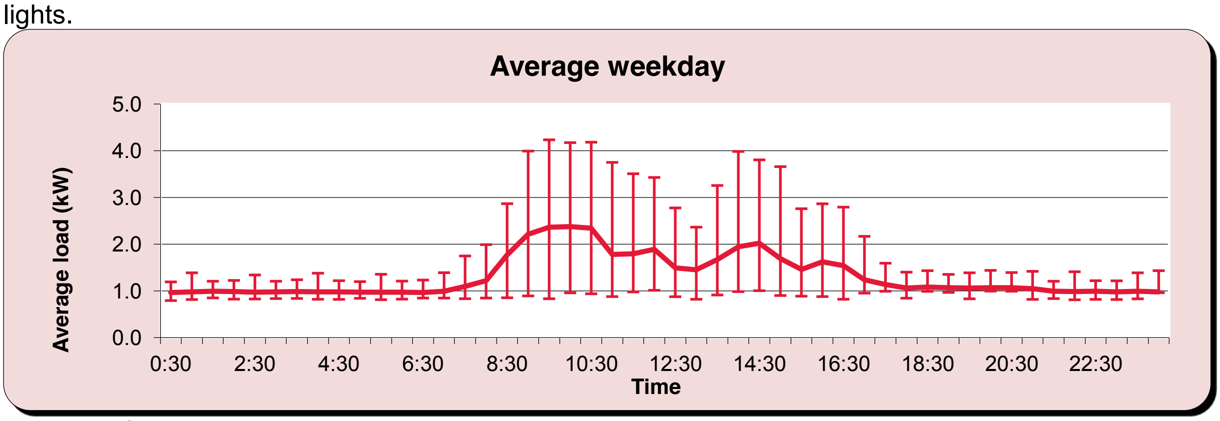


Figure 6.14 Sub meter power, 3 months data

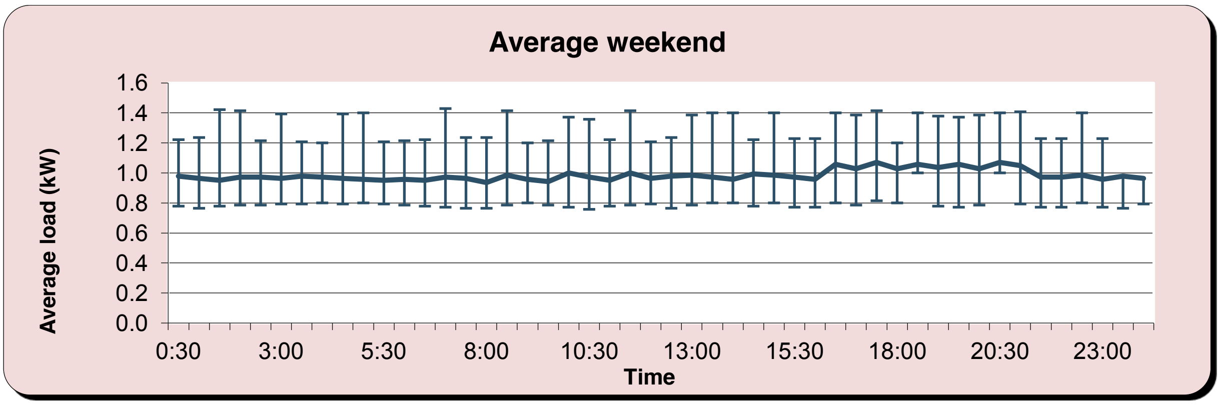


Figure 6.15 Sub meter power, 3 months data

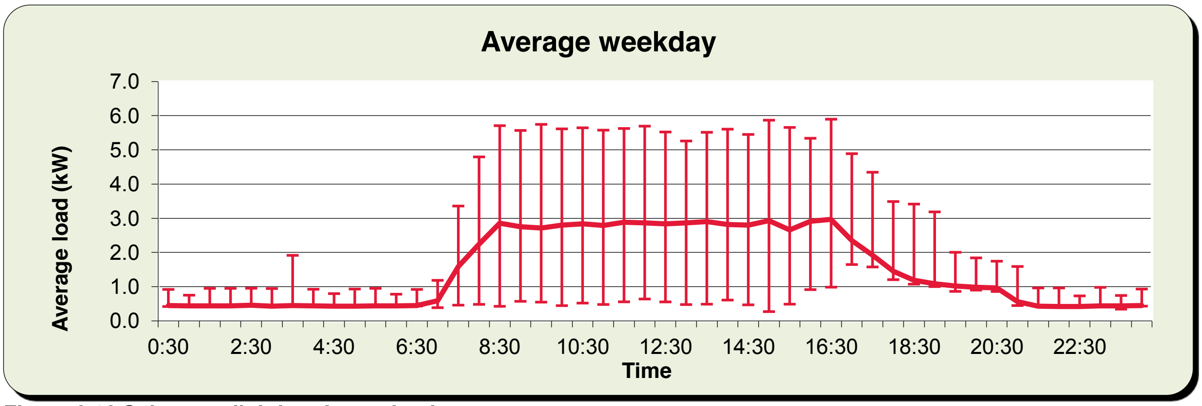


Figure 6.16 Sub meter lighting, 3 months data

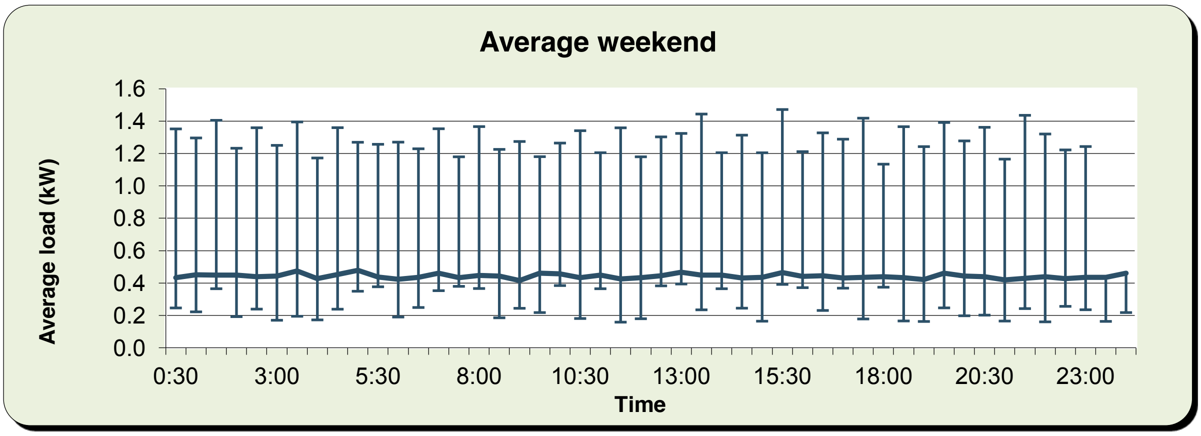


Figure 6.17 Sub meter lighting, 3 months data

In use vs. metered

The total in use vs. metered consumption was comparable with a 6% difference of ~1300kWh/year and 1.6 kWh/m^2 from actual use **[Table 6.10]**.

Lighting

The lighting consumption was also comparable in relation to in use against metered. A greater difference can be observed during the core hours of internal lights where the metered energy is greater than the in use entries **[Figure 6.18]**. This can be possibly explained by the fact that some light fixings are more energy intensive than stated or their use profile is slightly different from that as surveyed.

Power

The power includes the MVHR and warm air hand dryers; the Small power includes personal computers, monitor screens, interactive whiteboards/projectors and a desktop printer. The overall difference came to 859kWh which is about 1kWh/m^2. The difference is evident during non-core hours and weekends **[Figure 6.19]** where more is used than calculated and this is possibly being contributed to by equipment left on after the building's use.

Base loads

The base load of the lighting is 6 W/m^2 and of the Small power is 12.6W/m^2. These figures are comparable with the general benchmarks (CIBSE Guide F) of 12 W/m^2 and 10-15 W/m2 respectively.

Table 6.10 Sub meter reconciliation Junior Block

Sub meter	Description	Total	
		Metered	In-use (reconciled)
E01	Extension C - Lighting	11,635	11,157
E02	Extension C - SMALL POWER	11,255	10,396
TOTAL		22,890	21,553

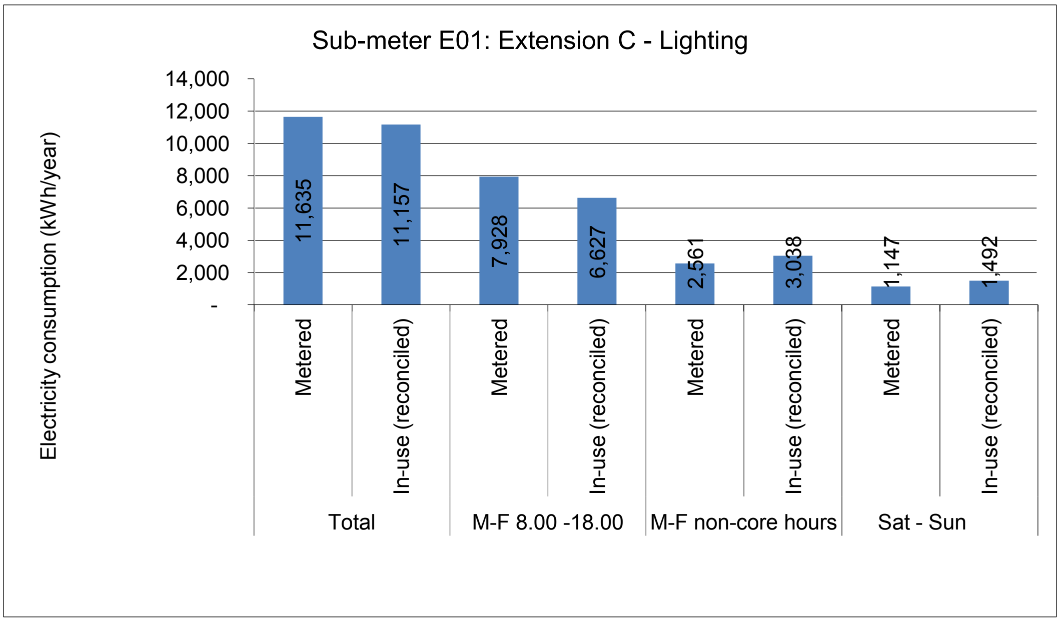


Figure 6.18: Sub meter E01 Extension C Lighting

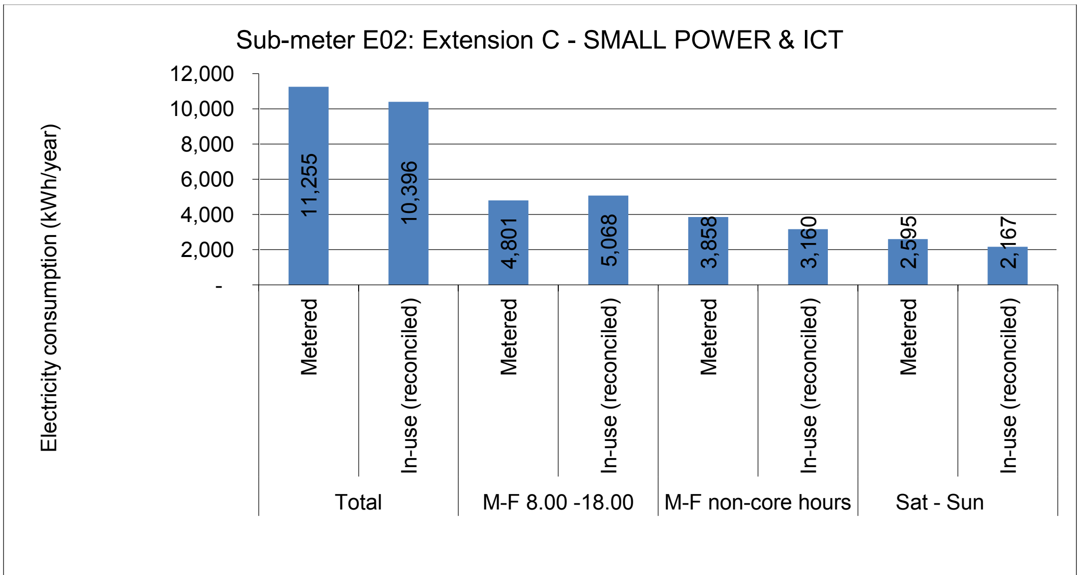


Figure 6.19: Sub meter E02 Extension C Small Power

Table 6.11 Energy use breakdown

ENERGY DEMAND
(kWh/m^2/year)

	Heat demand (kWh/m2/year)	Electricity demand (kWh/m2/year)		Additional metrics for electricity demand			
System	**In-Use (kWh/m2/year)**	**In-use electricity (kWh/m2/year)**	**In-use electricity (kWh/year)**	**In-use % of total**	**In-Use Full load W/m2**	**System hours/year**	**Utilisation**
Space Heating	46.5	0.0	0	0.0%	0.0	0	0.0%
Hot water	34.8	0.0	0	0.0%	0.0	0	0.0%
Fans	0.0	5.4	4,426	20.5 %	0.8	7,075	80.8%
Controls	0.0	0.1	88	0.4%	0.0	8,760	100.0%
Lighting (Internal)	0.0	9.2	7,490	34.8 %	6.2	1,473	16.8%
Lighting (External)	0.0	4.5	3,667	17.0 %	0.7	6,153	70.2%
Small Power	0.0	7.2	5,882	27.3 %	12.6	573	6.5%
Total	**81.3**	**26.4**	**21,553**	100.0 %	**20.3**		
Metered building energy use	81.3	28.0	22,890				
Variance TM22 versus metered total	0.0	-1.6	-1,337		**Building GIA:**	817	
Variance TM22 versus metered total	0%	-6%	-6%				

Summary: Junior Block

The electricity consumption was predicted to be 34 kWh/m^2 in total. For the gas demand, the predicted Figures were 37 kWh/m^2 for heating and 10 kWh/m^2 for hot water. The actual energy consumption from utility and sub meter data collected was 22,890 kWh/year for the electricity and 78,186kWh/year for gas which equates to 28kWh/m^2 and 95.7 kWh/m^2 respectively.

Carbon emissions can be calculated at 15.4 KgCO$_2$/m^2 for the electricity consumption and 18.6 KgCO$_2$/m^2 for the gas. The electricity consumption is 18% less of what was predicted and in contrast the gas consumption is around double. However, due to the gas' lower carbon intensity the total of the building comes to 34 KgCO$_2$/m^2 which is 6.2 KgCO$_2$/m^2 from predicted and 17.1 KgCO$_2$/m^2 from the TM49 benchmark **[Table 6.7]**.

6.3 Conclusions and key findings for this section

Dining Block

- The Electricity consumption was lower than predicted.
- The gas consumption was 4.5 times higher, due to various possible reasons, including the double space height of the Dining Hall, energy losses from the pipework, a poor air permeability score, the kitchen extract feedback loop discussed in section 7 and the space being used by community groups outside school hours, twice a week.

Junior Block

- The electricity consumption is lower than predicted. This could also be a result of sufficient signage for the staff as a reminder to switch off equipment when not in use.

- Heating and hot water use is higher than predicted. This can be explained possibly by two reasons: 1. Use of space outside school term dates and hours by other groups. 2. It was mentioned that the staff were not able to fully comprehend the correct use of the underfloor heating and thermostats. Additionally, this could possibly explain the overheating remarks recorded in the 2014 BUS survey.

The TM22 energy evaluation assessment looked at the two new buildings separately. Generally, the energy consumption and carbon emissions were within the range of expectations or better apart from the gas use in the Dining Hall which rose to be 4.5 times greater than expected.

If both of the buildings were to be reviewed as a total project, even with the "over consumption" of gas the total energy consumption falls very close to the available benchmarks/statistics[1] as seen from Figure 6.21. Furthermore, the Dining Hall due to its seasonal use falls into the category of TM46's"seasonal buildings", so its final energy consumption should perhaps not be compared with school/primary school benchmarks as a separate building but rather as part of it.

If the Junior Block is assessed on its own as seen in **Figure 6.20**, then the results presented are quite encouraging, as it shows to be much less energy intensive than other benchmarks/statistics presented.

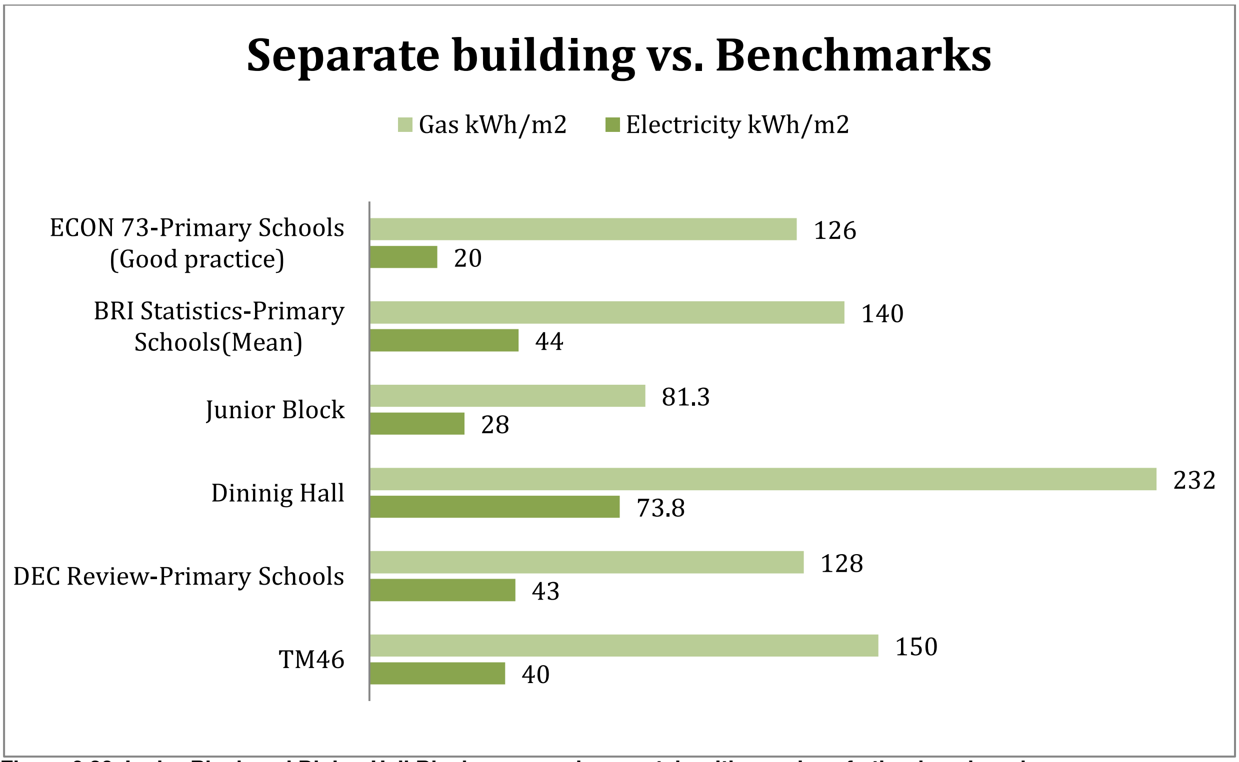


Figure 6.20 Junior Block and Dining Hall Block compared separately with a series of other benchmarks

[1] DEC, Sung-Ming Hong et Al, An Analysis of Display Energy Certificates for Public Buildings, 2008 to 2012 CIBSE, UCL 2013 AND BRI Daniel Godoy-Shimizu et. al Using Display Energy Certificates to quantify schools' energy consumption, BRI 2011 AND ECON 73, Energy Consumption Guide 73 Saving energy in schools, 1998

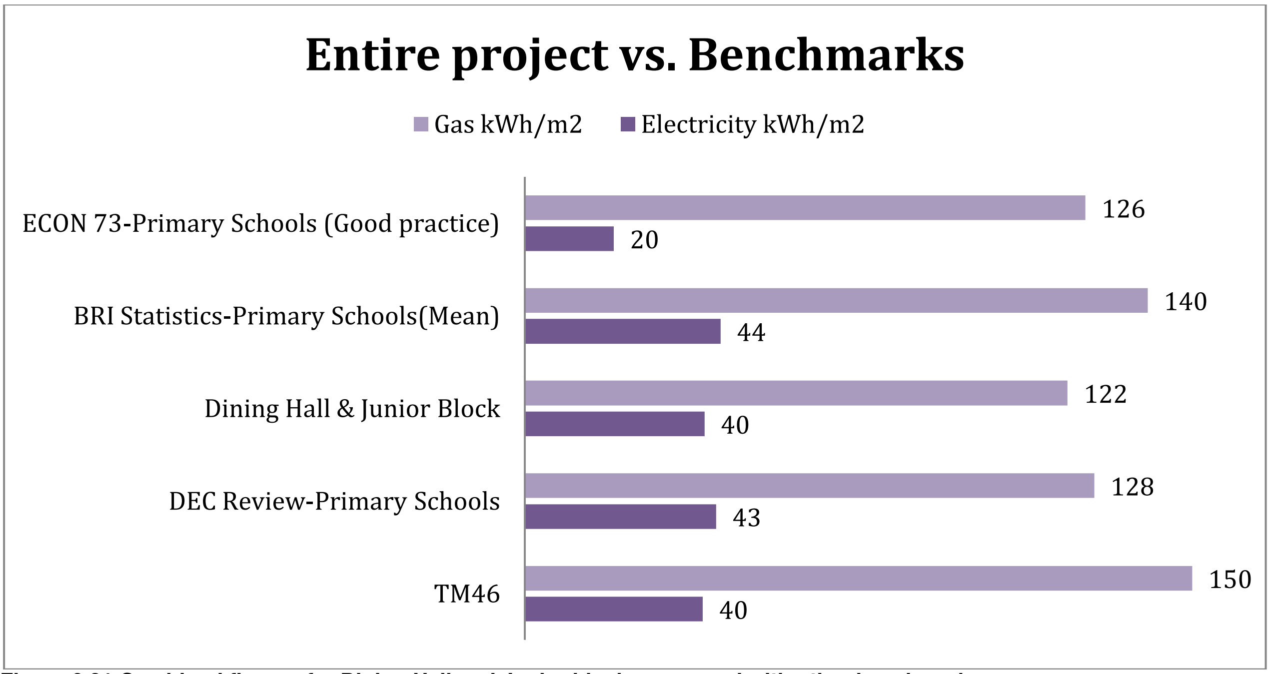


Figure 6.21 Combined figures for Dining Hall and Junior block, compared with other benchmarks

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 Technical Issues

Building fabric performance

*Findings in this section are based on results data from the APT air permeability testing reports **[Appendix 6]**.*

The Dining Block was certified under the 2006 Part L2a Approved Document. No air pressure test was required as this building was less than 500m^2. It was assumed to have an air permeability of 15m^3/hr/m^2 for the purposes of compliance energy calculations.

The Junior Block was an extension as opposed to a wholly new construction, so was regulated by Approved Document Part L2b, which also required no air test.

Had an air test been required for either building, the target that the buildings would have been tested against would have been 10 (m^3/hr.m^3)

As there was no data on air permeability that could be analysed as part of the BPE study, an independent air pressure test was commissioned by the BPE team. Five different areas of the site were tested, three areas of the existing building, plus the two focus areas of the BPE study. Each was subject to a pressurisation and a depressurisation test, the average of which can be taken as a representative value for the performance of the building fabric. The results of the pressure testing can be seen in the table below.

Table 7.1 Existing School Building

Area	Pressurisation (m^3/hr.m^2),	Depressurisation (m^3/hr.m^2)	**Average (m^3/hr.m^2),**
Existing School - Area A	8.00	8.17	**8.09**
Existing School Area B	8.66	8.74	**8.70**
Existing School Area C	9.22	9.10	**9.16**
Average Existing School	**8.63**	**8.67**	**8.65**

Table 7.2 New Build areas – BPE study focus

Area	Pressurisation (m^3/hr.m^2),	Depressurisation (m^3/hr.m^2)	**Average (m^3/hr.m^2),**
New Build Junior Block Extension	8.38	8.60	**8.49**
New Build Dining Hall Block	11.75	11.95	**11.85**
Average New Build School	**10.07**	**10.28**	**10.17**

The measured air permeability for the New Dining Hall building was 11.75 ($m^3/hr.m^3$) under pressurisation and 11.95 ($m^3/hr.m^3$) under depressurisation, an average of 11.85 ($m^3/hr.m^3$). The air permeability target under the 2006 building regulations was 10 ($m^3/hr.m^3$). Had it been required that this building was pressure tested for compliance, these measurements indicate that it would have failed.

The Junior Block extension performed significantly better, with results of 8.38 ($m^3/hr.m^3$) under pressurisation and 8.60 ($m^3/hr.m^3$) under depressurisation, an average of 8.49 ($m^3/hr.m^3$). This would have been a clear pass had the building been required to undergo a compliance test.

An interesting conclusion from the test was the performance of the existing building, which scored better average results than those of the new construction. Further, when one arranges the test results in order of date of building construction, it can be seen that air testing results get consistently worse, from the original 1950s school building in Area A, through to the later extensions in Area B and C, to the Dining Hall in 2011. The only exception to this rule is the Junior Block extension, which despite scoring under 10 ($m^3/hr.m^3$), is still leakier than the original school building.

RESULTS SUMMARY			
Air Permeability Target ($m^3/hr.m^2$):	10	Measured Air Permeability ($m^3/hr.m^2$):	11.75
Air Leakage Coefficient [C_L] (m^3/hr):	1,401	Air Flow Coefficient [C_{env}] (m^3/hr):	1,409
Air Flow Exponent [n]:	0.49	Correlation Coefficient [r^2] (%):	99.9
Flow at 50 Pa [Q_{50}] (m^3/hr):	9,531	Air Changes per Hour at 50 Pa (1/hr):	12.43
Specific Leakage Rate at 50 Pa ($m^3/hr.m^2$):	37.23	Equivalent Leakage Area at 50 Pa (m^2):	0.4753
Has the building envelope achieved the required air permeability:			NO

Figure 7.1 Dining Hall – Detailed air permeability report (pressurisation)

RESULTS SUMMARY			
Air Permeability Target ($m^3/hr.m^2$):	10	Measured Air Permeability ($m^3/hr.m^2$):	8.6
Air Leakage Coefficient [C_L] (m^3/hr):	1,764	Air Flow Coefficient [C_{env}] (m^3/hr):	1,780
Air Flow Exponent [n]:	0.5867	Correlation Coefficient [r^2] (%):	99.5
Flow at 50 Pa [Q_{50}] (m^3/hr):	17,510	Air Changes per Hour at 50 Pa (1/hr):	5.82
Specific Leakage Rate at 50 Pa ($m^3/hr.m^2$):	26.81	Equivalent Leakage Area at 50 Pa (m^2):	0.8732
Has the building envelope achieved the required air permeability:			YES

Figure 7.2 Junior Block – Detailed air permeability report (pressurisation)

Overheating Assessment

Findings in this section are based on the UCL Overheating Report ***[Appendix 1]****.*

A total of 3 classrooms, with 1 data logger per space, were assessed - location of spaces in the school and positioning of data loggers is summarized.

Table 7.2 - Overheating assessment methods

Current BB101[1]	Revised BB101[2]
Criteria 1: Maximum 120 hours T_{dry}>28°C	*Criteria 1*: Maximum 80 hours T_{op}>28°C *Criteria 2*: Maximum 200 hours T_{op}>25°C
Criteria 2: Maximum Average $\Delta(T_{dry}-T_{ext})$<5°C	*Criteria 3*: Maximum 150 hours T_{op}>T_{max} *Criteria 4*: Number of hours $\Delta(T_{op}-T_{ext})$>3°C when T_{ext} is >22°C = 0
Criteria 3: Maximum T_{dry}=32°C	*Criteria 5*: Maximum T_{op}=32°C

[1] Two out of the three criterions must be met.

[2] Either criteria 1&2 OR 3 must be chosen to comply with. All four criteria must be met.
Abbreviations: T_{ext} = External temperature, T_{dry} = Dry bulb temperature, T_{op} = Operative temperature, T_{max} = Maximum operative temperature defined by BS EN15251 (BSI, 2007)

Assumptions/Clarifications/Limitations:

- A school core hour period of 09:00 to 16:00 with no lunch break (Monday to Friday) is assumed, giving different totals of occupied hours for the different monitoring periods for the 3 classrooms. The 'hours over' threshold limits were calculated based on these occupied hours as documented in the results section.
- For Revised BB101 T_{max} was calculated by assuming a Category II building.
- Despite that the Revised BB101 specifies the use of the operative temperature, this was not available at monitoring stage and the dry bulb temperature was used instead. It is understood that effects of mean radiant temperature and air speed can create a significant difference between the two temperatures. This should be taken into consideration during the interpretation of the results.

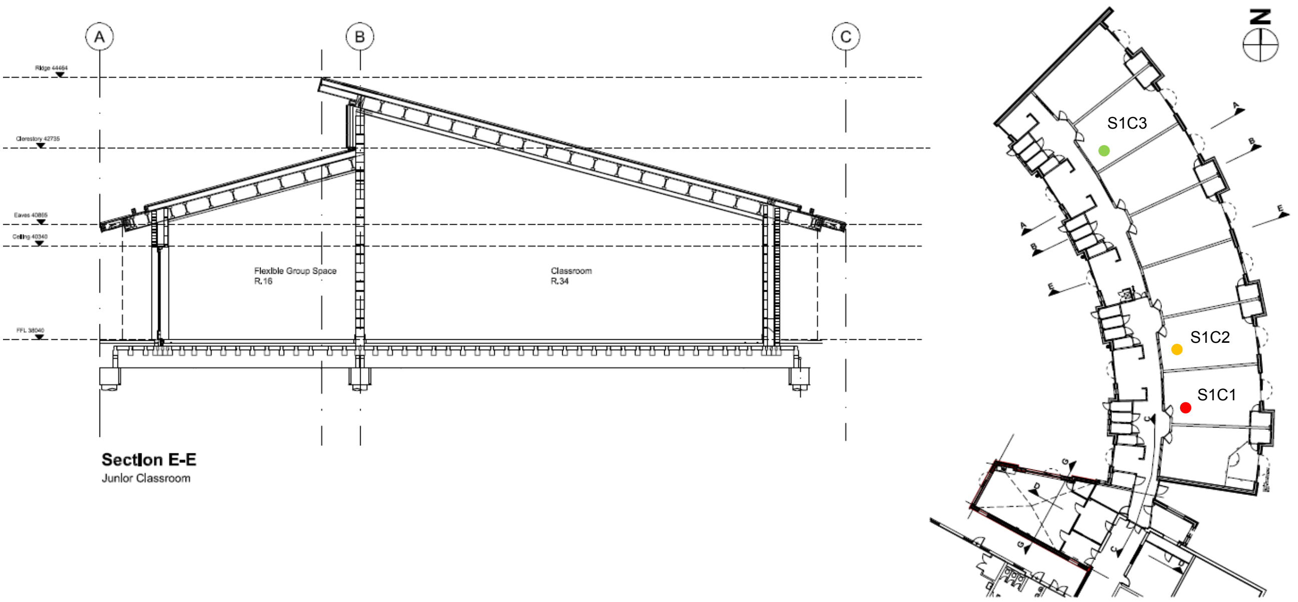


Figure 7.3: location of UCL data loggers in Junior Block Extension. Classrooms are labeled S2C1 (Red), S2 C2 (Amber), and S2C3 (Green)

Table 7.3 Two-stage analysis of monitored data

	Intended Deliverable
Analysis of temperature profile	Assessment of the diurnal fluctuations of temperature to indicate fluctuations with external temperature, operation of ventilation systems and response to internal gains.
Assessment of overheating	Assessment of the likelihood of overheating against the pre-defined criteria.

The monitoring period for the three classrooms is summarised below:
Class S2C1 19th April 2012 – 18th July 2012
Class S2C2 19th November 2011 – 23rd December 2011 and 19th April 2012 – 18th July 2012
Class S2C3 19th November 2011 – 9th July 2012

The external hourly data for the monitoring period was obtained from a weather station located within the school premises.

Results

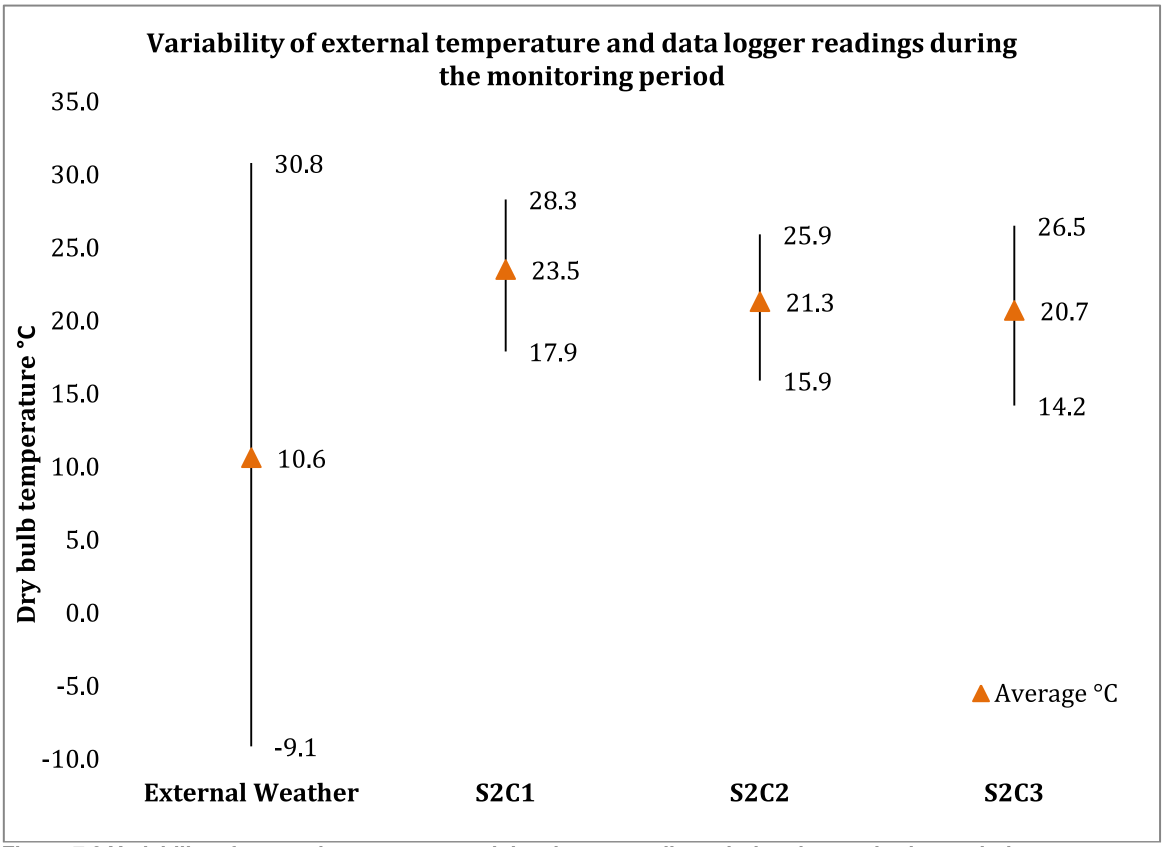


Figure 7.3 Variability of external temperature and data logger readings during the monitoring period

The following observations were made:
- Small variability range for all the three classrooms compared with the external temperature.
- Comparable ranges for the three classrooms with highest average recorded temperature in S2C1 and lowest in S2C3.

Classroom S2C1

The highest peaks in temperature were exhibited in Classroom S2C1. The internal temperature profile illustrates sharp peaks followed by decay in temperature. The peaks are presumably associated with instant occupation of the classroom in the morning. The decay in temperature is deemed to be representative of the effectiveness of the ventilation in dissipating the peaks in internal temperature. During the hottest days, despite that the internal temperature does follow the trend of the external temperature, it does not reach the highest peak of the outdoor temperature. However since the internal temperature responds to a certain extent to the external temperature, this might indicate that the space is vulnerable to overheat in future incidences of elevated temperature.

Classroom S2C3

The temperature profiles illustrate relatively stable space temperatures with minor peaks in temperature. The internal temperatures are unaffected by the sharp rise in the external temperatures, indicating that the space is not likely to be vulnerable to incidences of overheating.

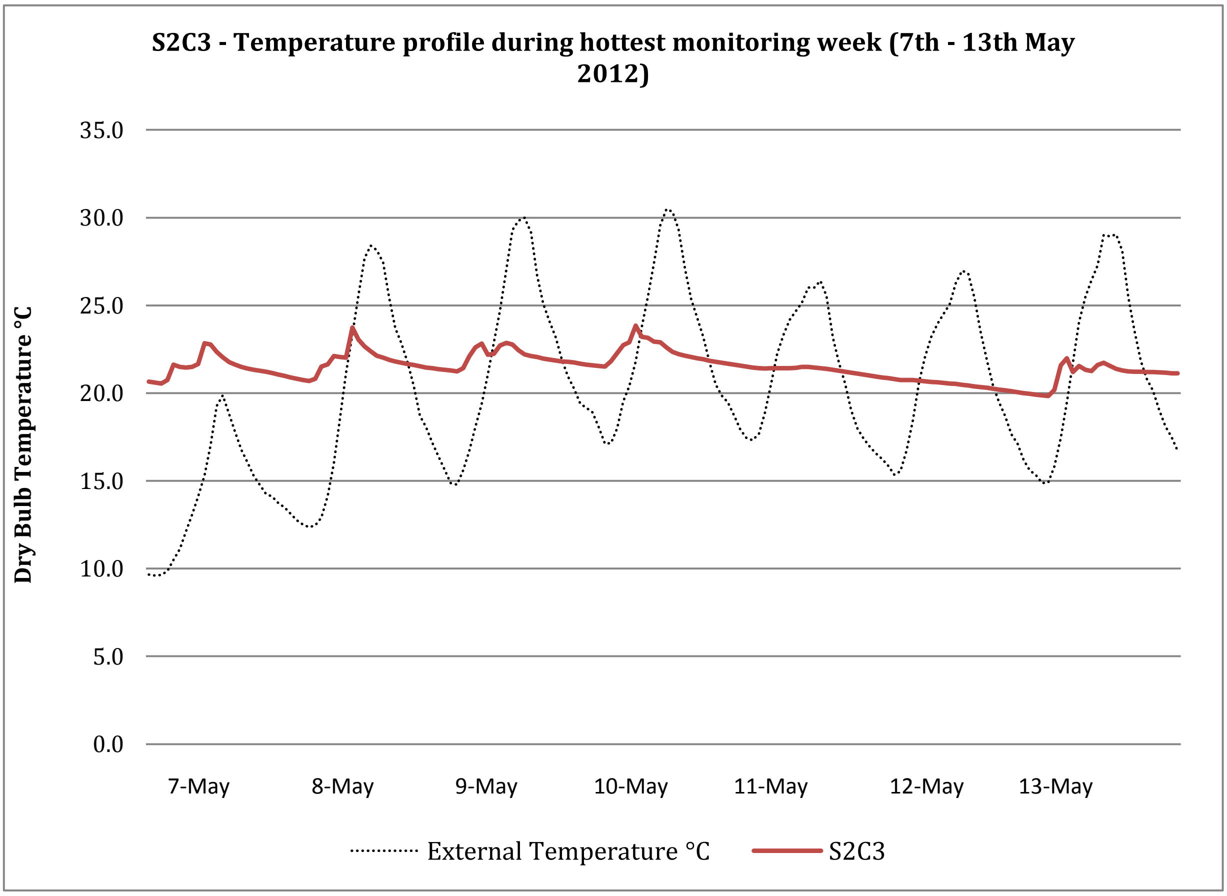


Figure 7.4: Temperature profile of classroom S2C3 for one monitoring week (7th to 13th May 2012)

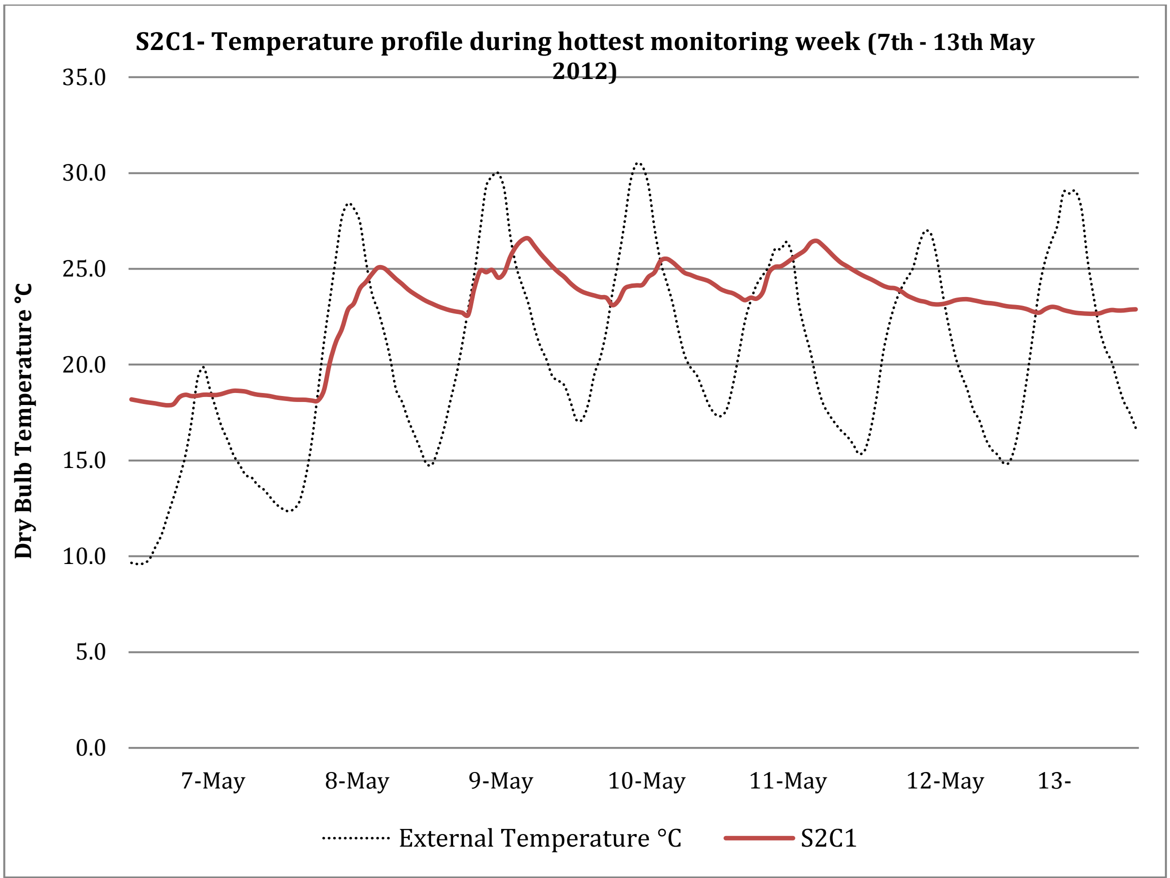


Figure 7.5 Temperature profile of classroom S2C1 for one monitoring week (7th to 13th May 2012)

The table below summarises the assessment of overheating results as per the Current BB101 and the Revised BB101 for the individual monitoring periods for each classrooms.

Table 7.4 Current and Revised BB101 overheating results for the 3 classrooms

	Current BB101			Revised BB101				
CLASS	Number of hours Tdry>28°C	Average Δ(Tdry-Text) (°C)	Maximum Tdry (°C)	Number of hours Top>25°C	Number of hours Top>28°C	Number of hours Top>Tmax	Number of hours Δ(Top-Text)>3°C when Text is >22°C	Maximum Top (°C)
S2C1	0	5.9	27.3	97	0	15	0	27.3
Threshold Limits	*104 hours*	*5°C*	*32°C*	*173 hours*	*69 hours*	*130 hours*	*0 hours*	*32°C*
S2C2	0	7.1	23.5	0	0	0	0	23.5
Threshold Limits	*144 hours*	*5°C*	*32°C*	*240 hours*	*96 hours*	*180 hours*	*0 hours*	*32°C*
S2C3	0	12.5	22.8	41	0	0	0	22.8
Threshold Limits	*269 hours*	*5°C*	*32°C*	*448 hours*	*179 hours*	*336 hours*	*0 hours*	*32°C*

Criteria PASS | Criteria FAIL

The results indicated that all three monitored classrooms in the new extension of the Castle Hill Primary School pass the overheating criteria prescribed by the currently used BB101 and the revised BB101 overheating assessment methods, showing that, based on the external temperature conditions during the monitoring period, the classroom spaces in the new extension are not foreseen to suffer from overheating. The performance in use (PIU) criterion was always passed. Only classroom S2C1 exhibited a tendency to overheat as the internal temperature profile followed the external temperature during the hottest monitoring period and also as shown by the incidences of dry bulb temperature above 25°C. It is likely that the exposed thermal mass of the building was influential in buffering the spaces against the outdoor environment.

ECD Walkthrough findings - Lighting

- Lighting is regarded as one of the most positive aspects of the building, both the provision of natural light and the provision of adequate artificial lighting **[Figure 7.6]**. The bursar explained that staff do not generally comment when services are performing well, as they seem to assume it should just be working, and so the fact that complaints are rarely received about the lighting is a good indication. These findings are corroborated by the **BUS survey**, where lighting scores highly in comparison to the ARUP benchmark.

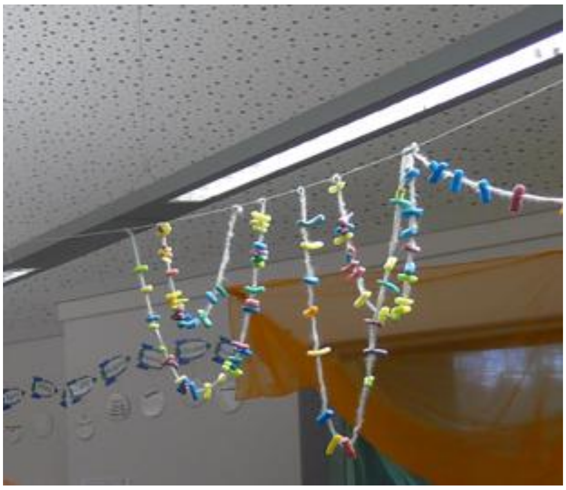


Figure 7.6: Lighting in the bulge classroom, (with additional improvements from the children)

- One suggestion from the caretaker was that the staff would have benefitted from additional training on using the lighting during early occupation. Although the daylight-linked dimmable low energy lighting and PIR sensors appear to operate correctly, the staff were unaware that if they wanted more light once the lights were dimmed, they could simply 'press and hold' the switch until the required brightness was achieved. The caretaker reported that once he had established this capability when using the controls, he subsequently informed the other staff.

Ventilation

- The staff present at the building walkthrough were familiar with the wall mounted control system for the ventilation, which has four simple buttons 'open', 'close', 'automatic' and 'manual', but they did not know what it was that was triggering the ventilation grills to operate. When it was explained that they were linked to wall mounted sensors **[Figure 7.7]** measuring readouts for CO_2 in 'Parts per million', this appeared to clarify the matter. It is suggested that one of the outcomes of the walkthrough will be to propose a further training session on ventilation strategy for the building. This is included within the Building User Guide, but as the information does not appear to have made its way to the end users, that additional training would benefit all involved.

Figure 7.7: CO_2 sensors in the Dining room (taken when room was unoccupied), appeared to be registering a sensible reading, 420 parts per million. Temperature for the same sensor appeared slightly

- During the walkthrough, when one of the teachers was questioned on the experience of her space during in the winter, she drew our attention to the ventilation grill located above the main teaching space **[Figure 7.8].** She explained that the in winter time, when the vent opens, it causes a cold draught of air to come down into the room. As a result she is often required to move children away from the area in order that they may continue their work unaffected.

- The UCL Indoor Air Quality assessment, as discussed in the next section, has confirmed that the ventilation grilles are operating correctly in the heating season. The vents are seen to activate above CO_2

levels of 1500ppm and they quickly reduce the CO_2 levels to acceptable limits. However, from the comments of the staff during the walkthrough, it is clear that this 'purge' type ventilation is uncomfortable for the children, as the air is brought in directly from the outdoor environment. Each time cold air is being brought directly in to the building, an equivalent amount of warm air is also leaving the building. This clearly has implications for the energy usage. Had the ventilators incorporated a heat recovery element, the observed problems with comfort and energy usage could have been dramatically improved.

Figure 7.8 - Passive stack ventilation system in classroom, overlay indicates effect of cold draught as reported by staff member.

- It was reported that some of the ventilators drip water, most notably in the Dining Hall, where occasionally a small puddle is found on entering the room. The staff thought at first that the dripping may have been a result of condensation, but since noticing that the problem increased when there was heavy snow on the roof, they now believe it is also possibly a result of poor weather sealing. The caretaker was asked whether switching the sensor to 'manual' and closing the vents addressed the problem. He replied that he had tried this once in the bulge classroom, but that it was still dripping after a couple of hours. It is likely that the system is in need of re-checking by the installer, with additional commissioning if necessary. The school have been informed of this recommendation, although at the time of writing a visit has not yet been scheduled for the vents to be re-commissioned.

- The MVHR supply and extract fans in the children's WCs were found to be operational (the extract checked using a piece of paper). The rooms did appear much cooler than the adjoining corridors and the air flow from the fans also appeared to be quite high. Blistering paintwork and dark staining is evident in certain locations locally to the WCs and it is possible that this is a result of temperature fluctuations.

- The control system for the WC ventilation system is located in the store room next to each set of WCs. There were no immediately apparent controls suggesting how the fan speed could be altered and the caretaker was not aware of whether this was possible. It is probable that the system would benefit from further calibration.

Indoor Air Quality

Discussion in this section is summarised from the UCL Indoor Air Quality Report ***[Appendix 2]***

An indoor air quality assessment was conducted at the school by researchers at UCL. As part of the study, the researchers took samples of CO_2 concentrations during spring and winter seasons within three classroom spaces in the new Junior Block. They compared these against Building Bulletin 101 (BB101) which provides the regulatory framework for the adequate provision of ventilation in UK schools and which is based on Part L and F of Building Regulations. BB101 ventilation performance standards regarding carbon dioxide levels can be summarised as follows:

- The average concentration of CO_2 should not exceed 1500 ppm during occupied hours.
- The maximum concentration of CO_2 should not exceed 5000 ppm during the teaching day.
- At any occupied time the occupants should be able to reduce the concentration of CO_2 to 1000 ppm.

The standard also recommends minimum, daily average and maximum achievable air flow dependent on number of occupants.

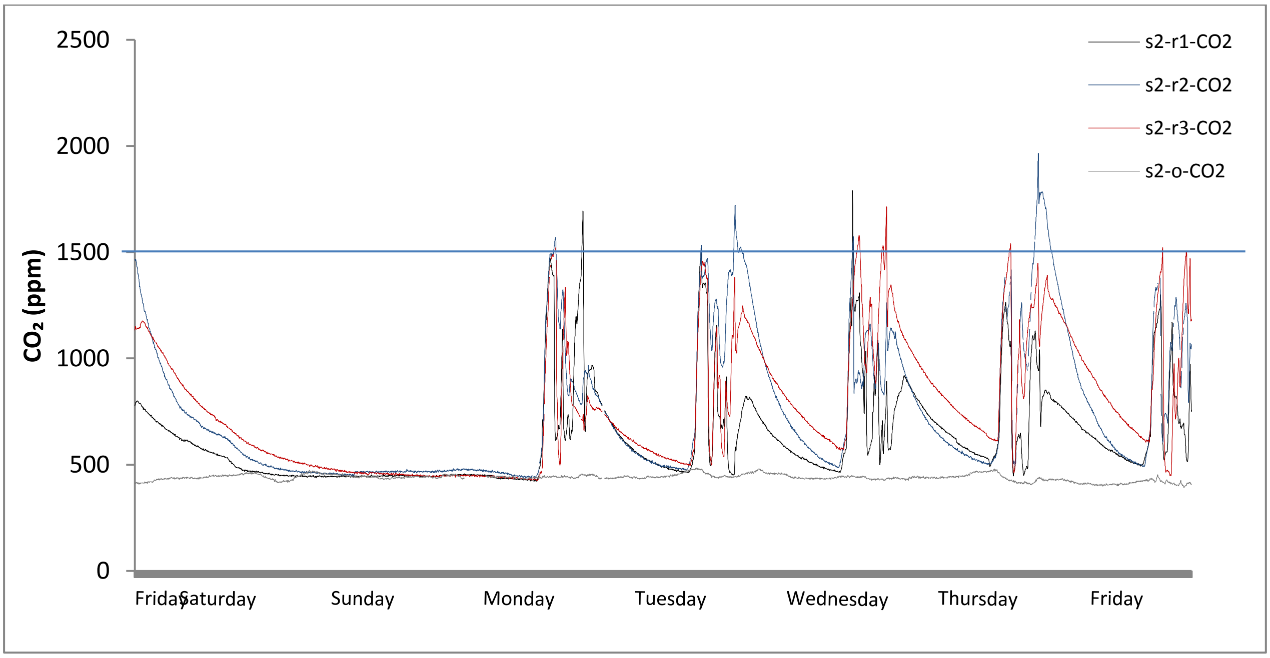


Figure 7.9 : CO_2 concentrations during the winter season in 3 investigated classrooms and the outdoor site

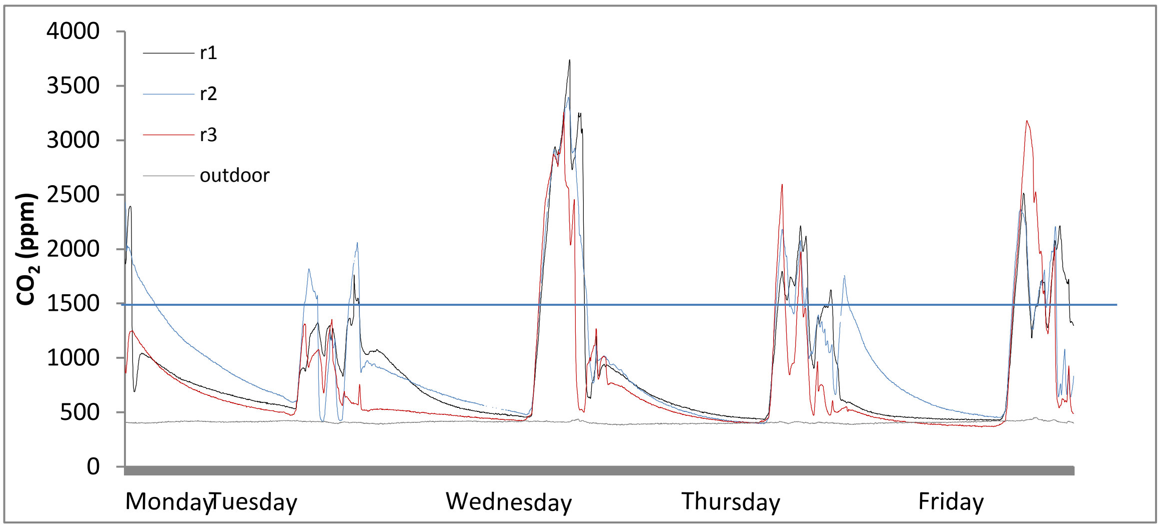


Figure 7.10: CO_2 concentrations during the spring season in 3 investigated classrooms and the outdoor site

A significant increase of indoor CO_2 concentrations was noticed in the non-heating season **[Figure 7.10]**. In **[Figure 7.9]** it can be noticed that indoor levels did not exceed 1500 ppm due to CO_2 controlled sensors of the mechanical exhaust. However, during the non-heating season, indoor concentrations of CO_2 exceeded 1500 ppm 50% of the occupied period **[Figure 7.10**. While there is not a clear explanation of the observed differences, it was speculated that an unsuitable setting of the mechanical exhaust was applied during the non-heating season.

The research concluded that the ventilation strategies were capable of providing a satisfactory environment according to BB101 guidelines in both seasons. However, it also found daily average concentrations of CO_2 above 1000 ppm in the spring season and cited increasing evidence in studies of other school classrooms that the high concentrations might be related to increased prevalence of SBS symptoms and reduced academic performance.

Table 7.5: Average CO_2 readings in the Junior Block

	non heating season				heating season			
room code	CO_{2max}	CO_{2av}±SD	CO_2±SD outdoor	ACH	CO_{2max}	CO_{2av}±SD	CO_2±SD outdoor	ACH
Classroom average	3464	1540±726	415±11	0.34	1823	938±299	428±17	0.18

Although the school complied with current BB101 guidelines recommendations on CO_2 levels, school children were less satisfied with IAQ. Reasons for the dissatisfaction noticed may be related to:

- High microbial concentrations.

Previous research has correlated carpeting with increased microbial concentrations. Fungi concentrations sampled in Castle Hill Primary school in settled dust were significantly higher than other schools with both hard floors and carpeted floors. Therefore, the fieldwork indicated that the combination of carpeting with underfloor heating provided a suitable substrate for microbial growth.

- High concentrations of organic pollutants (TVOCs)

While there are no thresholds on TVOCs exposure developed in the UK, most countries' thresholds are in the magnitude of 90 to 260 ppb. Daily average values in the school exceeded the values because of cleaning products used in the school. The high pinene and limonene concentrations indicated the use of inappropriate cleaning products introduced in the classrooms.

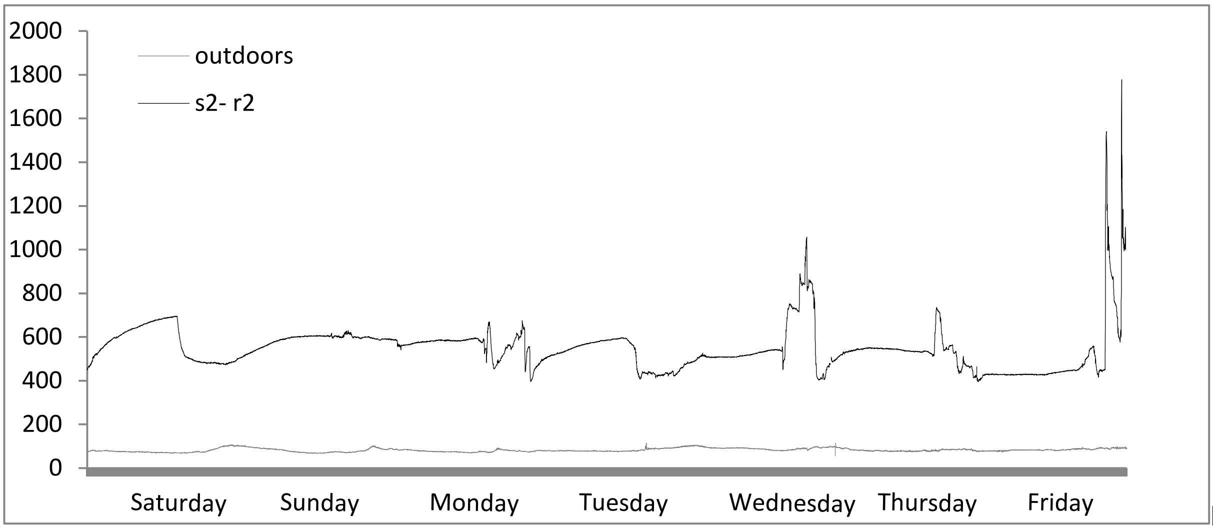


Figure 7.11 Indoor and outdoor concentrations of TVOCs in the non-heating season

Although obtaining emission factors from materials is still under development, the continuous TVOC profile and high formaldehyde concentrations indicated the presence of high emitting furniture and construction materials. It is therefore crucial that school management should use low emitting cleaning products and designers should consider emission factors of materials used in educational buildings and other buildings with vulnerable occupants.

The provision of storage space in the classrooms could potentially improve IAQ, as pollution sources in the classrooms, such as artwork products, can be eliminated from the teaching space.

The direct access to the playground provided purge ventilation during the breaks preventing the build-up of pollutants; however it might have significant energy implications. The strategy employed to provide fresh air supply with low inlet and extraction from a high ceiling is an excellent approach for maintaining good IAQ. A disadvantage of the mechanical exhaust included the relative complexity of the use by the occupants. Teachers were not aware of the use of the mechanical exhaust due to inadequate briefing. Moreover, the controls were located away from the teacher's desk possibly discouraging the use. The high concentrations of CO2 noticed in the spring season indicate that an inadequate setting in the operation of mechanical exhaust was applied. The efficiency of the mechanical exhaust system was tested with smoke tube tests in the non-heating season. It might be worth designing operable windows at the high level instead because the teachers are more familiar with their manual operation.

Radon concentrations indoors were higher than outdoors and were close to the WHO 2010 recommendations of 100 Bq/m3. Concentrations of Particulate Matter (PM) in the classrooms during the occupied period exceeded WHO recommended guidelines. In order to reduce indoor PM concentrations, it is important to reduce dust reservoir in the classrooms such as carpets and upholstered furniture, also acting as microbial reservoirs.

Gaseous pollutants such as nitrogen dioxide (NO2), ozone (O3) and carbon monoxide (CO) were low both indoors and outdoors. The relatively airtight envelope of the building provided protection of the occupants from these harmful pollutants.

Indoor PM concentrations were found to be exceeding WHO 2010 guidelines during the occupied period. A similar study was conducted in 8 English primary schools (BRE, 2006) and found mean PM10 concentrations of 30 µg/m^3, which is lower than the values recorded in Castle Hill primary school in both seasons.

Analysis of the samples collected in the classrooms did not detect any horse and dust mite allergens. Cat allergens ranged from below detectable limit to above allergic sensitization threshold. It was noted that fungi concentrations in Castle Hill were significantly higher compared with similar studies of other London classrooms.

ECD Walkthrough notes Space heating and DHW

- The thermostat controls in the new extensions appear to be the subject of good management, with thermostats set at consistent temperatures of approximately 16-17^{o}C **[Figure 7.12]**

- Temperature readings of 21 and 22^{o}C were observed on the display readings in the hall block and one of the classrooms, which indicated either that there is a large mismatch between the sensors or that the system is not calibrated correctly.

Figure 7.12: A vast difference was noted between the room thermostats and the display readings in the classrooms

- The caretaker reports that the heating system will not come on Wednesday in the Dining Block. The engineers from Smith and Byford that came to investigate the fault were unable to establish the cause of the problem: when the controls were checked, the BMS programming appeared correct. It was reported that the heating for the old building is also often operating outside of its programmed set points. The school do not know whether it is happening all of the time, but the majority of times when the caretaker checks the building out of hours it is on. The problem has also been noted when the building is occupied occasionally on weekends and has occurred ever since the new system was installed.
- One of the JEL systems in the main boiler house has to be left on 'manual' in order for it to function. If it is put on automatic mode then it shuts off the other systems. Engineers from Smith and Byford were called in to check and the last engineer who visited acknowledged that certain elements of the wiring in the panel were incorrect. He wrote a report explaining the problem, which the company are now aware of, although the matter has not yet been resolved. The bursar noted that as a result of the fault they were paying unnecessarily for heating the school at the weekend. It was confirmed that this particular issue did not concern the heating or DHW in the Dining or Junior Block extensions, even though the BMS also controls these areas.

- When the building was first occupied in 2010, the underfloor heating in the 'bulge' classroom was on the whole time. The contractor explained that the problem was a result of the manifold being knocked, and resolved the issue by boxing in the manifold. The school have not had recurring problems.

- In January 2012 there was a leak in the underfloor heating system in classroom 6 (numbering runs from 1 at the Southern point, to 8 at the Northern point) near the controls by the cupboard. As the system was no longer covered by warranty, the school paid for a call out to the installer Working Environments. The classroom was without heating for a period of 2-3 weeks, and the school reported that they found it difficult to arrange the call out, in part as a result of the ongoing maintenance support for the company being provided by a separate office, which was located on the South coast of England. They explained that twice appointments were arranged when the engineer did not arrive within the allotted time. Nonetheless, once the engineer did arrive, the school appeared to be very satisfied with his work. He drained down the system, found the leak, and subsequently the problem appears to have been fixed.

Figure 7.13: One of the Smith and Byford BMS control panels, which link the existing Jel Micro 2000 controls (as top left)

Photovoltaic Panels

- In October 2013, a month before the walkthrough, the project team were made aware that the Photovoltaic panels at the school had not been generating any power since June 2013. The school explained that had been in correspondence with the supplier, EVO Energy, which attributed the fault to a major electrical component, known as the 'G59 relay'. This is the safety device that is used to shut off the power to the PV system in the event of a grid failure, in order to protect the safety of any operatives who may be working on the grid fault to restore power. It was suggested that the G59 relay may have incorrectly detecting that the grid was de-energised perhaps as a result of a blown circuit or faulty sensor.

- The display panel in reception confirmed that the panels were not operational at the time of the walkthrough **[Figure 7.14]** although the problem has since been fixed. The engineer had found a loose connection, and it was not the G59 relay as suspected. The school has lost 6 months of generation as a result of this failure, though the effect is more relevant for the existing buildings than for the POE areas of focus.

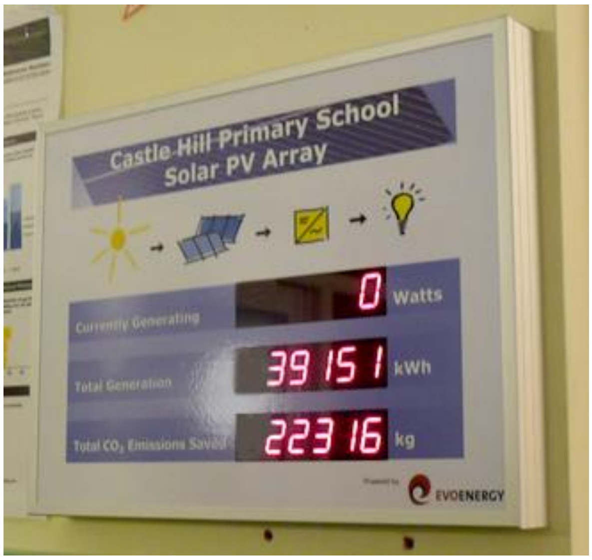


Figure 7.14: The photovoltaic array was not working at the time of the walkthrough. The Display panel in the hallway was reading correctly, and it was this that had alerted the school to the problem.

- Low-flow sanitary systems

Figure 7.15: The school has removed the pop-up wastes in all of the WCs. The children do not need them to wash their hands, and they cause additional maintenance issues.

- The WCs in the new building are installed with low volume flushes in an attempt to save water. The school demonstrated one of the flushing mechanisms in the Junior Block, a 'push button' mounted in the wall, which appeared to difficult to operate. It is reported that the children have greater difficulty.
- The main drain servicing Junior Block (Extension C) has blocked several times. The school are not aware exactly what was causing the issue, but that they have found paper towels in the blockages. The problem tended to occur after the summer holidays, when the pipes aren't continually flushed through by daily usage. The Building User Guide states that as the toilets are low volume flushes, that paper towels should not be put in the toilets, however it is apparently hard for the staff to police this, especially as the WCs are predominantly used by children. In part as a result of the blockages, and in part as result of cleaning up / restocking paper towels, the school have now removed the paper towel dispensers with and replaced them electric hand driers. Since these have been installed, the problems with the blockages are reported to be much improved. The school have also removed the pop –up wastes from the sinks, as these were not required for children to wash their hands, and tended to lead to additional blockages/overflows **[Figure 7.15]**.

Figure 7.16: Gas safety shut off switch in kitchen

- The classroom sinks in the Junior Block are adjacent to the East elevation, however the main drain for this building runs outside in the playground adjoining the West Elevation. As a result, each one of these waste pipes servicing the sink have to run across the entire width of the building. The staff often complain about smells emanating from the sinks, especially after the summer holiday, and are advised to run their hot taps to help clear any blockages. In the Northern most classroom at the end of the run, where the smell is worst, an additional stack has been installed. This has improved, but not eradicated the problem, which seems likely to be the result of an insufficient drainage fall. The Indoor Air Quality report by UCL highlights some concerns from occupants about the classroom air, and it is probable that these two matters are linked.

Catering kitchen

- As there were no catering staff present at the formal building walkthrough, it was not possible to discuss the workings of the kitchen in detail. The bursar and caretaker could not recall any specific problems that had been reported, but agreed that a follow up visit could be made to meet with the catering staff.
- The follow up visit occurred in June 2014, where it was possible to visit the kitchen in the morning whilst in operation. The staff present had participated in the BUS survey, but as none had specifically identified their within the questionnaire, it proved also beneficial to be able to get some further observations from the. The staff were able to give some general feedback to the working environment, which they noted on whole to be a clean pleasant space to work in. One of the staff members commented on the quality of the catering equipment that was installed, notably the large electric oven.
- The lack of office space was one of the only negative aspects mentioned by the catering staff. They reported that a catering office had been discussed during design stages, but was not included in the final plans. As a result there is now nowhere suitably quiet to review stock lists, make orders, carry out management activities or indeed to store personal items and change of clothes.
- However the greatest problem with the kitchen was actually a system which, on the day of the visit appeared to be working correctly. The gas supply to the kitchen is installed with a safety circuit, which is designed to operate the cooker extract fan whenever the gas supply to the building is also activated. This is a health and safety measure to protects building users from a gas leak, in the event that any cooking hob valves were inadvertently left on.
- This arrangement is a pragmatic approach to the safety of building users, and were the cookers the only load on the gas supply circuit, this arrangement would likely have provided a highly effective mitigation to the risk of a gas leak. However, the gas supply also feeds the boiler providing hot water to the Dining Hall Block. This brings the unfortunate consequence that whenever the gas is switched on to supply to boiler for hot water, the extract fans in the kitchen are also forced operate. The fans do not have an adjustment setting, so they run at the full capacity, pulling heat from the kitchen, regardless of whether there is any cooking taking place.

  The catering staff require hot water for preparation from the first time they arrive in the morning, so the caretaker switches on the gas supply when he opens up in the morning. The staff do not begin cooking with gas until much later in the day, which means that the kitchen becomes very cold in the winter mornings, as the extract fans quickly draw out residual heat within the space.

  There are only a small number of radiators in the cooking area, a result of a space restrictions and a requirement for large amounts of cooking equipment. The radiators which are present are unable to adequately meet the heat demand of the space when the fans are in operation. The school has attempted to remedy the situation by installing a dimplex fan heater above the door. As this is operated by electricity in lieu of gas it is a much more carbon intensive way of heating the space.

  As a result of this unfortunate arrangement, a kitchen fan, and an electric heating system are thus locked into a feedback loop, which needlessly strips out the heat extracted from the kitchen and Dining Hall, only for it to be replaced by an especially inefficient heating system, and stripped away once more.

  Not only can this system be described as wasteful in terms of energy, but can it also be blamed for decreasing comfort levels within the space. The extract fans are noisy, and also create negative pressure, which, within a leaky building such as the Dining Hall, bring in cold unpleasant draughts from outside, and affect the conditions within the adjacent Dining Hall space.

There are no cheap remedies to the situation that has developed, but had the system been designed a second time, the problem could be been avoided by installing a separate gas supply valve, or via the specification of an induction hob. These systems do not require gas, and do not emit combustion gases that need to be extracted – any fans can therefore have lower extraction rates. Another benefit can be found in summer, as the cooking process using an induction hob does not give off as much as when gas is used, and therefore the risk of building overheating is reduced.

The one positive observation that can be drawn from the visit to the kitchen was that a system designed to protect the inhabitants of the building, was correctly installed and doing its job. Nonetheless, had the project team been aware of the consequences of compiling the system in such a manner, they would likely have sought a different solution.

This unfortunate series of design decisions has resulted in an uncomfortable environment for the staff to work in, which locks the mechanical services into a wasteful energy usage profile.

Energy metering

In preparation for the formal building walkthrough, the project team carried out a TM22 analysis of the available sub meter data from Smith and Byford and incoming supply data from the utility company, in order that the findings of the analysis could be used to inform the on-site discussions with staff. Sub meter tree diagram was created by the project team, in order to condense the information from schedules and wiring diagrams into a more readily accesible format **[Figure 7.17].**

It became apparent from analysing the two streams of incoming data that the sub meters were not reading consistently with the utility company. As an example, the sub meter for the Dining Hall Block was using a consistent 6-7kW of Power, which seemed unlikely, and suggested instead that the meter was inaccurate. The extent of the problem was less than clear, as the school had access only to paper bills, not all of which were 'actual' readings.

An engineer from Smith & Byford came to site to investigate the issue. He reported that he could not find significant problems, although he did reset the meters. The Bursar noted that whilst they were unable to comment one way or another how well the meters were working, they agreed that it seemed highly unlikely that the usage was like this.

After lengthy but helpful discussions with the school's energy broker, it became apparent that the utility company were able to provide half hourly electrical data. The data was sent to Smith & Byford for their comment, however the BPE team was unable to get the company to agree that their system was at fault, noting that the system had been set up correctly when installed, and that they were not responsible for issues caused by power outages and other site issues since that point.

Further interrogation of the sub meter data however, the BPE team was able to show that the meters had never been functioning correctly, and the company agreed to return to site to fix the problem, on the condition that the school added annual maintenance of the metering system to their ongoing contract.

A timeline has been provided below in order to better describe the process;

Sub metering timeline

Feb – Sept 2011	Project agreed Feb 11, contracted mid-2011; it was agreed that the existing metering was not sufficient for the BPE (The existing condition of the systems is set out in the following section)
Sept 11 – Mar 12	The task of providing the metering equipment was carried out by a specialist sub contractor Smith and Byford, who installed, commissioned and signed off the system. (as an architecture focused BPE team, ECD did not have the in-house capacity to design and install sub metering equipment). Commissioning Certificates dated 15th March 2012 were provided by Smith and Byford as evidence that the metering had been installed and was working correctly.
Apr12 - Dec12	The BPE Contract was realigned to April 2012 – June 2014, in order that revised contract term could start with correct metering in place
Dec 12	The first portion of data (18 April 2012- 13 Dec-2012) was issued to TSB in raw format for Analysis as part of its Q3 submission
Jan13 – Mar 13	In the feedback provided for the Q3 submission, the TSB project technical evaluator requested a further level of analysis regards the submetering, warning of the inconsistencies that are often experienced with meter installations. ECD responded to note that further analysis of this data would be conducted by DMP (the M&E consultants from the Castle Hill project team), who were attending the TM22 training provided by the TSB. (In the tender bid it had been intended that ECD Project services would complete the TM22 in-house, however this part of the company was later closed, and ECD no longer had the skills in house).
Apr 13	The TSB project technical evaluator noted a probable inconsistency in the Mains Block electrical meter which suggested that the total usage was almost continuously at or around the 7kW level. In response ECD contacted Smith and Byford, and also the school to obtain Utility metered data – it was hoped a comparison with the utility readings would enable any issues to be highlighted.
May 13	ECD arranged and attended a meeting on site on May 7th 2013 with Smith and Byford to look at the meters and check that the readings were correct. The meeting highlighted that the three phase mains supply, and the dining block three phase supply potentially had issues, and that the power factor was unusually high.
June-July 13	Further correspondence between the BPE team and Smith and Byford confirmed that there appeared to be a mismatch between the utility data and the sub-meter readings. As it was not clear whether the problem was a result of utility or Sub meter equipment, Smith and Byford proposed a clamp test to be carried out onsite to test the meters and the utility supply. The earliest date that was available for this test was 2nd August 2013
Aug 13 – Sep 13	On 2nd August 2013 Smith and Byford attended site and provide a report to the effect that all meters were reading correctly, with the exception of two phases (one on the main block electrical meter, and one on the dining block power meter) which were not reading. ECD responded to request that the faults be rectified, but S&B were not willing to accept responsibility, noting that the installation was outside the 12month warranty period. Concurrently, DMP the sub-consultant allocated the task of conducting the TM22 proved unable to conduct the TM22 in the manner/timeframe agreed, and so as a result of changes in the ECD project team, it was agreed that this could and would be done in house

Sep 13 – Jun 14 ECD used the TM22 tool to interrogate the submeter data to a greater level of accuracy. During this period it was established that Half hourly data was also available for the incoming supply, and this data was used to be able to compare the submeter readings like for like.

Using the TM22 tool ECD was able to prove to Smith and Byford that the problem with the submeters was indeed as a result of its submeter equipment and interventions on site, and it was agreed that an enginer visit site on 06th June 2014 to fix the problem once and for all

June 14 – Sept 14 Reliable data collected for Dining hall sub-meters: E5 (Lighting Sub meter) and E6 (Power Sub meter); Junior Block sub meters for power and lighting. Holiday and term time data was used to extrapolate a year's worth of readings– refer to section 6. During this period it was also established that the sub-meter readings for the gas supplies for the 2 year study had been accurate.

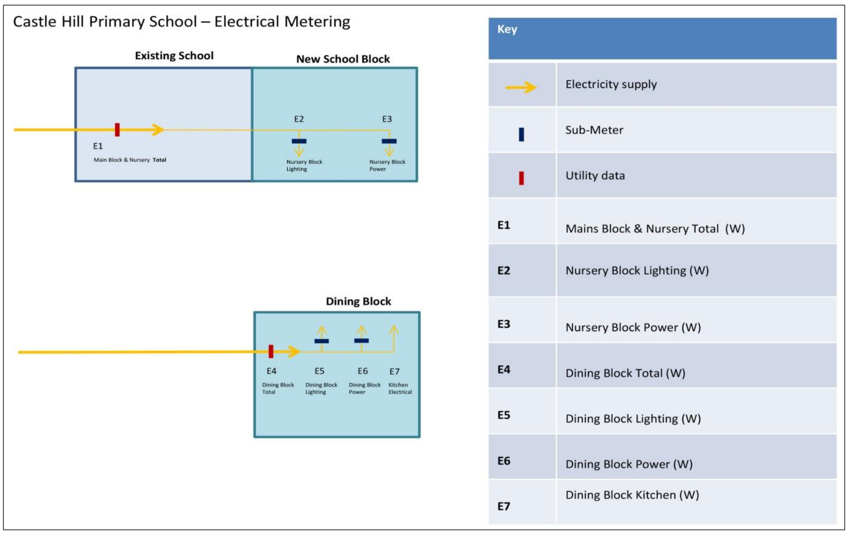
Energy metering - Existing condition

Electrical Services
At the point of commencing the BPE study, the electrical sub-metering situation was somewhat complicated for the new build extension and dining block. Check meters had been installed, however these did not have a pulse output and furthermore, for the new-build extension the current sub-metering was not 'adequate' as the main supply meter was shared for the entire school (excluding dining block) so there was no possibility of deriving the total consumption of the new build extension.

For the existing school areas, due to the age of the electrical installation it had seemed likely that lighting, power and other electrical services were supplied from the same Fuse/ Distribution Boards, and that sub-metering would not be a practical option. However upon more detailed investigation it became apparent that there were in fact separate distribution boards for these services that would enable these end use loads to be separately metered

Mechanical Services

- At the time of commencing the BPE study, there was no heating and no hot water sub-metering provision for the existing school nor the new build extension and dining block.
- Half-hourly gas meters were present on the gas supply to each plant room.



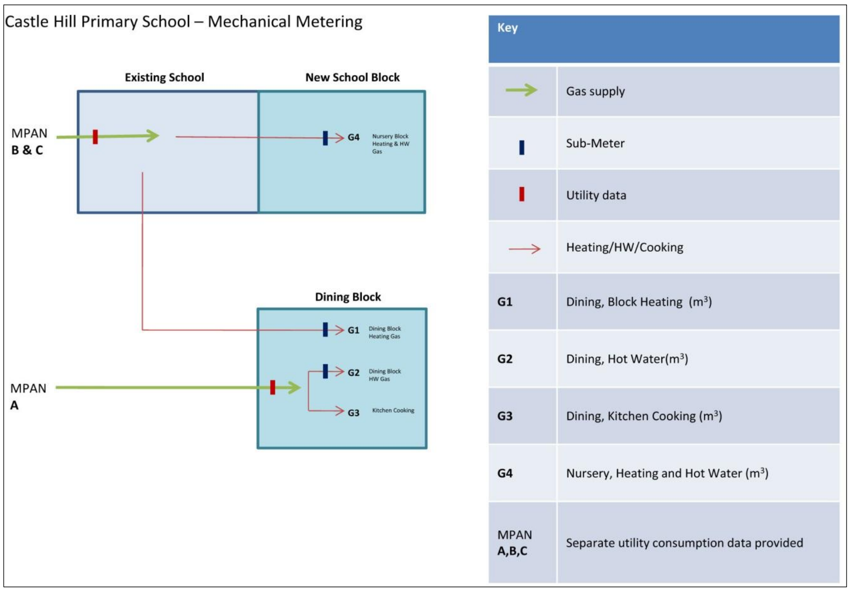


Figure 7.17: A Sub meter tree diagram was produced by the BPE project team, to assist with meter reconciliation in TM22

Targets and feedback systems

- As a result of the difficulties that have been experienced with the Building Management system and sub metering, the school have a far less complete picture of their own energy usage. Given the encouraging level of the engagement and understanding displayed by the school, it is likely that this information would have been put to good use had it been it good working order, and explained to the staff. Despite these problems the school nonetheless have an awareness of their own usage, and were able to produce energy bills and Display Energy Certificates as evidence of this.

- **Figure 7.18** provides perhaps the most telling indication of a mismatch between the apparent willingness of staff to understand their building, and the failure of the building feedback systems in providing this information. The photograph taken during the walkthrough is of the BMS display screen in the main reception. The screen is intended to provide live and historic readings of the school's energy usage and assist in the creation of targets; however despite repeat visits from Smith & Byford, the school report that it seldom functions. The school now have an ongoing maintenance contract in place with S&B, and on the last visit to the school by the BPE, the display was operational.

Figure 7.18: The BMS 'energy usage' display was using energy, but it was not displaying energy usage

Other notes: Specialist doors

- The accessible WC in the Dining Hall Block has a sliding door which was out of service at the time of the walkthrough. The caretaker reported that the door is exceptionally heavy, requiring two people to lift it. Some children found it very difficult to slide the door, whilst others pushed at it expecting it to be a regular door. The fixings for the rail were unable to take the load, and the door mechanism is now broken. The school are arranging for an outward opening door to be fitted in its place.

- The low energy doors to the new classrooms were supplied by Protek, and it appears that the school has had a number of problems with them. The main issue reported is that the multipoint locks often 'freeze' closed, with the result that children must go in and out of the playground via another door. During incidents when the glass in the doors has been cracked or broken, the school have also found it very difficult to arrange for repairs, as the doors have a special 'clip in' system, and the UK glazing repair firms they have approached are not familiar with the system. The school have approached the original supplier, who have come back to adjust the doors a number of times, sometimes without charging, even though their own fitting engineers did not carry out the installation. One of the staff has found evidence suggesting that at least one the doors were forced into position with a metal bar, and believes that this may be the cause of many of the problems.

7.2 Conclusions and key findings for this section

The BPE team have carried out a significant number of qualitative and quantitative assessments on the building fabric, services, and internal environment. The two buildings have had very mixed outcomes, from the analysis, with some encouraging findings but also some notable weaknesses.

Had an air test been required for either building, The target that the buildings would have been tested against under current regulations would have been 10 ($m^3/hr.m^2$). The Dining hall would have failed significantly at 11.85 ($m^3/hr.m^2$), and the Junior Block would have passed at 8.49 ($m^3/hr.m^2$). In practice, neither the Dining Hall or Junior Block required an air pressure test as part of building certification, the former being too small and the latter exempted as an extension. Some might note this a positive outcome for the Building regulations certification default figure of 15 ($m^3/hr.m^3$), which proved to be a good conservative backstop..

An interesting conclusion from the test was the performance of the existing building, which scored better average results than those of the new construction. Further, (with the exception of the Junior Block) when one arranges the test results in order of date of building construction, it can be seen that air testing results get consistently worse, from the original 1950s school building in Area A, through to the later extensions in Area B and C, to the Dining Hall in 2011. The Junior Block extension is the second best performing, but despite scoring under 10 ($m^3/hr.m^3$), is still leakier than the original school building (Area A) from the 1950's.

The air permeability target for optimal MVHR performance is typically considered to be <3 ($m^3/hr.m^2$). With the air-permeability results at Castle Hill, the MVHRs in the WCs will be much less effective in recovering heat than they could have been with better air tightness. Given that current regulations allow design and construction teams to simply bypass good airtightness practice and assume figures as low as 15 ($m^3/hr.m^2$) it is perhaps unsurprising that the most airtight construction on site is the original 1950s school.

The UCL overheating study results indicated that all three monitored classrooms in the new extension of the Castle Hill Primary School pass the overheating criteria prescribed by the currently used BB101 and the revised BB101 overheating assessment methods, showing that, based on the external temperature conditions during the monitoring period, the classroom spaces in the new extension are not foreseen to suffer from overheating. The performance in use (PIU) criterion was always passed. Only classroom S2C1 exhibited a tendency to overheat as the internal temperature profile follow the external temperature during the hottest monitoring period, and also as shown by the incidences of dry bulb temperature above 25°C.

Lighting is seen as one of the most positive aspects in the building, the design team's analysis at the UCL helidon was clearly put to good use. Though there are instances of glare in certain areas of the building, the general shading strategy is well conceived.

The UCL IAQ research concluded that the ventilation strategies were capable of provide a satisfactory environment according to BB101 guidelines in both seasons. However, it also found daily average concentrations of CO_2 above 1000 ppm in the spring season, and cited increasing evidence in studies of other school classrooms that the high concentrations might be related to increased prevalence of SBS symptoms and reduced academic performance **[Table 7.6]**.

Although obtaining emission factors from materials is still under development, the continuous TVOC profile and high formaldehyde concentrations indicated the presence of high emitting furniture and construction materials. It is therefore crucial that school management should use low emitting cleaning products and designers should consider emission factors of materials used in educational buildings and other buildings with vulnerable occupants.

Table 7.6: comparison of Indoor Air Quality parameters to average values

	Winter	Spring
T	Good	Good
RH	Good	Good
CO_2	Good	Average
PM_{10}	Average	Average
$PM_{2.5}$	Average	Average
Radon	Bad	.
Microbial concentrations	Bad	.
TVOCs	Bad	Bad
Gaseous pollutants	Good	Good

(NO_2, O_3, CO)

Though a considerable sum was paid for the installation of the equipment, and though the meters were commissioned, with formal signoff, the BPE study found that the data was useless for a number of the submeters. In effect, the commission certificates were worthless for a number of the sub-meters. The BPE team were reliant on the specialist subcontractor to proved the correct information on the site, and did not have detailed electrical engineering expertise to be able to highlight the specific issues with the system. As such they were reliant on TM22 to determine the root causes of the problem.

That the data was not checked for accuracy throughout the first year by the BMS metering company is a serious matter, and were it not for the BPE study, and the use of the TM22 software this would have likely remained unchecked. The metering company were eventually persuaded to return site to rectify the situation, however the level of detailed analysis and correspondence required to provide the evidence was not something that most design teams would have had the resources to commit to.

The data that was compiled for the school during this time was not checked for accuracy either, with the result that a number of charts and data readouts that were presented on the 'energy usage display' displaying erroneous data. After the first year's subscription came to a close, the school were not contacted to arrange a repeat contract, and the data was left uncollected until the problem was spotted by a member of the BPE team.

The building Walkthrough has picked up a raft of minor defects, and a few much more significant faults. The findings of this and all other investigations will be summarised for the benefit of the client, building users, design team and wider industry in the following sections **[Section 8-9]** and the full documents can be found in the Appendices **[Section 10]**.

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 Key messages

Design
The project team appear to have gone to significant lengths to consider the design and specification of the Dining Hall and Junior Block Extension and although the school has reported faults with certain elements of the finished buildings, they appear overall to be happy with the buildings.

Daylight
The design team went to considerable effort to model and optimize the predicted daylight levels within the new buildings, building a physical model which was tested on the Helidon at the Bartlett School of Architecture, University College London. Amongst the aims of the design team was to increase the daylight factor such that lighting was not required in the day. They also modelled the brise soleil and vertical shading louvres, in order to test that the rooms were adequately shaded from summer and winter glare.

The BPE study has tested the impact of these design decisions by looking at energy usage profiles for the lighting, by conducting a building walkthrough, and by conducting a BUS survey amongst the users. The energy usage profiles found that lighting was being left on at fairly consistent levels throughout the working day, indicating that staff either did not find the daylight levels adequate, or that they were not aware of the energy impact of leaving on the lights. The BUS survey reported that daylighting levels were rated highly in comparison to the Arup Benchmark, which was corroborated in the building walkthrough, where individual staff were interviewed. It appears that the design team's efforts were well spent, and the lighting levels are good in the building. However it also appears that lights are being left on necessarily, even at breaktimes and lunchtimes. The school could benefit from introducing a 'switch off' policy on artificial lighting when not completely necessary, which would save energy and increase the operating life of the fittings. .

Overheating
The design of the building has been tailored to minimise the possibility of overheating. The design team were sensitive to the fact that the building was highly insulated, and combined this insulation with appropriate shading and ventilation, in order to ensure that the building would buffer the occupants from summer overheating as well as winter temperature drops. One key feature of this approach was to increase the thermal mass within the building, by exposing the concrete blockwork as the internal wall finish.

The BPE study has tested the performance of the thermal mass / insulation / shading approach by commissioning an overheating study by researchers at University College London (UCL). The study has demonstrated that the approach was successful, indeed the classrooms were able to maintain and moderate their temperatures at a level below the external summer environment.

The team's environmental reports assessed the potential for Overheating, and poor Air Quality. These assessments were based upon Building Bulletin 101: Ventilation of School Buildings.

The UCL Overheating Report states that the classrooms are not predicted to overheat in accordance to the BB101 Criteria, with the exception to Classroom S2C1. The occupants' perceived view is that the new build is hotter than the existing, and compares with other surveyed buildings in the BUS data set.

Operation and maintenance
The walkthrough has brought to light a number of issues at the school which have either not been reported or not resolved, especially where the problems arose outside of defects rectification period. It appears that the majority of issues should be easy to resolve, but perhaps the bigger challenge is agreeing who will pay to have them resolved.

There is evidence that the project team's on-going relationship with the school, both in and out of the BPE programme has had a positive effect on the resolution of certain problems.

Though a full O&M manual and Building User Guide were prepared, giving detailed information on the operation of the building, in practice these do not appear to have been used to full effect. The school feel that the building handover they were given was limited, and that they would have benefitted from additional training for non-intuitive items, for example the ventilation.

Energy metering
Although the school appear keen to track, understand and improve their energy usage, the problems with the sub metering have meant that they have been unable to properly understand the energy usage, other than via monthly bills. This seems a great shame given the high specification, and expense of the equipment installed.

The first year's support and data connection that came with the energy metering equipment has proved to be of limited use to the school, as with the energy display in reception. Though a considerable sum was paid for the installation of the equipment, and though the meters were commissioned, with formal signoff, the BPE study found that the data was useless for a number of the submeters, That the data was not checked for accuracy throughout the first year by the BMS metering company is a serious matter, and were it not for the BPE study, and the use of the TM22 software this would have likely remained unchecked. The data that was compiled for the school during this time was not checked for accuracy either, with the result that a number of charts and data readouts that were presented on the 'energy usage display' displaying erroneous data. After the first year's subscription came to a close, the school were not contacted to arrange a repeat contract, and the data was left uncollected until the problem was spotted by a member of the BPE team. Now that the meters are functioning correctly, it is advised that the BMS metering company be checked in upon periodically to ensure that it continues to download and compile the data into a format that is usable for the staff as part of its ongoing service. Alternatively, this is something that could be discussed with ECD as part of a continued aftercare or 'building check up' agreement.

Separating energy consumption through Sub Metering has been particularly problematic, with difficulties early on for the BPE team understanding the existing building, as well as ensuring accurate and useful data. This has been a major concern for the robustness of the evaluation.

The TM22 assessment of the new buildings found that a number of services are being left switched on overnight amounting to an average load of approximately 1-1.5kW in each building **[Figures 9.1-3]**. Further investigation is advised.

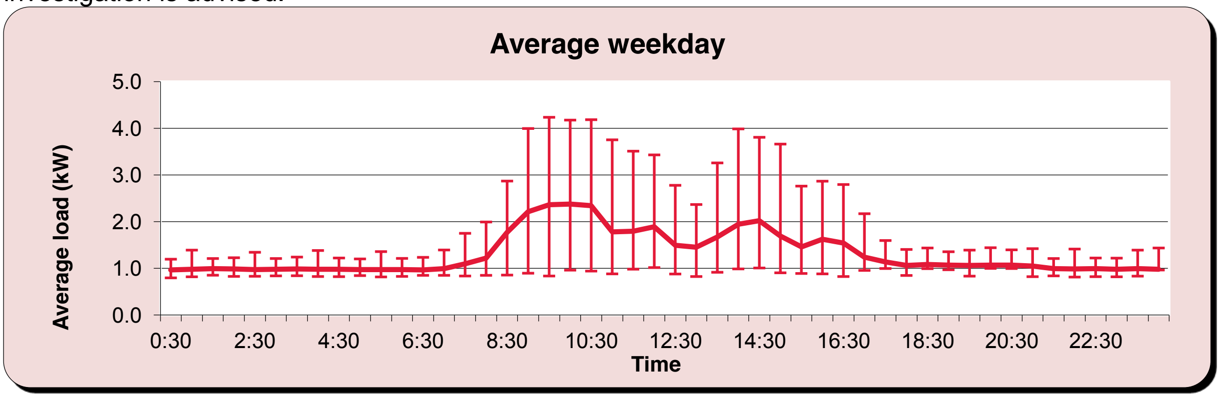


Figure 9.1 Junior Block, Average weekday power consumption profile , 3 months data

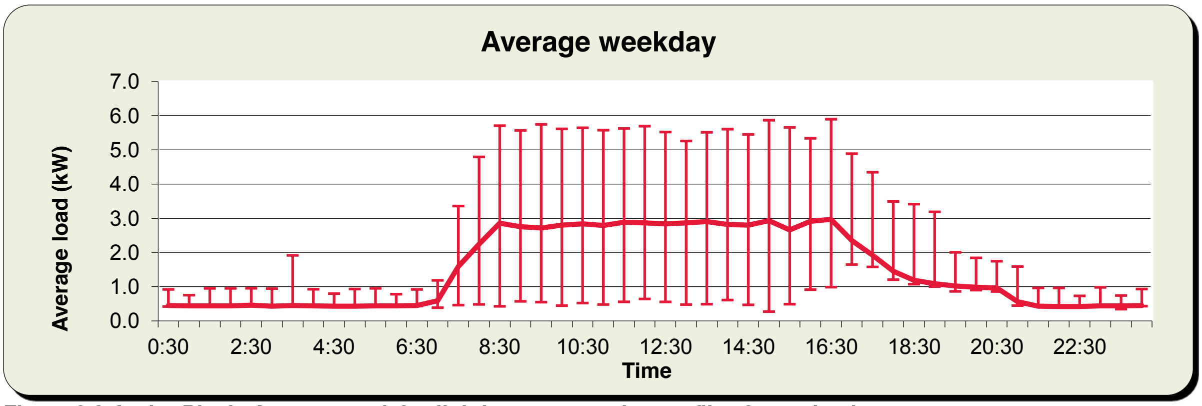


Figure 9.2 Junior Block, Average weekday lighting consumption profile , 3 months data

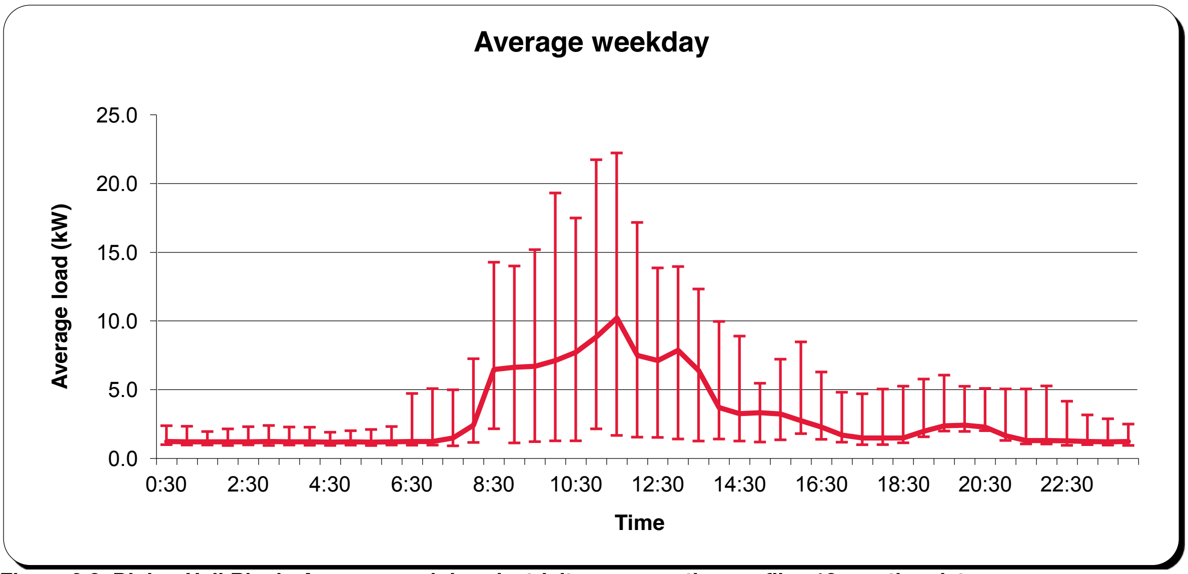


Figure 9.3. Dining Hall Block, Average weekday electricity consumption profile , 12 months data

Walkthrough and Feasible Improvements Plan

At the end of the first year of the BPE study, the BPE team became aware that the submetering at the school was not working correctly. By this point, it should have been possible to gain a full understanding of how the various circuits in the school were operating, however the failings of the metering equipment meant that this was not possible. Instead, whilst the problems with the meters were resolved, it was agreed that the team should refocus its time to conducting a thorough walkthrough of the building, the building conducted at the end of the first year of the BPE a 'feasible improvements plan' was generated, to give the school an indication of possible measures it could enact in order to improve conditions and save energy in the building. It is also recommended that the school commit to addressing the remaining points listed on the Feasible Improvements Plan **[Appendix 11]**

BMS system

Arguably the principal concern for the school's on-going operations is that of their difficulties with the Building Management System. This proprietary system now controls the majority of the services within the building, and if/when it fails in its operations, or even when simple adjustments are required such as clock changes, the school are reliant on call out services. The BPE study has found that the heating control system was not operating correctly, with areas in the existing building being heated over the weekend, and incidences of heating not coming on in the new dining block. Though the school and the BMS management company appear to be aware of the problem and steps are being taken to resolve the matter, it is strongly recommended that this issue is monitored, and escalated if it does not get resolved quickly.

Indoor Air Quality

The UCL Indoor Air Quality Study indicated that the building was compliant with BB101 guidelines for ventilation, however also found a number of causes for concern, including high microbial concentrations, high VOC levels and high concentrations of Particulate Matter (PM)
There is strong evidence to suggest that the ventilation systems are not functioning correctly outside of the heating season, with CO_2 levels over the 1500ppm threshold **[Figure 9.4]**, and it is recommended that a visit is booked in with the manufacturer Midtherm to resolve these issues.

The UCL IAQ study found significant levels of Volatile Organic Compounds (VOCs) It is advisable that school management should change their cleaning products, favouring low emitting cleaning products. Some of the VOCs can be attributed to paints and solvents, which should be stored away in cupboards when not in use. If the school come to replace any furniture, soft furnishings, or paint finishes it should consider using natural or low VOC emitting materials.

Certain staff members reported illness in the BUS survey which they attributed to the building air quality. This is a potential health and safety concern and it should be raised with the staff members to ask if they wish to come forward anonymously and discuss the matter further.

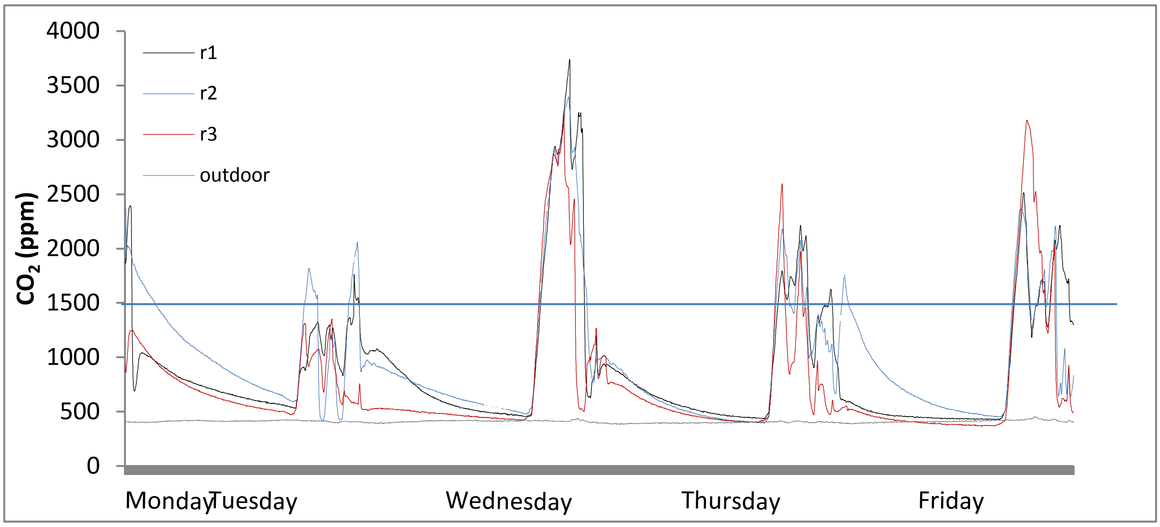


Figure 9.4: CO_2 concentrations during the spring season in 3 investigated classrooms and the outdoor site

The Building User Survey revealed that the users experienced thermal comfort issues, particularly in the winter. An unexpected result was that the users' experienced thermal discomfort moving from the new extension which was felt to be warm, to the existing building, where the temperature was perceived to be significantly lower.

Air Tightness
Air Tightness is much lower than expected, with the Dining Hall achieving a value of 11.85m3/hrm2 and the Nursery Extension a value of 8.49m3/hrm2. As the buildings were assessed under Pat L2a and b 2006 of the Building Regulations, no target was required to be met, but the implication of a much higher air leakage would reflect the higher than predicted heat requirement, and therefore energy consumption.

The Thermography Survey revealed 3 areas in the building fabric where the temperature was above the threshold of the requirements set out in BRE IP17/01 and BS EN 13187:1999, which have been identified as areas where the layer of insulation and air tightness are not continuous **[Appendices 4-5]**.

Within the existing building, the survey found that there were numerous areas where insulation and air tightness were compromised. In addition, the proportion of heat loss through the existing windows was identified as significant, and some thermal bridging was identified within the structural elements.

The BREEAM process was started later than ideal in this process, ideally the design stage assessment should be completed at Stage D. It is a poor outcome for the project that the BREEAM certification was not completed.

Although some Soft Landings activities were pursued at Inception and Briefing, and again at Post Occupancy, to ensure an efficient and well used building further involvement by both design and construction teams should be allowed for. Changes that occurred during the design and construction may have had a detrimental effect on the building's energy performance.

When compared with other benchmark buildings shown in **Figure 9.5**, both electricity and gas usage for the Junior block can be seen to be comparatively low. The Dining Hall on the other hand has a comparatively poor result, most notably for the gas usage. Taken as an average, the buildings are comparable in performance with a number of the other Benchmarks **[Figure 9.6]**

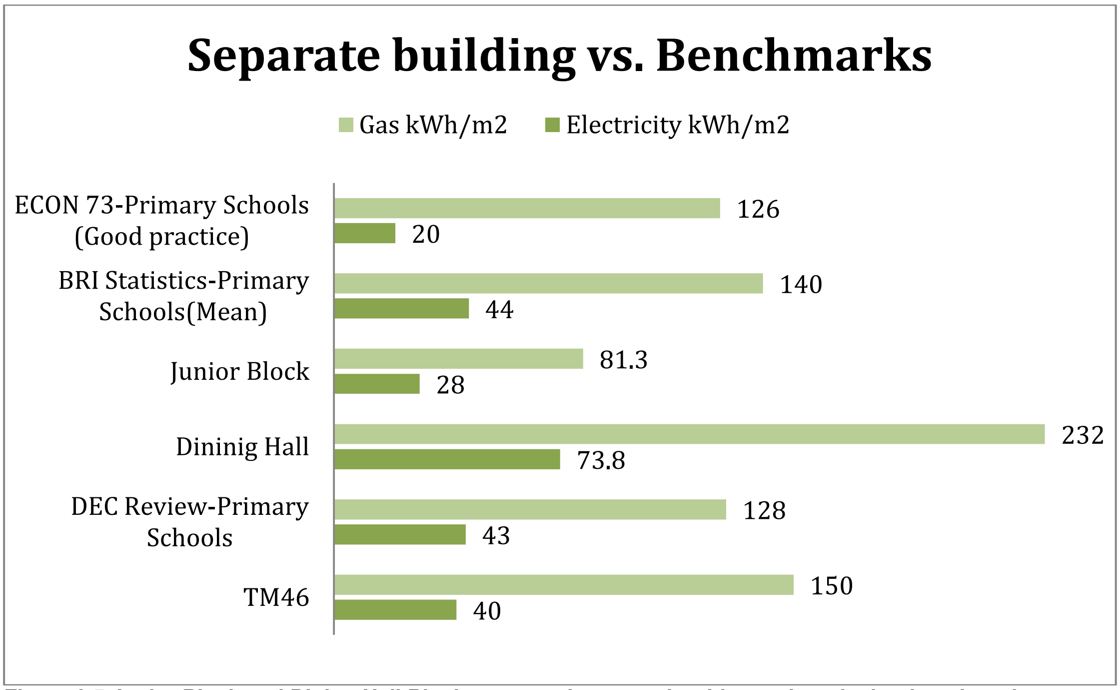


Figure 9.5 Junior Block and Dining Hall Block compared separately with a series of other benchmarks

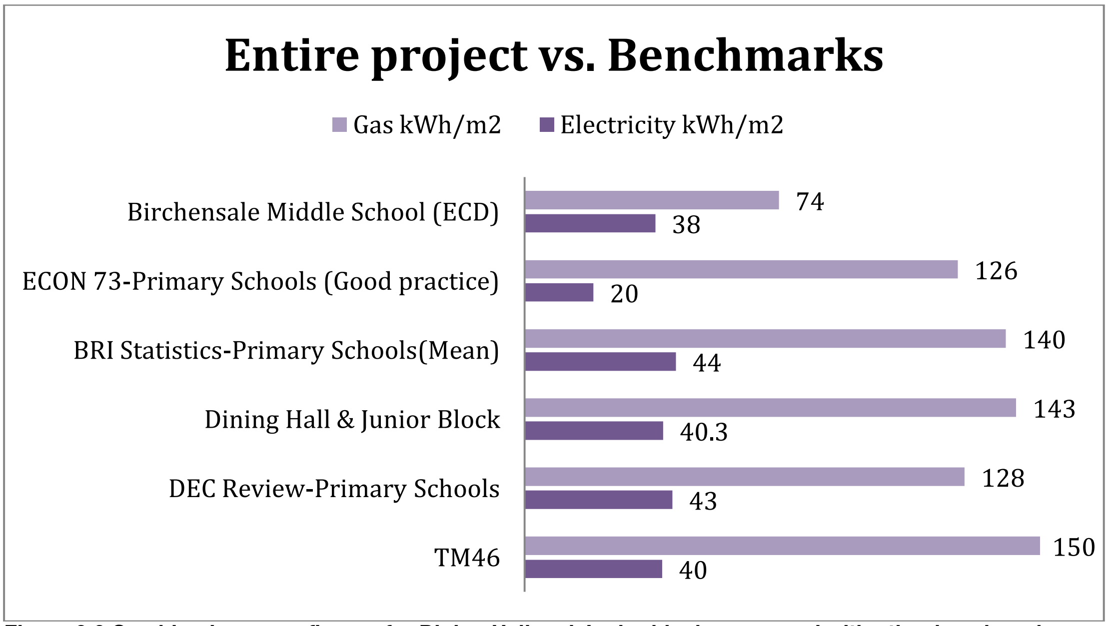


Figure 9.6 Combined average figures for Dining Hall and Junior block, compared with other benchmarks

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.

9.1 Wider lessons

The Soft Landings approach should be adopted at the earliest possible stage, and the whole process should be adhered to throughout the building conception and hand over. Picking and choosing elements from the Soft Landings Framework does not provide sufficient benefit to the users. Future occupants of the building should be engaged with the throughout the process.

The ability to use energy modeling software as a design tool may assist in delivering low energy buildings, but time and expertise must be allowed for this. Using compliance only tools does not provide design teams with sufficient information quickly enough to be able to make iterative informed design choices. As soon as the energy modeling and design teams are separated, problems are bound to ensue.

Air-tightness design should be considered early, with sections and plans showing airtightness strategy. Supervision of the Contractor with regards to air tightness, particularly with traditional procurement, is imperative to ensure test results meet design predictions.

Value Engineering should be approached with caution, with more emphasis placed upon the effect that it will have on building performance and usability (for example; the natural ventilation strategy, PV array, additional classrooms).

Sub metering needs to be planned, and if cost savings are required, it is advised that it is clear what has been value engineered out and all energy is accounted for.

Continued support for occupants would reduce confusion over controls, as suggested in the Soft Landings Framework. Having someone on site during the first few weeks has been shown to greatly increase the users' understanding of the building. Building User Guides should be clearly illustrated and written with the occupants in mind; jargon and complex information can lead to confusion.

Value Engineering should be approached with caution, with more emphasis placed upon the effect that it will have on building performance in use.

It should not be assumed that systems are working correctly, simply because they have been installed and signed off.

'Passive stack' ventilation vents provide purge ventilation to the space at the expense of energy usage and user comfort. The CO_2 levels rise sharply under occupation until the vents are triggered to open at 1500ppm, at which point CO_2 levels fall sharply, in line with drops in temperature. One teacher reported having to move her children away from the area of classroom underneath the vent as it was too cold for them.

Had the design team chosen to install a system incorporating heat recovery, such as the MVHR systems used elsewhere in the building, then the incoming air would have been preheated by the exhaust air, thus preserving the temperature in the room, protecting the children from cold draughts and saving energy.

UCL reported that, although obtaining emission factors from materials is still under development, the continuous TVOC profile and high formaldehyde concentrations indicated the presence of high emitting furniture and construction materials. It is therefore crucial that building owners should use low emitting cleaning products and designers should consider emission factors of materials used in educational buildings and other buildings with vulnerable occupants.

Figure 9.6: Members of the design team were brought together at an event in October 2014 to discuss the BPE findings

The problems that have been discussed in this section were unearthed only as direct result of the BPE study. The design team would certainly not have had the time or resource allocation to be able to carry out such a detailed investigation. Findings such as the above are valuable to building users, who may not have technical understanding, and to design teams who can learn from their past experiences. As part of this BPE, members of the design team were brought together at an event in October to discuss the BPE findings and take forward the lessons into their own work.

The event was divided in two parts. The first consisted of a presentation on the 'BUS Survey, which guided staff through the basic principles of conducting a BUS, and the benefits it could bring in terms of better understanding the comfort of users in any given building. The second (main) section was a workshop on the findings of the BPE final report for Castle Hill. The BPE team presented each section of the study, talking through design, construction, handover, and post occupancy. Whilst the presentation continued, staff were asked to make notes of any lessons that they had learned as a result of listening to the presentation, lessons that could be taken forward to their own designs. After the presentation, the staff split into two groups to share their individual notes, and were then brought back together to relay the messages to the whole group at the end of the event

The responses were collated and used to help inform 'Key Messages' in Section 8 of this report. Perhaps the most salient recommendation that came from the workshop was that Soft Landings POE and in use performance targets should come to form a mandatory part of building procurement and certification. If procurement contracts were required to be structured with in use performance targets, rewards could be offered for good building performance and penalties for failed targets, i.e. the design team has a longer term interest in the project. This would drive aspiration and innovation, as design teams sought to test, understand and improve their buildings for the benefit of themselves and their clients.

The BPE team would like to offer special thanks to the staff at Castle Hill for their assistance in enabling this study to continue, and supporting the team along the way. It is hoped that the findings will prove useful for the ongoing management of Castle Hill Primary School, and any future building procurements.

Figure 9.7: P is for Pirate (and Post Occupancy Evaluation)