Brine Leas Sixth Form Extension

NOTE: This report combines two studies into one report: Brine Leas and Loxford Schools

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	450004
Project lead and author	AHR (formerly AEDAS Architects
Report date	11 June 2013
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Schools	Nantwich	Design and Build	2010
Floor area	**Storeys**	**EPC / DEC (2010)**	**BREEAM rating**
2843 m^2 (Also reported as 2799 m^2)	3	B / E (106)	Very good

Purpose of evaluation

To investigate the impact of the procurement processes and contractor engagement on achieved build quality, with particular emphasis on the relationship between construction methods, construction quality and occupant comfort. The project also intended to determine whether measures to address unregulated energy use were effective, and to identify the main contributors to any discrepancy between forecast and actual energy use. The ventilation strategy, commissioning and effects of value engineering were also analysed.

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

Meters on the low voltage switchgear panels were faulty from the start of the study and could not be used. Good quality data was available for lighting, power, and catering facilities. A bottom-up approach was used to reconcile end-uses with the metered data. Gas consumption at 55.2 kWh/m^2 per annum was considerably lower than all benchmarks. Electricity consumption at 69.4 kWh/m^2 per annum was higher than prevailing benchmarks. Total performance was better than DEC/CIBSE TM46 benchmark at 48.9kg CO_2/m^2 per annum. In the CIBSE TM22 electricity analysis the end-use consumption was reconciled with the main meters to within 6%.

Occupant survey	**Sample size**	**Response rate**
BUS, paper-based	51	100%

The summary BUS responses were positive. There were general concerns about temperature (too cold) and a few issues specific to rooms such as the recording studio, entrance foyer and chemical storage room. There were many complaints about the water fountains (smelly water), particularly in the staff room. There were also some complaints about echoes from the atrium and the media suite not being soundproof.

Loxford School of Science and Technology

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Building sector	**Location**	**Form of contract**	**Opened**
School (secondary)	East London	N/A	2010
Floor area	**Storeys**	**EPC / DEC (2010)**	**BREEAM rating**
14,610 m^2	3	B / E	Excellent

Purpose of evaluation

To investigate the impact of the procurement processes and contractor engagement on achieved build quality, with particular emphasis on the relationship between construction methods, construction quality and occupant comfort. The project also intended to determine whether measures to address unregulated energy use were effective, and to identify the main contributors to any discrepancy between forecast and actual energy use. The ventilation strategy, commissioning and effects of value engineering were also analysed.

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

Loxford School's detailed metering strategy was said to provide good quality data for a TM22 energy analysis. A bottom-up approach was used to reconcile different end-uses with the metered data. The BMS initially was not reading the electricity or gas mains and the sub-meters. During the first year of the study, sub-meter readings had to be carried out manually to record the data from over 50 meters placed in different metering cupboards across the school. Electricity consumption was measured at 69.1 kWh/m^2 per annum, with thermal energy consumption (gas) at 97.4 kWh/m^2 per annum.

Occupant survey	**Sample size**	**Response rate**
BUS, paper-based	195	146 (76%)

Overall, the building was said to be better than the average for air quality, comfort, image, lighting, noise and productivity and about average in meeting occupants' needs, design and health. Winter temperatures came out better than average, while summer temperatures were average. The main issue was found to be related to the storage and furniture, fixtures, and equipment. The most frequent comment was about ICT. Teachers felt strongly about the position of whiteboards, IT support and the quality of equipment. Using laptop trolleys was said to have been made difficult by failures in electromagnetic locks on some corridor fire doors.

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About this document:

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

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

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

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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 project is a compare and contrast exercise between two schools: Loxford School of Science and Technology and Brine Leas sixth form. They have been chosen as case studies as they both have some similar aspects as well as some good contrasting qualities. Although different in capacity, both are recently completed schools, designed by Aedas, by the same main contractor Willmott Dixon (WD) and under the Design & Build procurement route. In both cases the client and design team were heavily involved as part of the design and build process and were looking to understand how their building supports learning excellence and how they can improve the building's performance and emissions in operation as a result of our evaluation. The evaluations began during the defects period for both buildings, providing the potential for extra fine-tuning. Initial study visits highlighted that commissioning, BMS systems, controls and facilities management were major areas for research in both buildings. Unregulated energy use and the reasons for the selection of technical solutions (i.e. Loxford mostly natural ventilation vs. Brine Leas mechanised system with heat recovery) was also investigated.

The initial step for both buildings was to reconcile sub-meters with main meters and install data loggers. This was followed by an investigation of out of hours energy use, occupant interviews, surveys and workshops. Concurrently, technical workshops with Max Fordham and TACE Consultants were carried out to review design data, metering strategy and specification, and to obtain detailed energy use data. A desktop study of design and as-built documentation by the M&E consultants was commissioned. The aim of this was to identify reasons behind any discrepancy between design and the completed building. Intensive study weeks were also carried out for each case study; these included detailed thermal comfort and CO_2 monitoring, detailed plant, BMS and unregulated energy use observations and thermal imaging.

There are substantial differences between the two buildings. Brine Leas is a small sixth form college with a head of sixth form who has a background in construction. Loxford School is an Academy-size secondary school with a passionate commitment to academic achievement and discipline but little expertise in the running and management of a complex building. The comparison between the two buildings is even more insightful when considered in the context of the three Academies studied in parallel by Aedas under a different TSB BPE project.

Brine Leas is a fully mechanically ventilated building while Loxford School is the only naturally ventilated building in the Aedas BPE studies, which constituted 7 buildings in total. Both have building management systems but different levels of user engagement with the controls. Neither building had bespoke BMS manuals or user-friendly descriptions of the building systems and building managers learned ‘on the job’ with minimal assistance provided downstream.

Site visits were carried out quarterly; in the case of Loxford School, sometimes several times per quarter. Data loggers were installed to record temperature and humidity readings. An intensive study week has been carried out by the monitoring team to study the building systems and their out of hours’ operation as well as resulting comfort conditions. CO2 levels, temperature spot checks, acoustic performance tests and external envelope studies were undertaken during the seven days while the BUS was carried out on or near the first day of the study week. The monitoring team liaised with the teachers responsible for the Eco-Schools programme at both schools and presentations/discussions were held with the pupils as part of the study.

Both Loxford and Brine Leas have a B rated as-built EPC. In terms of operational energy consumption, Loxford School achieved a DEC rating of E and Brine Leas’ consumption was the equivalent of a D, the only school to meet the national average in our studies. Both buildings started off performing a full grade worse during the first year of operation and have made subsequent improvements prompted by the study. These two buildings had better Building Use Survey results than the academies, with Brine Leas, scoring the best out of all the buildings studied.

Current energy legislation is not targeting the full picture when it comes to energy use by omitting ‘occupant related energy use’. Evidence from the school buildings studied under the BPE programme shows that this has grave unintended consequences. There is a growing tendency for highly mechanised schools with complex control systems and low/zero carbon technologies. In practice these appear to bring a much greater risk of increased energy consumption and occupant discomfort, resulting in high operating and maintenance costs and a loss of productivity.

1.1. Aims of the evaluation

The aims of the evaluation were as follows:

- To investigate the impact of procurement processes and contractor engagement on achieved build quality, with particular emphasis on the relationship between construction methods, construction quality and occupant comfort.
- To demonstrate if current measures used to address unregulated energy use in school projects are effective.
- To identify the main contributors to the discrepancy between forecast and actual energy use through good access to design data and a high degree of design team collaboration.
- To perform a ‘forensic’ study of the ventilation strategy, commissioning and the role of ‘value engineering’ in the installation of controls

1.2. Summary of the basic key facts, figures and findings

The Building Performance Evaluation (BPE) of Loxford and Brine Leas Schools has been carried out in parallel with the BPE of three academies designed by Aedas. A further five Aedas buildings were surveyed outside the TSB BPE programme by the same team during this period.

Alongside the detailed study of these the R&D team was leading the development of the new CarbonBuzz platform. This is a free online data-hosting and benchmarking service to improve the availability of building performance data in the public domain and inform new policy on closing the performance gap. Key findings from the BPEs of Loxford and Brine Leas Schools have amalgamated lessons learned from these parallel projects wherever possible.

One of the key lessons from the BPE programme was how difficult and expensive it was to extract robust energy data from buildings. In the twelve projects looked at by Aedas R&D between 2009-2013 end use energy data was not routinely available from submeters via the BMS (in some cases not even from the main meters). In fact end users, contractors and operators alike seem to be unaware of the purpose and benefits of submetered energy data despite the significant capital cost of installing and commissioning elaborate submetering in line with CIBSE guidance.

At the start of the study there was little industry awareness of the scale of the gap between expected and achieved energy performance. The team used energy calculations prepared for Part L compliance and Energy Performance Certification (EPC) as the baseline against which operational performance could be compared. At this stage there was still a widely held view that a good EPC/BREEAM rating would lead to a good Display Energy Certificate (DEC) rating. BREEAM energy credits are also based on National Calculation Methodology (NCM) used for Building Regulations compliance and energy performance calculations. However, much evidence has emerged in the past two years demonstrating little correlation between EPC/BREEAM ratings and actual energy use (Carbon Trust LCBA/LCBP, JLL report, CarbonBuzz). The projects studied by Aedas R&D demonstrate some of the key causes for this discrepancy. These are as follows:

- **Optimistic assumptions in EPC regarding system and fabric performance (e.g. system efficiencies, no. of hours of open windows in wintertime, open external doors)**
- **IT server room loads significantly greater than what is often assumed in compliance calculations (x10 depending on the profile used)**
- **Appliance loads optimistic and not included in NCM total kg $CO_2/m^2/yr$ figure**
- **Increased occupancy and out of hours use**
- **Equipment relating to special functions, such as training kitchens, workshops, cafeteria, reprographics, etc. not accounted for in EPC**
- **Ambiguous controls (e.g. CO_2 monitor signage discourages some teachers to use windows as intended, faulty PIR sensors linked to cooling terminals keeps chilled water pumps working out of hours)**
- **Building not commissioned according to specification (thermal/CO_2 set points for automated ventilation missing, actual specific fan powers significantly higher than design intent, lack of**

seasonal commissioning, missing zoning and inefficient scheduling, BMS not calling for heat from GSHP, large overnight base loads)

- **Lack of expert management (e.g. lack of usable building manual documentation, poor training, little aftercare, no template for FM contracting)**

The issues encountered have resulted in higher than expected energy and maintenance bills in in the case of both Loxford and Brine Leas Schools although when examined in the context of all the buildings studied by Aedas these two schools were some of the better performers, in particular Brine Leas. This building is much smaller than all the others surveyed and the fact that Head of School had a background in construction meant that the building controls were expertly managed. However, the carbon emissions associated with energy use was significantly higher than the EPC would suggest even in this building.

Heating consumption in almost all the buildings surveyed is lower than the TM46 benchmark while electricity consumption is significantly higher. Contrary to expectations, the increased electricity consumption is mainly associated with poorly commissioned and poorly controlled building services rather than the increase in IT density, which is often quoted as the main culprit.

Complexity of systems and controls has been identified as a key risk factor – in all the schools studied the BMS and lighting controls were not set up to optimise building services. The team has identified the opportunity for further research to establish whether new buildings or refurbishments are more likely to end up with BMS and complex building services in order to meet increasingly tight building regulation and performance targets.

It was apparent from all the buildings studied that schools are not equipped to maintain and operate such systems even when the relating FM services are outsourced. All the school business managers that the team spoke with agreed that a standardised scope of service and performance contract template would transform the way in which they procure such services.

There are important conclusions for the funding and procurement of new school buildings as well as refurbishments. The collection and dissemination of energy and maintenance cost information would highlight the downstream implications of installing complex services in schools. Where investment in long-term expert maintenance is unlikely to be available, it is strongly advised that building services and their controls are kept as simple as possible with automation and mechanisation 'designed out' and replaced by a 'fabric first' approach.

The team found carrying out the Building Use Survey most helpful to identify how a building design and systems met the needs of occupiers. It has not been possible to identify a clear correlation between energy consumption and comfort or productivity. In the case of Brine Leas School, where systems were well configured and relatively simple, the BUS scores were higher than at Loxford School, where problems with the BMS controls compromised ventilation and thermal comfort. Anecdotal evidence from parallel studies points to users being less 'forgiving' to problems arising from poorly configured building services where they are less satisfied with design and usability. The evidence gathered shows that fresh air and thermal comfort can be equally well provided by active or passive means although if passive systems worked at optimal settings they are likely to outperform mechanical systems both in terms of comfort and carbon emissions. It also seems possible to provide reasonable internal conditions with poorly configured systems, albeit at greater energy and carbon costs.

It was the observation of the monitoring team that active energy data collection quickly revealed critical problems with metering, controls and BMS early on in the BPE, with the majority of the remaining project time being spent on finding the causes for these. For the projects that were still in early stages of the defects liability period some of the problems found could be addressed. However, once the defects period ended it became costly and time consuming for occupiers to undertake remedial action, which were only undertaken once a member of staff with experience in construction exercised leadership. Whilst some of the issues could have been raised as latent defects it is unlikely that education clients would have the time or the resources to enter into extensive negotiations with contractors who have entire teams of legal staff dedicated to claims.

Displaying energy consumption as a simple 'energy bar' diagram, as seen in the Energy section of this report has proved to be very helpful. Most end users would not be able to interpret tables of kWh figures for end uses but a bar chart displaying a benchmark, a target (or baseline) and achieved energy use side by side is a quick and easy way to understand building performance shortcomings. Having seen the energy data published in this way, business managers at a number of schools mentioned that they would be more likely to take action to reduce building energy use if they could have annual data reported in this way. Standards for systematic collection of energy use data and clear communication will be fundamental to make progress in this area.

The purpose of this study was expressly to uncover the key contributing factors to the 'energy performance gap' collaboratively, to be able to make evidence based recommendations to overcome these. The TSB acting as an impartial client for the BPE and the monitoring team not being part of the original design team helped achieve this. Going forward, the recommendation is that energy monitoring is carried out as a routine on every project for a minimum of one year and that this is undertaken, or at least signed off, by an independent expert responsible to the project funding body.

It is the experience of Aedas R&D that targeting measured energy use over and above 'compliance' is a cost-effective way of overcoming the issues uncovered. With NCM calculations currently being the only mandated metric relating to a building's energy use and carbon emissions during design stages, most buildings do not have energy consumption baseline figures against which they can diagnose building performance in operation like for like. Incorporating measured energy use targets in building contracts and mandating the sharing of assumptions behind any energy calculations is one of the most important recommendations of this report.

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. Loxford School of Science and Technology

Loxford School of Science and Technology replaced an existing secondary school in the London Borough of Redbridge. The Head of School who instigated the project was replaced by a new head teacher following the tender stage, which meant that some parameters of the original design and brief were altered to match the new head teacher's vision. The building achieved a BREEAM Excellent rating and a BER of 18.5 kg $CO_2/m^2/yr$.

The total area of the school is 16,000m^2 with a footprint of just over 4500m^2. The final cost of the project was just over £32.7M which puts the area weighted cost of the project at around £2K/m^2. This project underwent extensive value engineering to deliver a building which is by no means extravagant. Based on this experience, it is difficult to see how quality education projects that inspire the next generation can be delivered for the government's proposed £400/m^2.

Two ribbons of three-storey teaching accommodation stretch north to south, with three four-storey pods separating the ribbons and forming courtyards in centre of building. These house the main assembly hall and refectory at one end and a library and learning resource centre at the other. Both east and west facades have vertical louvres which gradually change in depth depending on the exact orientation of the façade. Classrooms are accessed via single sided corridors that overlook a series of landscaped courtyards achieving optimum daylighting and visibility across all major circulation spaces. The corridors are painted white and are flanked by colourful lockers. On the third floor, where the art classrooms are located, the corridor walls are covered with impressive work by the students, bringing lively colours to the third floor spaces. Apart from a handful of classrooms, all rooms are cross-ventilated via corridor plenums or stacks. The building has ample exposed thermal mass and good floor-to-floor heights.

Most teachers drive to work although up to ten cycle spaces are frequently used, more in the summer. Entry to the building is via a landscaped car park into a triple-height atrium space. There is no sealed entrance lobby – as this was agreed to be removed by the school under cost pressures. The first pod houses the Learning Resources Centre and other high IT load classrooms, the majority of which are mechanically ventilated with chilled beams. The second drum has meeting rooms and language classrooms, many of which have single sided ventilation. A large double height cafeteria is located at the southernmost ends of the classroom wings – on sunny days this space is bathed in sunshine from late morning onwards.

The School provides 10 forms of entry for up to 2000 students in South Ilford and 220-250 full and part time teachers which the school reached in the second year of occupation. Out of hours use is limited to the drama hall and ground floor spaces although the school is investigating the option to rent parts of the building as meeting/seminar rooms. Core hours are between 8am-6pm with most classes finishing by 3:30pm. Cleaners start at 6:30am and finish at 6pm. The school owns a sports hall and swimming pool adjacent to the building, these are accessed by 20-30 visitors on Saturday and Sunday mornings.

Figure 2.1: 3D Model of Loxford School developed during the design stages by Aedas

Figure 2.2: Loxford School West Façade

Figure 2.3: Loxford School Landscaped Courtyard and motorised vents embedded into the facades

Figure 2.4: Loxford School Landscaped Courtyard

Figure 2.5: Loxford School Cafeteria – south facing room with lights off!

Figure 2.6: Loxford School Corridor with Lockers – and lights on

Figure 2.7:Loxford School Auditorium/Drama School showing some AV equipment

The building constitutes a concrete frame with flat slab construction. The external skins being formed from pre-cast concrete panels finished with brick tiles for the outer walls of the classroom blocks. Courtyard-facing facades are clad with a Velfac wall system. The pods are rendered brilliant white on insulated blockwork. The school has a quality feel with good workmanship but some areas have started to show limited wear and tear, such as the magnetic locks holding the fire doors open.

Fabric areas have been calculated based on as-built drawings and U-values are area-weighted. The figures given here are based on a desktop study of information issued as part of the building contract and are hand calculations from drawn information. Other figures can be found in the BREEAM Materials report, cost report and service engineers' documents. U-values are based on information found within issued project documents such as the Part L report and were not confirmed by site surveys. Air tightness target was 5 $m^3/hr/m^2$ @ 50Pa while the achieved value was better than that at 4.36 $m^3/hr/m^2$@ 50Pa.

There is a catering kitchen, drama studio, assembly hall/performance space, large cafeteria and kitchen and well equipped workshops. A reprographic centre with a number of professional photocopiers serves the school and the energy centre/plant room is situated in a dedicated building adjacent to the school on the eastern side of the building.

There is a building log book with good description of the building systems and some instructions to occupants, but no detailed BMS strategy, description of zones and recommended setpoints could be found.

	Orientation	Descritption	Area	U value
Facade type 1	More than one	blue engineering brick	3594.6	0.35
Facade type 2	More than one	velfac wall system	1408	0.35
Facade type 3	More than one	Insulated Sto render on blockwork	988.4	0.35
Facade type 4	Click to select			
Glazing type 1	More than one	Polyester powder coated composite aluminium and timber frame, with integral louvres and inward opening windows to louvre panels, double glazed, solar control glass, low emissivity coating with argon fill to cavity, toughened / laminated glass.	1931	2.18
Glazing type 2	Click to select			
Glazing type 3	Click to select			
Glazing type 4	Click to select			
Solar shading type 1	All	Perforated Aluminium		
Solar shading type 2	Click to select			
Solar shading type 3	Click to select			
Solar shading type 4	Click to select			
Roof type 1	More than one	In situ concrete roof slab 350mm thick	4747	0.25
Roof type 2	Click to select			
Rooflights	Click to select			
Ground floor type 1	All	150mm rc slab. 150mm insulation, 50mm blinding and DPM. Floating wood finish	4644	0.25
Gound floor type 2	Click to select			
External door type 1	More than one	Aluminium framed glazed single door, polyester powder coated finish.		
External door type 2	Click to select			

2.2. Brine Leas Sixth Form

Figure 2.8: Entrance elevation, north facade

Figure 2.9: Courtyard elevation, south facade

Brine Leas Sixth Form -Technology, Languages and Applied Learning is a thin, L-shaped building profile with triple-height light wells. It is a 3-storey, 2,969m^2 new-build of steel-frame main construction with ground-bearing in-situ concrete slab and composite deck upper floors. External walls are cavity construction; where brickwork is specified, the outer block-work leaf is replaced with locally sourced facing brickwork. Heavy construction of floors and walls add to the thermal mass of the building helping to regulate temperature. The design target airtightness value was 10 and the building passed with 9.03 $m^3/hr/m^2$ @ 50Pa.

The design intent consists generally of narrow plan teaching spaces to optimise natural light and ventilation. Three light wells provide interest, natural daylight and a feeling of openness along the circulation routes; these are constructed with GluLam timber columns and beams. At ground floor, the main social/ dining space, a study area and the large vocational spaces have direct access to the external social/ work space.

Figure 2.10: Atrium spaces – used for eating lunch, free periods, social space and alternative study space

The building was procured through a Design & Build contract by Cheshire County Council and achieved a BREEAM rating of Very Good and a BER of 17 $KgCO_2/m^2$/annum. It is located in a semi-rural area with normal exposure to weather. Construction started on 27.07.09 and phased occupation began on 03.09.10. The building was at full capacity after one year of occupation. Hours of operation are from 8:30 – 15:30 for students, with cleaners in the building from 6:15 and staff in the building until 17:30 or 18:00. Regular night school sessions are run on Tuesdays and Thursdays.

There is good availability of public transport, though only approximately 40% use it for their journey. There are 70 secure bike parking spaces with shower and changing facilities available and 64 car parking spaces. The material was kept to a limited number of items; a through-colour render system, fibre cement panels, timber boarding, aluminium windows / curtain walling, and a single ply roofing membrane. The finish materials are arranged to give solid corners to the building (creating an aesthetic link with the existing buildings), broken by full height glazed curtain walling to the triple height light wells. The building is covered by linear cladding, render and ribbon windows, reflecting the scale of the existing three-storey building. The feature multi media room is visible from the outside via two of the light wells, and is expressed as a solid volume, distinct from the general teaching spaces. The large canopy to the south and east elevations facing on to the external social space, provides solar shading and access to the upper level of curtain walling for maintenance. A sustainability advisor / BREEAM assessor was engaged throughout the materials selection process and products given at least an 'A' rating in the BRE Green Guide to Specification have been specified wherever possible. This includes the non-visible materials such as insulation, as well as the internal and external finishes.

Description of building elements				
Element	**Orientation**	**Brief description of design**	**Area (m2)**	**U value**
Facade type 1	Click to select	Clay Facing Brickwork	521	0.32 (area weighted)
Facade type 2	Click to select	Concrete block cavity render	845	0.32 (area weighted)
Facade type 3	Click to select	Concrete block cavity timber	164	0.32 (area weighted)
Facade type 4	Click to select	Aluminium curtain wall	307	0.32 (area weighted)
Glazing type 1	Click to select	Aluminium windows	294	1.9
Glazing type 2	Click to select			
Glazing type 3	Click to select			
Glazing type 4	Click to select			
Solar shading type 1	Click to select			
Solar shading type 2	Click to select			
Solar shading type 3	Click to select			
Solar shading type 4	Click to select			
Roof type 1	Click to select	Warm deck cover	1517	0.19
Roof type 2	Click to select			
Rooflights	Click to select			
Ground floor type 1	Click to select		1517	0.21
Gound floor type 2	Click to select			
External door type 1	Click to select			2.38
External door type 2	Click to select			

The building was designed by Aedas Architects with M&E input from TACE. Willmott Dixon picked up the contract post planning with EIC as their mechanical and electrical engineers. TACE were novated to them for continuity of project knowledge. There is evidence of good occupant engagement throughout the design process; all staff members were invited to assess the accommodation schedule, and comment on its shortfalls. The live document was put back to the school, and amended several times. Pupil and parent input was sought. Year 7 carried out an environmental project in Geography which is effectively contained within the brief, while Year 9 looked at the whole project in English lessons, and their ideas on social areas and curriculum were included in the brief. Parent Forums were held and the brief addresses their ideas and concerns. Following approval of the Options Appraisal by the Learning and Skills Council, the design team consulted with the stakeholders regularly. The school staff and governors, in turn, consulted with the pupils, their parents, the local residents and the wider community through a number of open day events and leaflet drops. Feedback from all stakeholders was presented to the design team, who then responded to any concerns where appropriate, and proposals were adjusted where necessary.

However, the Building Performance Evaluation (BPE) kick off meeting highlighted some issues with engagement at the end of the project and at commissioning and handover stages in terms of personnel changes and a lack of communication with occupants; Head of Sixth form in particular. The school reported that communication dropped off towards the end of the project. Representatives from the parties concerned who were present at the kick-off meeting explained that this was normal as there is little need for design team meetings at this stage in a project. Once the building was handed over, Willmott Dixon handed the building from their construction team to the customer care team, which was problematic from the School's side as they had lost continuity in personnel, knowledge and their working relationship with the company. This is an example of something that could be improved inside large companies with multiple teams. Clients are under the impression that they are dealing with one company, but in reality the company often operates multiple companies under one umbrella.

There were reports from staff at the school that the Operation & Maintenance (O&M) documents received upon handover were incomplete as there were bits of equipment still being commissioned. In particular, the school were missing contact information for installers during construction and so were unable to action any maintenance or repairs themselves. A 'full' copy was requested from Willmott Dixon following this. The manuals received consisted of two volumes; Main Manual volume 1 and Volume 2 containing all subcontractor information. Volume two seems to be all present and correct, while volume one has some missing information:

- Contract Directory, Sub-contract directory and Building Components section are complete as far as the building is concerned but there are no HVAC / plant details included.
- Section 12: Manufacturers' certificate information refers the reader to the EIC O&M manuals, although these seem to be missing.
- WML Structural and civil drawings, Aedas Architects as-built drawings & log book information and a full set of landscape drawings are included. All EIC – mechanical and electrical – information is missing. We were not able to source the as-built mechanical & electrical drawings for the BPE project despite multiple requests to the contractors.

An independent examination by TACE, under the design vs. as-built work-package found the following issues with the O&Ms:

- Section 2: Description of Equipment and Systems is missing
- Section 4, 'Operating Instructions' within the mechanical O&M manuals is unclear and describes services that don't exist, i.e chilled water.
- Section 6, 'Testing and Commissioning Information' within the mechanical and electrical O&M manuals is missing and there is no evidence that the appropriate certification has been issued.
- Section 10, 'As Fitted Drawings' are not present within the operating and maintenance (O&M) manuals.

Following a meeting with Willmott Dixon Rethinking representatives at the end of the evaluation, a copy of the log book, prepared by Willmott Dixon, was received. Some sections contained detailed information, while others were lacking; Section: 3. Links to other key documents is missing. Section 8: Summary of main building services plant, Section 9: Overview of controls / BMS and Section 11: Metering, monitoring and targeting strategy are almost entirely incomplete.

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. Loxford School

Environmental Strategy

The environmental approach of Loxford School, developed in close collaboration with Max Fordham, aimed for a naturally cross-ventilated building with simple controls. Classrooms along the teaching 'ribbons' have openable windows.

Figure 3.1: Plenum ventilation strategy of classroms showing windows, plenum vents and courtyard flaps

Figure 3.2: Stack ventilation strategy showing atrium vents and roof lights

Motorised vents to plenums above corridors exhaust to the courtyards and centrally located top-floor rooms have operable roof-lights. Feedback from CO2 sensors installed in classrooms prompt users to open windows for ventilation instead of relying on an automated Building Management System for fresh air supply.

In the central classroom blocks with high density of ICT equipment, where it wasn't possible to achieve natural ventilation, active chilled beam cooling is used. Several rooftop air handling units serve these areas. Cooling is provided by direct coupling with the ground loop via a heat exchanger.

Radiators are connected to the closed loop ground source heat pump. Hot and cold water services have been provided via the cold water mains, which serves the hot water outlets via a booster set with hot water provided via a hot water calorifier.

The building manual in the Log Book describes the heating as 'being provided via a ground source heat pump with backup boilers serving the emitters throughout the building'.

Lighting in classrooms is manually controlled – perimeter daylight dimming has been installed and the front row lights can be switched off separately to avoid glare on whiteboards. Common area lights are automated with presence detection. Daylight and PIR sensors are programmable via a hand-held remote control.

The building log book describes the design criteria for external/internal conditions as follows:

Hot Water production flow and return: 70/50°C
Space Heating PEAK: 70/50°C
Space heating 45/35 and weather compensated above ambient: 3°C
Hot water circulation temperature: 60°C max / 55°C min
Blended water: 41°C
Office areas: 10l/s/person
General Occupied areas: 8l/s/person (5l/s/p heating allowance)
Changing Rooms: 10ACH
Chemical Store: 6ACH
Dance Studio: 8l/s/person
Reprographics: 20l/s/photocopier
Assembly/Dining Hall: 5l/s/p
Food technology classrooms: 30l/s/extract hood

Heating Details

The heating comprises two ground source heat pumps (GSHP) with 100 kW capacity/unit which act as lead system for heating and are supplemented by three gas-fired, condensing boilers 460 kW each (total capacity 1380 kW; this covers both heating and hot water). Heating is provided via the heat pump units and the boilers located in the plantroom. These serve all occupied areas of the building via air heating coils to all air handling units, underfloor heating, radiant heaters and wall mounted radiators. The air handling units have been fitted with a heater to lift the supply air temperature in the event that the heat recovered from the exhaust is insufficient to maintain a comfortable air temperature. Fresh air and exhaust air enters the building through dedicated weather proof housing at roof level. The system is controlled via the BMS.

The log book states that under extreme outdoor conditions, when high flow temperature is required, the GSHP system will be disabled in heating mode and the heating will be entirely provided by gas-fired boilers.

A large stand-alone plant room adjacent to the East Wing of the school houses the electrical mains as well as the boilers and ground source heat pumps.

DHW details

A complete domestic hot water service (DHW) has been installed to serve the school via an indirect hot water calorifier which is fed from the LTHW heating system's primary heating circuit connections. The system is controlled via the BMS. Thermostatic blending valves (TBVs) and thermostatic taps have been installed to provide blended hot water to sinks and basins and showers at 43°C.

Details of Ventilation and Cooling Systems

Classrooms are generally naturally ventilated across corridors via sound attenuators fitted with electrically operated operable panels. The top floor accommodation is generally ventilated via north-facing roof lights with electrically operated openings. Some internal spaces are ventilated via vent shafts to the roof in the atrium where there are insulated control dampers behind louvres to control the stack effect. Make-up air is generally supplied from the external elevation with manually operable panels behind louvres and manually operable windows.

Double height classrooms also have high-level louvres and operable windows. These are electrically operated on BMS control with local user override. Night-time ventilation has been provided in warm weather when room temperature is high and there is potential for free cooling.

In this mode the users close the external windows on the facade. Manually operated louvre panels remain open/closed as left by users to suit the weather. The electrically operated louvres, panels and dampers are controlled by the BMS.

In total, there are 6 main AHUs (Pot wash, North Pod, North Pod SEN, South Pod, Music rooms, and the Kitchen AHU) plus the reprographics extract fan, two assembly hall extracts and 24 toilet extracts. The BRUKL report describes a specific fan power of 1.4 W/l/s, while the as-built SFP was confirmed as 1.96 W/l/s by the building services designers. It appears that there is a minimum 40% difference between the design and the as-built figures pointing to the need to highlight the importance of SFP in an Energy Efficiency Measures Risk Register in future projects.

Passive and active chilled beams have been installed to provide cooling to some areas of the school to maintain the internal design conditions – this system is controlled via the BMS. Comfort cooling to ICT enhanced spaces is provided by direct coupling with the ground loop via a heat exchanger; there is no back-up cooling system.

The Server Room and Data Hub Rooms were provided with cooling by means of variable refrigerant flow (VRF) systems to maintain the internal design temperature; these are controlled locally via wall mounted controllers.

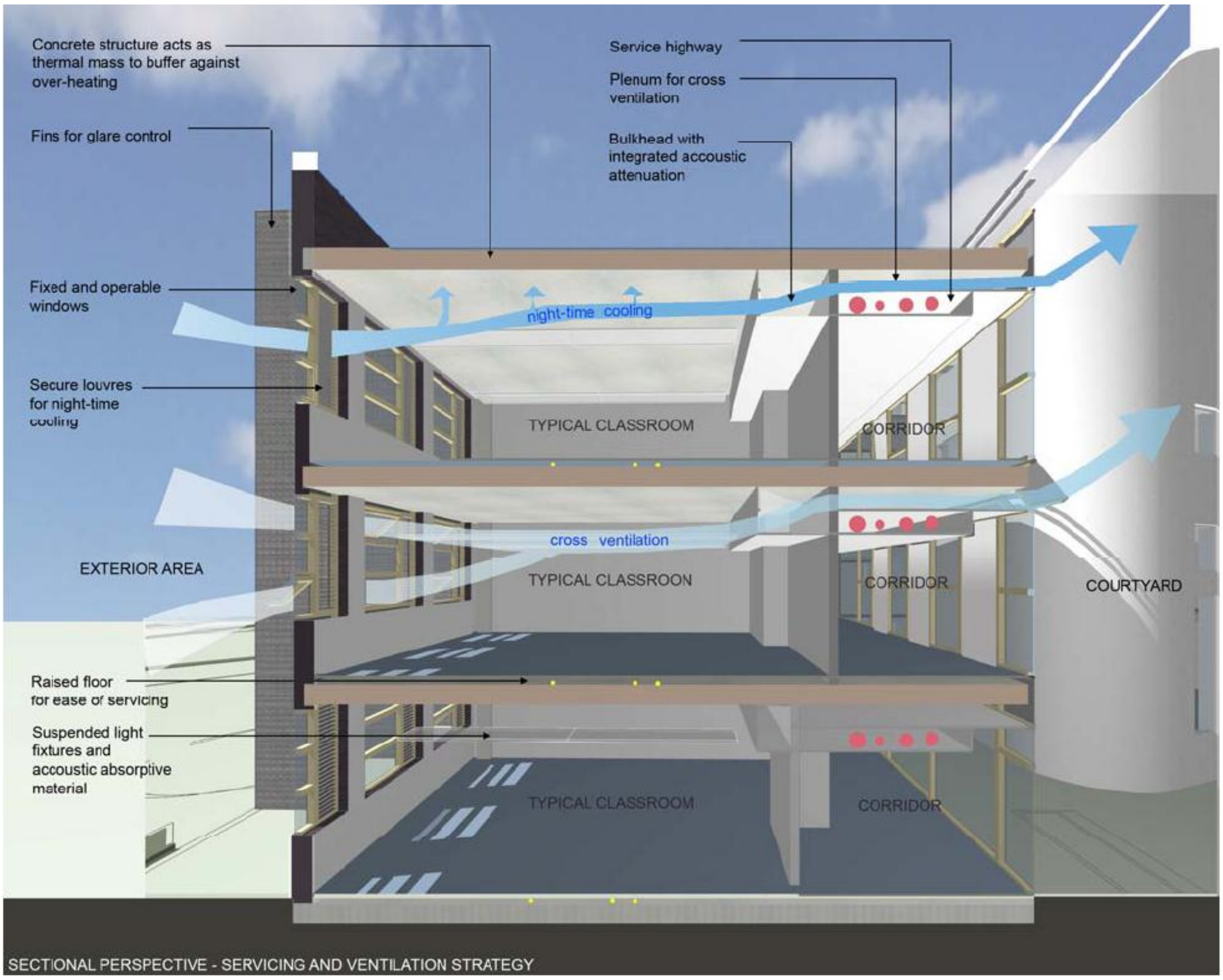


Figure 3.3: Classroom ventilation strategy image from the Log Book

Main plant items above 5 kW are shown below:

Main plant	Location	Input Output
Plate Heat Exchanger	Energy Centre	105 kW
Boilers B1 - B3	Energy Centre	460 kW
Ground Source Heat Pumps HP1 and HP2	Energy Centre	100 kW
Air Handling Units	Various	7.5 kW each

Lighting system details

Daylight and sunlight is controlled to provide a comfortable, low glare working environment with a psychologically beneficial level of natural light while reducing electric lighting requirements and energy consumption. A networked digital lighting management system has been installed. The system is configured using an HP2000 Digital System programmer enabling the user to re-configure all parameters of the system devices/detectors directly.

Figure 3.4: Handheld device for programming all the school's lighting sensors and their zoning found by IT manager in a box two years after the building opened.

The Lighting Control system operates on a standalone basis (local presence, dimming & switching) even if the local Bus Power Supply Unit is disconnected or the local network bus cable is disconnected. Classroom lighting switches default to manual on with absence detection and photocell dimming controls. Circulation areas have switched on presence detection with run-on timer, linked to remain on when any adjacent spaces are occupied. The Switch Control Module is linked to adjacent classrooms and corridors have combined absence/photocell dimming detectors. Stair lighting has presence switching with run-on timer while the dining and assembly hall has more elaborate manual switching and dimming controls on the ground floor or the control room. All offices have manual switches that control zoned lighting to allow for partial occupation.

Emergency and emergency escape lighting have been installed to both internal and external areas of the Building. The system comprises of batteries/inverter units mounted within the general lighting luminaries as well as dedicated luminaires denoting escape routes, all are fed by local lighting circuits.

Exterior lighting has been installed to provide lighting to roadways, footpaths, and emergency exits as well as providing lighting to enhance horizontal and vertical surfaces at the major entrances to the building. Pedestrian routes/areas are generally lit by luminaires on columns which provide diffused light in all directions around the column with minimal upward light. Wall mounted fittings have also been installed where routes traverse adjacent to building.

The external lighting is controlled via a battery backed 365-day solar time clock control with 2-on and 2-off periods per day for individual programmable time-clock control with manual on/off/auto manual switching for each external lighting circuit. Switching of external lighting circuits is generally via contactors.

3.2 Brine Leas Sixth Form

Brine Leas Sixth Form is a fully mechanically ventilated building with active heat recovery using thermal wheel heat exchangers. The plant is maintained largely by the school. The designers estimated the carbon emissions to be 17kg of CO_2 per m^2 per annum against a target of 25kg of CO_2 per m^2 per annum, excluding ancillary services and small power. The HVAC plant is zoned by floor level.

The Building Management System controls the central air handling unit, the hot water system and the heating by timing schedule. Hot water is provided by solar thermal collectors and assisted by stand-alone gas-fired heaters. Radiant panels serve most classrooms and laboratories with heating and are fed by gas-fired boilers. The installed boiler plant – 3 low-NOx boilers - provides low temperature hot water to radiant ceiling panels. Low temperature hot water (LTHW) is compensated on outside air temperature to increase energy efficiency. The boiler plant is also optimised to ensure indoor temperature is correct when schedule is enabled on the BMS, i.e. it is not necessary to programme a preheating period. Rooms are controlled via local room thermostats. These reset overnight to set-point – 21°C . Heating and cooling are provided to the music suite, language laboratory, ICT enhance classrooms and office spaces by two pipe DX indoor units mounted in the ceiling void. The air-source heat pump set points are set manually by the school.
Supply air is delivered to the space via flexible ducts running to 2 supply air diffusers off each unit; return air is via matching return air diffusers. The supply and extract air-handling plant is located on the roof.
In classroom and teaching areas, the ventilation is supplied via a central air handling unit (AHU), designed to be inverter driven, with the ability to boost by 20% on demand. Motorised dampers at the main branch of the ductwork on each floor are linked to the BMS. Air quality sensors located in all teaching rooms detect CO_2 levels in the space with the purpose of increasing or decreasing the supply fan's speed . The kitchen is ventilated via extract fans and ductwork up to the kitchen, enabled via a switch within the kitchen. Water closet ventilation operates on a timer switch.

Figure 3.5: High-level vents in atrium spaces

Natural ventilation is provided in the atria spaces by high level actuated opening lights. The system also incorporates local controls which enable the occupants to open the windows in warm weather.

Internal lighting is fitted with presence and absence controls. In the classrooms, luminaires are controlled via absence detection. The row of fittings closest to the window is also fitted with dimming ballasts. These are commissioned to allow for daylight dimming. In WCs, cleaners' rooms and corridors, luminaires operate on presence detection. External lighting is controlled via photocell and time-clock; when the daylight level decreases to a set level where the lighting is required, the fitting will be turned on.

3.3 Conclusions and key findings for this section

In comparison with Brine Leas, Loxford School has far more complicated systems that need careful control and overseeing. This is despite the intention of the design team to keep the building and controls as simple as practically feasible. Documentation describing the systems did not make it easy to extract useful information for understanding how the building systems worked in either case. It is difficult to gauge what level of information is required for laypersons to understand and look after the mechanical and electrical building systems. Perhaps more so than in the case of any other non-domestic building type, it is essential that end users of schools are provided with a simple illustrated document that describes the relationships between different systems, their set points and schedules. The proportional contribution to the total energy consumption of the building of each system should be highlighted along with the potential increases in energy use if the systems are not run or maintained as designed.

4 Key findings from occupant survey

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

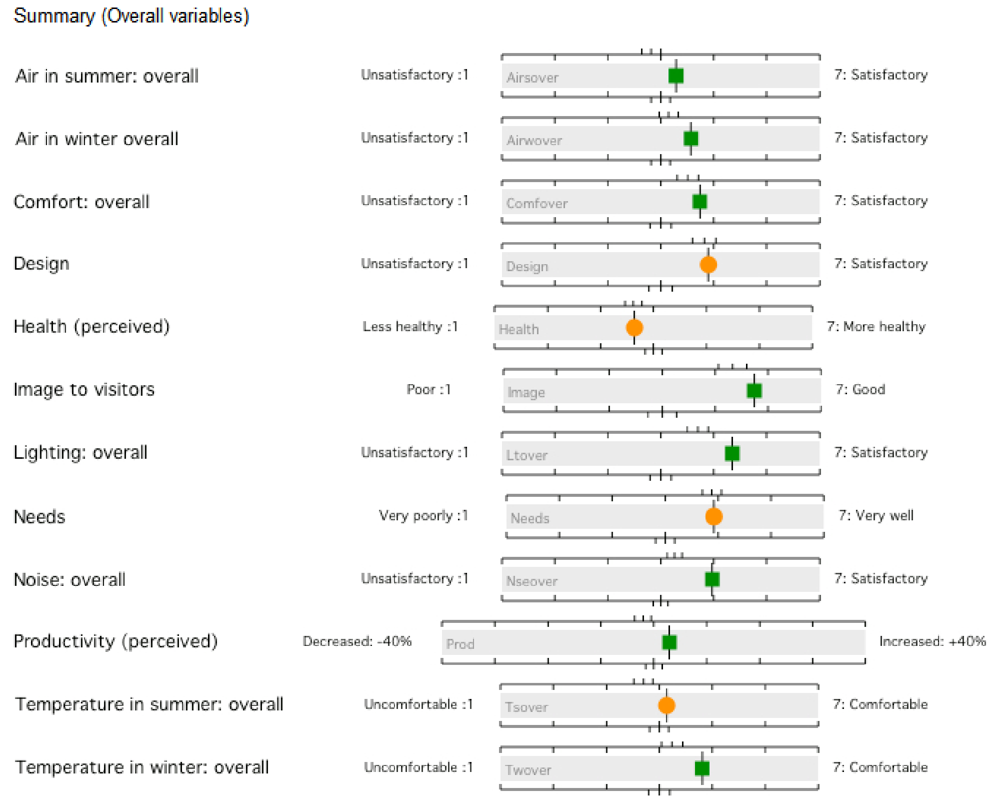
4.1. Loxford School

BUS Survey responses (146/195)

The Building Use Survey was carried out towards the end of the study period in January 2013. The monitoring team were somewhat apprehensive about the outcome as over the two years of the study some complaints were received about aspects of the building. With hindsight, these may have been due to the difficult circumstances of the handover and the fact that the deputy head, who had a good understanding of the systems and beneficial relationships with contractors, became gravely ill during the first year of the study and sadly passed away. Understandably, during this period, any issues raised by staff and the monitoring team about the building were difficult to address, which may have affected the feedback received.

The Aedas team were delighted with the response rate as well as the content. The results and comments received demonstrate that the teachers and staff like the building, the size and volume of the classrooms, the daylighting of the spaces and the good visibility across the common areas. The main issue raised related to storage and furniture while the technical problems identified regarding ground level doors, heating and BMS affected thermal comfort and fresh air provision. A key lesson for the design team was that design standards for education buildings seem to under-estimate the requirement for storage space and that more needs to be done by architects to increase such provision during design.

Overall, even with the issues identified, the building was better than the BUS midpoint benchmark for air quality, comfort, image, lighting, noise and productivity and in a par with BUS midpoint benchmark in meeting occupants' needs, design and health. Even winter temperatures came out better than midpoint benchmark, showing that the atrium problems were local issues. Building occupants' perception of Summer temperatures were close to the BUS midpoint benchmark despite the comments pointing to some overheating in some areas.



Space, storage and furniture provision

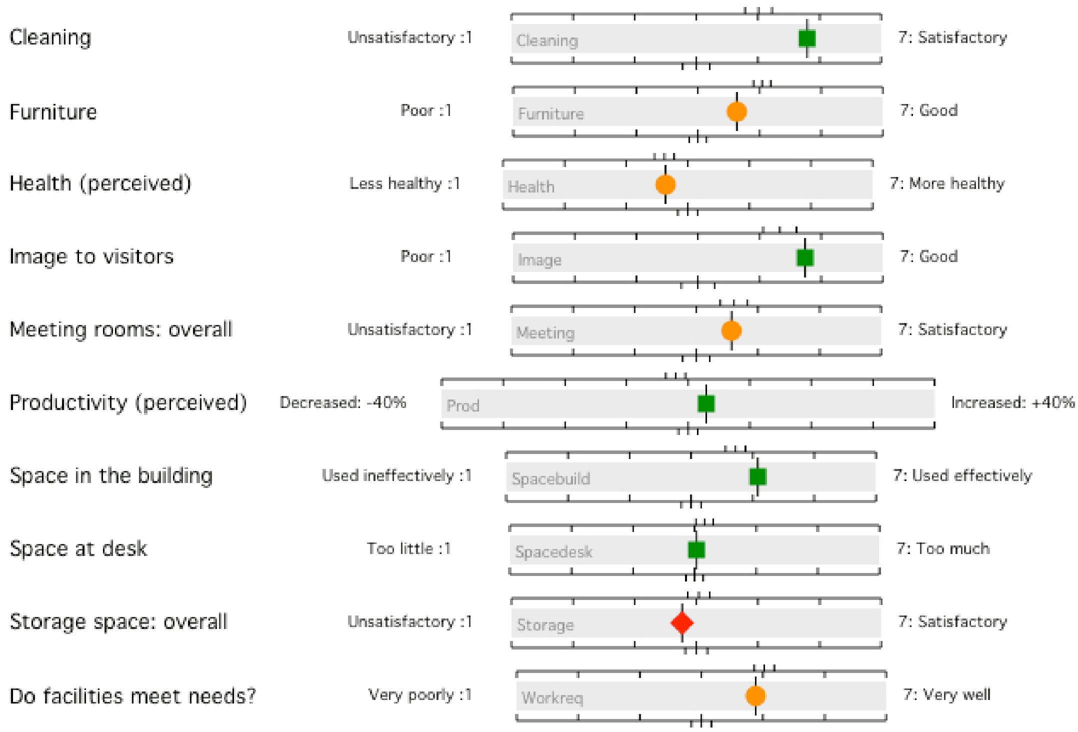
The daylighting of classrooms and their size were generally praised by teachers. However the lack of a teacher's desk with built-in lockable storage and the absence of enough wall-storage were raised by many as an issue. Some classroom furniture was deemed too inflexible, limiting teachers from changing the focal point of the room or from circulating. The position of the lecterns and working from a stool with no back support were described as uncomfortable and inflexible.

The location of the staff room on the top floor of the building was raised as inconvenient, making teachers feel disconnected as they cannot see the common areas; many chose to work in the classrooms instead. A short supply of personal/confidential space and meeting rooms was mentioned but others felt these were more than adequate.

The most frequent comment was about ICT, which respondents seemed to associate with the core functionality of the building. Teachers felt strongly about the position of whiteboards, IT support and the quality of equipment. The use of laptop trollies was not favoured, made especially difficult by the failures in electromagnetic locks on some corridor fire doors.

Student lockers were frequently described as too few for the number of pupils and not of high enough quality, with the locks showing wear and tear after two years of operation.

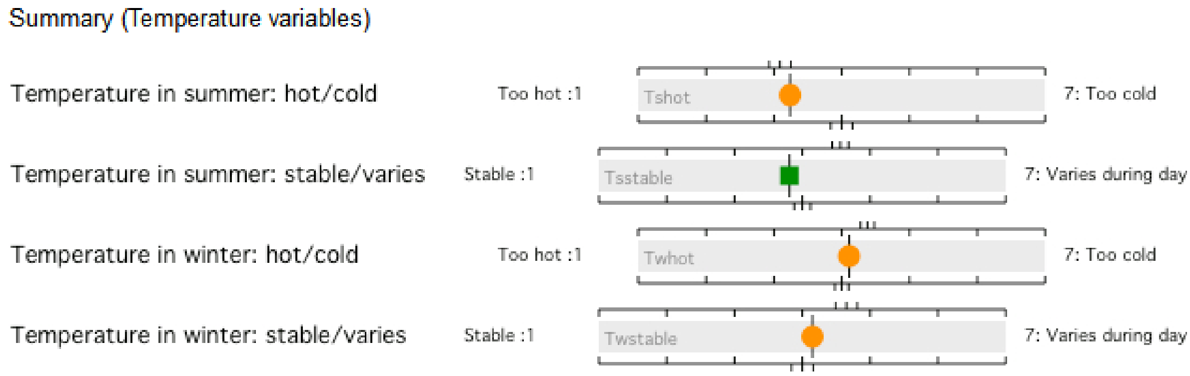
Summary (FM Variables)



Ventilation/Thermal comfort

Summary (Air Variables)

As the above chart and the comments listed in the appendix show, air quality in the summer was clearly problematic. Interestingly, complaints about air quality were rarely accompanied by complaints about temperature.



We know from Safe and Sound (S&S), the company responsible for the installation and commissioning of the BMS, that the thermal triggers for the plenum vents were not programmed in and the vents only open if CO_2 levels reach a certain level. It is possible that pupils have more body odour during the summer and without the temperature triggers the plenums would only open if CO_2 levels reach critical levels during a class. Opening the windows would help; however, we noticed that during the summer teachers often do not open the windows despite the thorough training session provided by Max Fordham engineers after handover.

Some comments allude to plenums not opening if windows are open in the summer. Interview with S&S revealed that the temperature set points for the plenums have not been implemented in the BMS. As the windows are often open in the summer, CO2 levels are mostly below the threshold required to open the plenum flaps. The cross-ventilation strategy is thus compromised and classrooms may overheat. The school asked S&S to provide a control button to be able to manually lower CO_2 thresholds in the summer season so that the plenums actually open at lower CO_2 levels. Instead, the school should insist on thermal triggers being reinstated as per the design control strategy.

The BUS results related to thermal comfort and air quality are consistent with the plenum damper issues. Without the temperature triggers installed, the expensive automated plenums do not operate to their full potential and even compromise fresh air provision and cooling/heating strategy. In the winter, when it would be enough to open the windows only, the plenums still open at higher CO_2 levels, causing unwanted heat loss in the corridors and classrooms. It is somewhat contradictory that following the adjustments to the CO_2 triggers, the plenums were closed during an intensive monitoring week undertaken at the school, even with the BMS reporting high CO_2 levels. The monitoring team recommended that this is further investigated by S&S, the original installers and programmers of the system.

The atrium in the West wing has an important role in the ventilation of the adjacent classroom cluster. Dampers positioned at the top of the atrium are intended to be opened by temperature and CO_2 triggers. However, without the temperature set points programmed, these do not open especially as these classrooms are A-level rooms, i.e. more scarcely occupied in the warm summer months. Consequently, the atrium does not function as a stack and can also overheat, which several users raised.

In the winter, the atrium has been particularly cold due to the ground-level circulation doors being left open throughout the day regardless of the season. The reason for this is that the school was not aware that the latch on the escape doors could be withdrawn during the day with a special Allen key. Without this it is not possible to open the door from the outside and the doors have been kept open throughout the year to facilitate circulation at ground level between classroom wings. Some respondents remarked that the atrium can have cold ‘gales’ blowing through it in the winter. The draft from the open corridor doors was further exacerbated by the fact that at the opposite end of the corridor, at the main entrance, the sealed entrance lobby was value engineered. The evaluation team experienced these strong drafts first-hand when all the doors in the entrance hall were open on visits.

A secondary impact of the cold atrium was that heating flow temperatures were raised from 45^{o}C to 75^{o}C during the first cold spell. The head teacher’s office opens out to the atrium and she was keen to address any discomfort in such a key circulation space. The ground source heat pumps cut off beyond a 45^{o}C flow temperature. Under these circumstances, the building management system calls for heat from the boilers rather than from the ground source heat pumps, which are inefficient beyond this point. Despite the substantial investment, the GSHPs ended up contributing to less than 3% of the heating load in the past two years. A side effect of the high flow temperatures was that upper corridors and many classrooms experienced overheating. Depending on where teachers and staff spent the majority of their time, they would experience the school as either too hot or too cold during the winter months. This is consistent with the findings of the BUS. Having resolved the door problem, the monitoring team hopes that the newly adjusted temperature profile will be sufficient to heat the atrium space with the GSHP acting as the primary heat source.

One of the science room teachers mentioned that ventilation in science prep rooms is inadequate, with teachers having to set up experiments in spaces with better ventilation far away from the classrooms. Some BUS respondents complained of headaches in classrooms, again the monitoring team attributed this to the windows not being opened when needed. It doesn’t help that the CO_2 sensors provide confusing feedback.

Figure 4.1: CO2 sensor annotation

The labelling on these is ambiguous and the additional notes provided by the schools are incorrect. Detailed examination of the original specification revealed that while red refers to high CO2 levels, in excess of 1200ppm, and green between 800-1200, orange light comes on when the CO2 levels drop below 800. Although the annotation clearly states ‘excessive ventilation’, implying the necessity of closing the windows in Winter to avoid heat loss, users find the orange light so confusing that they do not refer to the CO_2 sensor any more to decide when to open/close the windows.

Maintenance

Most comments about maintenance related to the toilets, which were frequently out of order with the consequence of the remaining washrooms being overcrowded. As in most modern schools, toilet lobbies have been designed-out in order to limit bullying in the toilets. However the toilets are mixed, which is tricky to manage under crowded conditions and the school eventually segregated these. In addition, the water supply to the corridor fountains has been wired up to be triggered by the selonoids of the toilets. Unless someone is triggering the PIR sensor in the toilets, the corridor fountains have no water supply.

Some teachers mentioned sinks leaking and some leaks appearing in classrooms and under the roof. A rooftop inspection verified limited areas of the roof leaking.

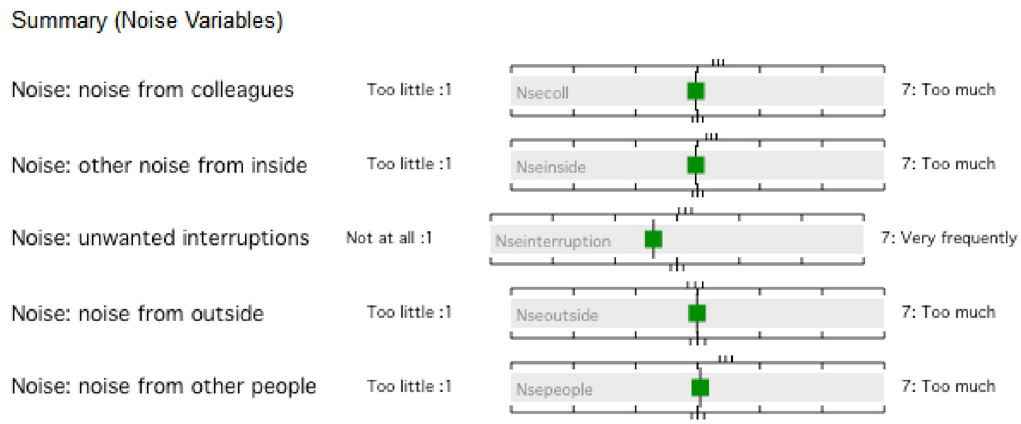
Lighting

Occupants have noticed the excessive artificial lighting in common areas. It became clear that all common area lighting had been programmed onto the same zone, which means that if a PIR sensor is triggered in any of these areas all the lights come on in the building. The common area lighting is generally on continuously during school hours.

A very small number of rooms are without natural light and users clearly don’t appreciate this. In classrooms where the daylight dimming works, this is much appreciated and ability to turn off the first row of lights to limit glare on whiteboards is well liked.

Apart from the excessive energy use arising from the common area lighting, the lighting strategy is successful overall. There are some glare problems where blinds are missing and users dislike the resultant glare from lights in the sports hall. The only spaces without enough light are in the workshops, where precision works take place. The recommendation here is to check dimmer settings and set these to be higher than in other areas for when the lighting engineers re-commission the lighting system.

Noise



The school is in a suburban location and set back from the road. Building occupants mentioned noise in corridors, echoes in the atrium and noisy fans and ventilation pipes being sources of annoyance. Noise insulation between classrooms was also mentioned. However, others remarked that noise from children was part and parcel of schools and not a design issue. A particularly strange measure in the school is that the alarm bell is being used as the school bell. This is due to a last minute client change – the initial head teacher did not want a bell while the incoming head thought that a bell was essential. Since a bell was not planned, the alarm was altered to provide the signal.

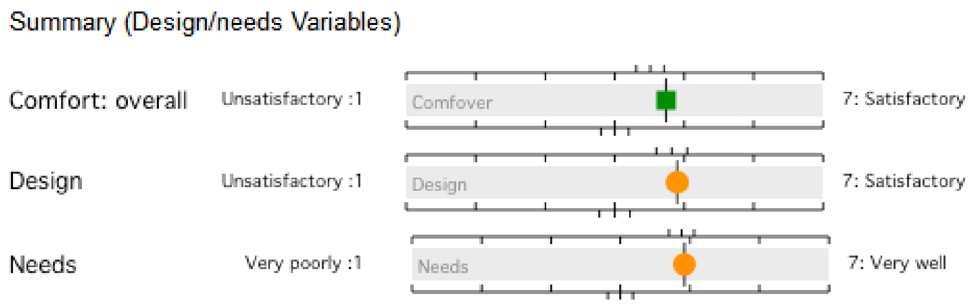
Control

The heating system set points have been affected by the overrides put in place due to discomfort at ground level. Several users found the thermostats in classrooms unresponsive and the monitoring team observed many radiators on outside scheduled hours in their specific zone. This indicates that zonal controls on the BMS may not be properly working.

Roof vent controls were frustrating to some users who did not realise that once they activated the manual switch for the roof vents these would no longer open automatically on that day as this triggers the 'user override' mode in the BMS. The time settings can only be modified by the BMS 'administrator'. The switch is a simple button located on the CO2 sensor and no status information is provided anywhere to the user. In the third floor art room the CO2 sensor was hidden behind a storage cabinet which meant that the vent would never open and the override button was out of reach.

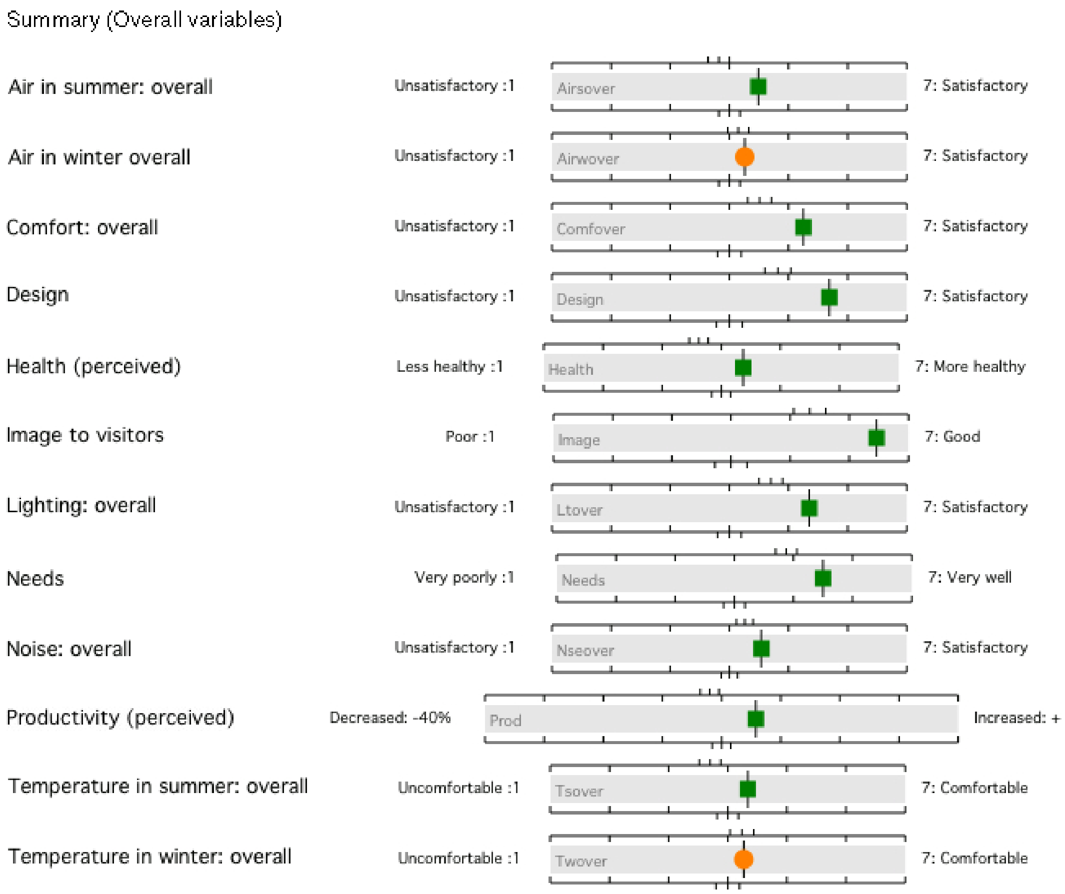
Lighting controls in classrooms are well liked although users pointed out that the buttons took a great deal of pressure to operate. The zoning and daylight dimming was popular where it worked.

Needs



In total, 85% of people surveyed found the building better than BUS midpoint and over 40% scored it in the upper quartile. In terms of meeting needs, the figures are 65% and 40% respectively. Although comfort scores in the BUS appear generally lower, with 84% of responders rating the building as better than BUS midpoint, and only 33% of these in the upper quartile, the building still fared better than BUS midpoint.

4.2. Brine Leas Sixth Form



BUS Survey Reponses (51 / 51)

Narratives have been compiled for the BUS surveys. Bullet points have been included to show the spread of responses received, while short summaries of the general tone for each section convey the strongest message in the responses.

Design

The responses were overwhelmingly positive in terms of design with occupants enjoying the light, airy feel. There were general concerns about temperature (too cold) and a few specific room issues, namely, recording studio, entrance foyer and chemical storage room.

- Excellent
- Light, space, comfortable
- I think a huge atrium is a waste of space
- Certain areas not big enough
- Music studio used for recording isn't sound-proof
- The building itself is lovely. Very spacious
- Wasted space. Noisy – especially reception. Main doors have been kept locked most of the time

- Science preparation / storage is inadequate – particularly in terms of safe chemical storage

Needs

Overall, it appears that room design is a little too standardised and not quite fit-for-purpose.

- Larger lecture rooms and heating needs reviewing
- Not enough sockets in workroom
- Disappointed with art room – feels like a science room
- Except gym, work rooms are good
- Media suite would be better as two separate rooms
- A great working environment
- Noise from heating system above classroom (roof plantroom), can be cold when cold outside.

Meeting

Generally happy with meeting space, most reported that the media suite is always available for this purpose.

Storage

There are mixed responses for storage. Many respondents are satisfied but storage is not adequate in some areas, particularly in the arts classrooms.

- Storage space is good but there are far too many locked cupboards and too many keys
- Science preparation storage is inadequate – particularly in terms of safe chemical storage
- Not enough cupboards in classrooms
- Not enough storage space for students work in Technology and photography
- Storage poor in art room

Space

This section also returned mixed responses. In particular, complaints about poorly positioned lecterns; lack of enough space to use the computers come up repeatedly across Aedas' 5 schools and academies.

- I haven't got a desk
- Good, long bench at front of lab but position of lectern with computer is poor
- The seats available to students are not practical
- Problems due to sharing and not having any space
- No need for staff desk

Comfort

There were many complaints about the water fountains, particularly in the staff room. Other issues were generally about temperature – particularly due to the lack of a buffer zone in the design of external doors.

- Smelly water fountains
- Temperature is a big issue!
- Huge drafts in areas next to doors to outside. Need two sets of doors
- Nice environment

Noise
While the positive outcomes from the atrium spaces are widely recognised, they seem to be the subject of many noise transfer issues into classrooms.

- Media suite should be sound-proof.; Gym noise; Pipes from 3rd floor when recording
- Echoes from the atrium are very noisy when working
- Noise from coffee shop
- Students on balconies; voices travel; no privacy

Lighting
Lighting is reported as generally fine, apart from a couple of glare issues. These issues seem to be very common in school buildings.

Health
Comments seem to centre on temperature – many report being too cold.

Behaviour
Many respondents report feelings of happiness and relaxation, although many reported having to change the way they dressed because of being too cold.

- Happier in pleasant conditions
- Relaxed, students seem to enjoy the building too
- I wear two coats to keep warm

Thermal comfort
Almost 50% of building respondents complained about low temperatures in winter. The focus studies started on a day with an unusually high ambient temperature for winter (around 15°C). The internal temperatures were very high (as high as 25 °C) in the morning. There were attempts to identify the root cause for this problem. According to the building manager, the VT circuit valve was wrongly set up back to front and therefore the valve responded wrongly to the BMS command: closed when set to be open and vice versa. The valve wasn't refitted until during the focus week and therefore could go some way to explaining the reports of low temperatures by the occupants.

Acoustic studies (sound levels & reverberation times)
Noise levels and reverberation times were investigated as part of a week-long intensive study at the school, following complaints from staff about noise from a language laboratory. They were found to be generally acceptable across the building and compliant with BB93 requirements i.e. ambient noise level less than 35 dB & reverberation time less than 0.8 seconds. However, the internal noise level in the first floor language classrooms underneath the mechanical ventilation plant is higher than this limit. According to the measurements, the indoor ambient noise level was constant at 37 dB when the school was empty and the plant still running (measurements carried out in accordance with BB93 requirements).

Reception and Media Suite

The entrance foyer is a triple-height space that is designed to provide a tall view to balance the long view through reception and down one leg of the L-shaped floor plan. A draft lobby was not designed in as this would compromise the design; instead, the mechanical engineers introduced an air curtain above the entrance door. In hindsight, elimination of draft lobby wasn't very successful and should be avoided in future. A similar situation has occurred in Loxford school also, where the staff at the student reception desk – also located in a triple height space – keep 4 large, personal heaters underneath the desk to keep warm.

Figure 4.1: Triple height entrance foyer with redundant reception desk

4.3. Conclusions and key findings for this section

Having completed the Building Use Surveys for three large academy buildings in parallel with Loxford and Brine Leas Schools, it seems more appropriate to compare Loxford with the Academies due to its size and operation. Whilst the academies were all mechanically ventilated or mixed-mode, the majority of Loxford School's classrooms and common areas are naturally ventilated. Yet the BUS scores for air quality and temperature in winter in this building are better than Brine Leas School despite the teething problems experienced with building management systems and external doors. The story of Loxford School shows that a naturally ventilated school building may be more resilient to commissioning and operating issues and have greater potential for providing a comfortable environment at low energy operation even when the controls are complex and facilities management expertise is limited.

Brine Leas has done rather well in terms of energy consumption (as explained in Section 6) and also in terms of occupant feedback compared to the BUS dataset. Being a much smaller school with a head of Sixth Form that has experience in construction, it didn't experience the range of operating problems that the other buildings encountered. This supports the point above that simple controls and greater expertise in the management of a building in operation is a key factor in achieving design intent. End user expertise and interest in the electronic control systems has emerged as a key factor in operating mechanical systems to their full potential in all the seven buildings studied by Aedas under the BPE programme.

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. Loxford School

Operations, Maintenance and Management

Loxford School was handed over to the client in May 2010. Initially, the handover went smoothly however problems surfaced quickly which led to a three-year dispute between the school and the contractors Willmott Dixons. The then Deputy Head was very supportive of the monitoring project but when he was taken ill shortly after the project started, it became difficult to maintain continuity. Valuable first-hand information about commissioning, training and building management was lost and, given the contentious legal situation, members of the design and construction team were understandably wary of releasing more information than was absolutely necessary.

The school's day-to-day management fell to the caretakers of the building who moved with the school from its simple old building and found the high-tech controls challenging. Facilities managers were contracted in, initially to iron out problems with the building management systems that "reported too many alarms". CLC Facilities established early on that essential BMS documentation was missing and that they could not access the underlying BMS settings without the original contractors Safe and Sound. Arising problems were dealt with as best as possible without this information but it was clear to the monitoring team that the building systems were not running at optimum performance. This was communicated to both the school and the contractor but neither were in a position to act on the findings.

As found on the other design and build projects, towards the end of the defects liability period, the school just wanted to proceed with repairing the problems themselves without engaging further with the contractor. With the sad loss of the Deputy Head, other staff found it difficult to pick up the building's operation and management.

With the recruitment of the new Business Manager during the last quarter of the project, many of the findings were taken on board and begun to be addressed. Safe and Sound were invited back to review the BMS settings and some of the underlying problems were diagnosed and limited changes were made to the system. Further BMS training is planned for the Business Manager and the on-site Facilities Manager. CLC also seem to have received the information they were asking for to manage the control systems. The school management were not aware of the possibility to procure FM services via performance contracting and in general are too busy with the day-to-day running of the school to weigh up the potential savings and research the scope and pro-forma required to put such a contract in place.

Metering

Metering at Loxford School is elaborate with a clear sub-metering strategy that allows good assessment of energy end uses. The only oversight of the strategy was to omit the electricity meters for the Ground Source Heat Pumps. These have not been installed and have been one of the reasons why it has been so difficult to establish that the GSHP was so severely under-utilised. The location of the GSHP electricity meter is marked on the LV panel although the meters themselves are missing.

The BMS initially was not reading the electric or gas mains and several sub-meters. In the first year of the study, sub-meter readings had to be carried out manually, recording readings from over 50 meters placed in different metering cupboards across the school. The connection between BMS and sub-meters was eventually fixed and by the time the TM22 was carried out all the submeters could be reconciled and tracked remotely for some time. Nevertheless, weekly readings had to be taken by Aedas as the facilities managers were not happy to set up the logs required to download this information automatically, stating that this was beyond the scope of works agreed with the school.

During the second year of monitoring, the team gained access to the half-hourly electricity data and could establish the electrical base and peak loads and analyse consumption patterns since the opening of the school.

The main LV Switchboard includes metering on the incomer mains, which should have been monitored by the BMS system to record energy usage, instantaneous demand log and monthly maximum demand. Small power and lighting are being served via local distribution boards. These distribution boards allow the lighting and power circuits to be isolated. Sub-meters are also connected to the Building Management System (BMS) in order to log energy use from pulsed output.

The electrical supplies delivered by EDF Energy are terminated onto the intake cubicle which serves the main LV switchboard located in the Energy Centre and provides an unmetered separate supply to the sprinkler pump and sprinkler distribution board which serves the trace heating and pump. The incoming intake cubicle incorporates all necessary CT's for EDF's metering.

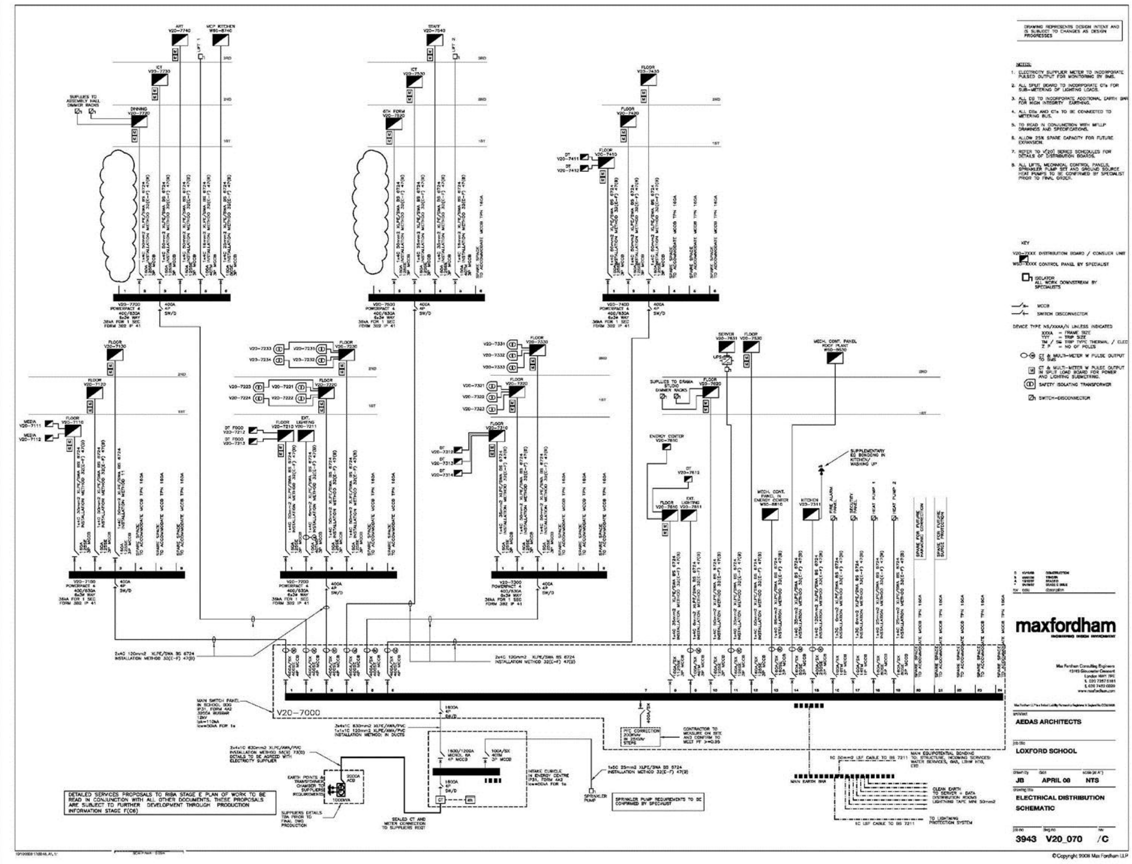


Figure 5.1: Loxford School Electrical Metering Strategy

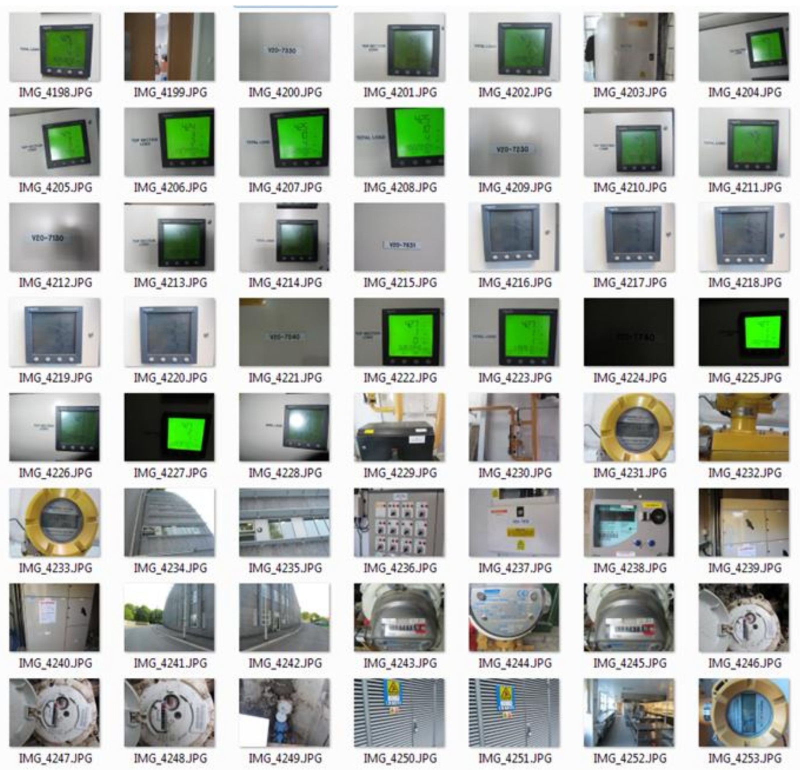


Figure 5.2: Loxford School meter snapshots

5.2. Brine Leas Sixth Form

The Business Manager for Brine Leas has been the main point of contact throughout the study. Amongst other responsibilities, she looks after the energy budget for the whole site and was concerned from the outset of the evaluation that they had spent their annual energy allowance on the sixth form building in just a few months. The Head of Sixth form was very engaged with the project during the design and construction process. Once the building was handed over, he took responsibility for the BMS. Although he had some understanding of the systems, he struggled with a seemingly incomplete BMS interface and a lack of clear instruction as to how the systems were supposed to interact. These issues will be outlined further in the Technical Issues section.

During the course of the evaluation, there have been three consecutive members of staff appointed as caretaker / facilities manager for the building. The first person appointed was a caretaker who had been looking after the old, secondary school building for some years and seemed overwhelmed and undertrained. When he left, a temporary replacement looked after the systems while the current, permanent Facilities Manager, was secured. These changes in personnel may have contributed to gaps in knowledge in terms of systems interaction and the smooth-running of the building. Over the past year, the new FM has secured maintenance agreements that cover a number of the building components; separate, annual agreements for the sprinkler system, the lifts and the moveable walls and a cyclical agreement for the AHUs including air filters. They currently have no maintenance contract for the heating system, although they do have their own plumbers who come in. There is also no contract for the BMS or controls. The approach to maintenance has been reactive up until now. With the confirmation of the maintenance agreements, this is likely to move in the direction of proactive but there still remains a large knowledge gap over the BMS and the systems interactions. Willmott Dixon report a lot of problems with training towards the end of the project where Client FM teams cancelled at last minute together with confusion over what staff were looking after which element and problems with staff turnover. After a number of attempts, EIC decided not to carry out further training without instruction. It is difficult to decipher what led to the knowledge gaps; it may have been a combination of a lack of detailed training and personnel discontinuity at Brine Leas.

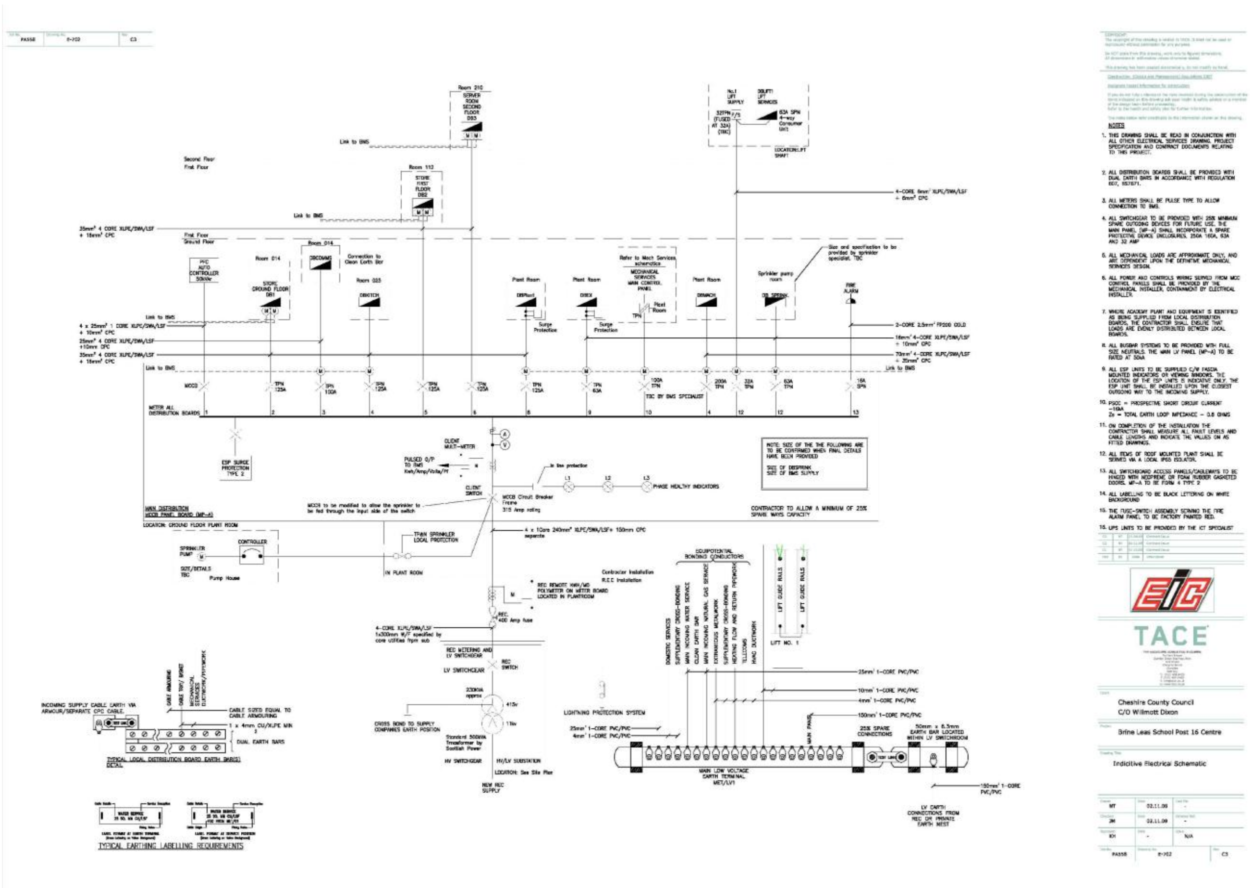


Figure 5.3: Brine Leas School Electrical metering strategy

The electrical metering strategy consists of local distribution boards serving the individual floors. These distribution boards are split metered. The lighting and power are metered separately. Separate distribution boards are also provided for high usage areas such as the kitchen, technology rooms and comms rooms. All these boards are fitted with meters. These are linked to the BMS for monitoring purposes. The building is supplied via substation located on the site. A utility cut off switch is located in the plantroom. The main panelboard is used to distribute the power and is located adjacent to the incoming supply utility cut-out.

5.3. Conclusions and key findings for this section

Continuity is a critical part of establishing and maintaining a successful operating regime in any building. Schools are even more sensitive to this as they have limited resources allocated to building management. In the case of both Brine Leas and Loxford School we have witnessed the impact of broken chain of responsibility which in both cases was detrimental to building performance and occupant comfort.

Another issue is the technical preparation and expertise of the persons responsible for coordinating the operations and maintenance of school buildings. In both cases great progress was made when persons with a background in the construction industry took charge of building management. Yet in both cases the monitoring team had to provide substantial support to catalyse change. This reinforced the view that there is great value in design teams’ continued involvement in aftercare and monitoring until a building finds its optimal operating regime. If done with intent from the start of the project, as prescribed by Soft Landings, then the expectation is that significantly less time and effort is required for a building to reach such an optimum. However, if collection and benchmarking of detailed energy consumption data is not part of the Soft Landings implementation then there is a risk that Soft Landings will be ineffectual.

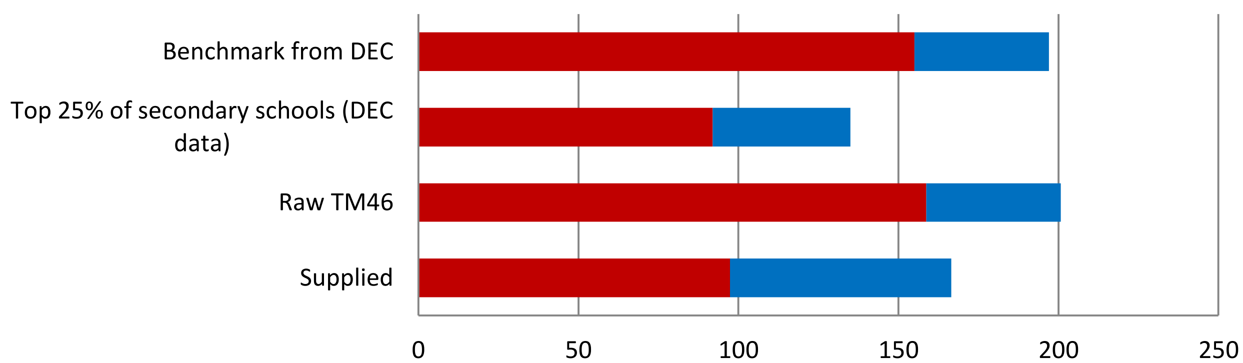
Lastly, we cannot overstate the importance of acquiring detailed energy consumption data from the first month of a building's operation. Missing, disconnected and poorly calibrated meters will not get rectified unless someone is after the information they offer. Missing energy end use data needs to affect the contractor's final payment for problems with metering to be flagged up during the defects liability period. Without automated meter and submeter readings, the collection of energy consumption data becomes prohibitively expensive, which means that the diagnostics of any problems relating to energy use is hampered. Performance contracts based on building energy use targets cannot be set up easily and facilities managers do not currently treat energy consumption related issues as part of their scope under standard contracts.

6 Energy use by source

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

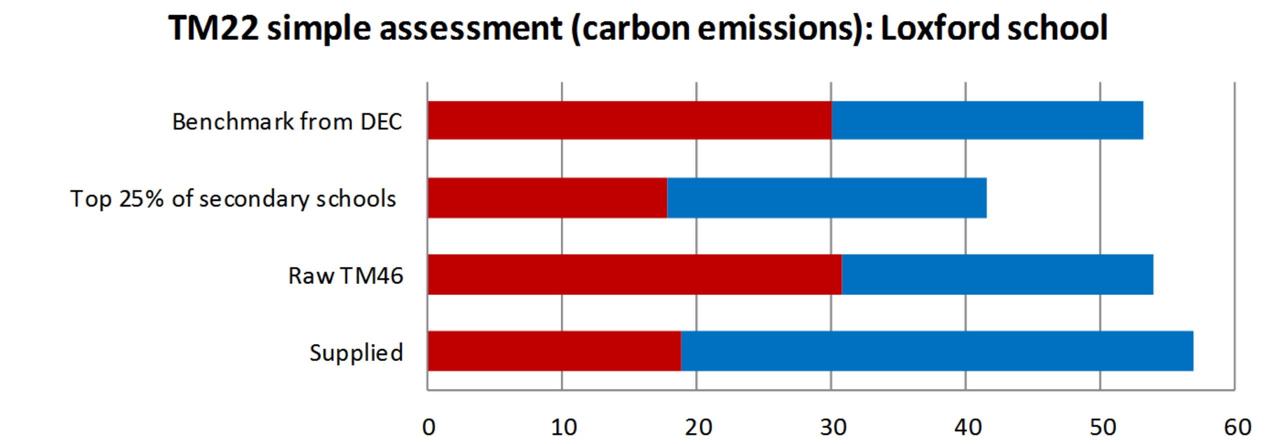
6.1. Loxford School

Loxford School's detailed metering strategy provided good quality data for TM22 analysis. A bottom up approach was used to reconcile end-uses with the metered data. The following Figures provide the outcomes of the TM22 simple analysis.



	Supplied	Raw TM46	Top 25% of secondary schools (DEC data)	Benchmark from DEC
Fuel/thermal (kWh/m²/annum)	97.4	158.7	92	155
Electricity (kWh/m²/annum)	69.1	42	43	42

Figure 6.1: TM22 simple assessment for Loxford School: energy supplied



	Supplied	Raw TM46	Top 25% of secondary schools	Benchmark from DEC
Fuel/thermal (kg CO_2/m^2/annum)	18.9	30.8	17.8	30.1
Electricity (kg CO_2/m^2/annum)	38	23.1	23.7	23.1

Figure 6.2: TM22 simple assessment for Loxford School: carbon emissions

The user specified benchmark for this study is the median of the top 25% secondary schools data reported by Godoy-Shimizu et al. (2011) based on the Display Energy Certificates lodged for secondary schools.[1]

These graphs show that School's gas consumption is better than DEC/TM46 benchmark and almost on a par with top 25% of secondary schools. However, electricity consumption is higher than all benchmarks. The School's performance is also worse than all benchmarks when the CO_2 metric is used. The lodged DEC for the school is E-rated.

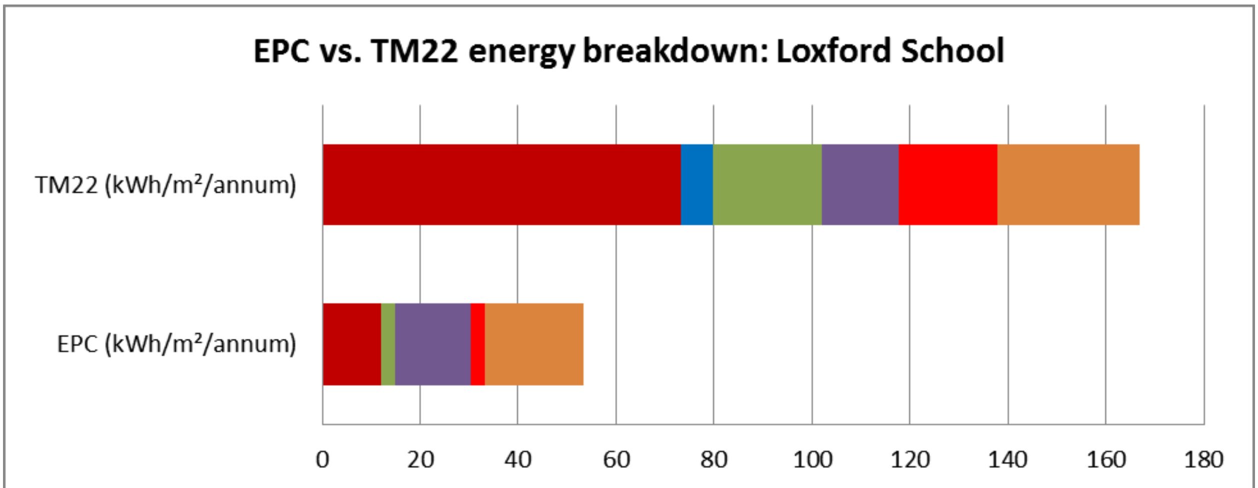
The end-uses reported in Table 1 were reconciled with the mains electricity in the TM22 detailed analysis.

[1] Godoy-Shimizu, D., Armitage, P., Steemers, K., and Chenvidyakarn, T., 2011. Using Display Energy Certificates to quantify schools' energy consumption, Building Research & Information, 39(6), pp535-552.

System	Fuel/Thermal demand (kWh/m²/year)	Electricity (kWh/m²/year)
Space Heating	71.8	1.5
Hot water	20.0	0.0
Refrigeration	0.0	6.4
Fans	0.0	1.8
Pumps	0.0	20.0
Controls	0.0	0.5
Lighting (Internal)	0.0	15.7
Lighting (External)	0.0	1.7
Small Power	0.0	5.4
ICT Equipment	0.0	12.2
Catering - Central	5.6	4.3
Total	**97.4**	**69.6**

Table 6.1: TM22 energy assessment for Loxford School: detailed analysis

The Energy Performance Certificate (EPC) produced for the school following the completion of the building is B rated. Whilst EPC calculations are based on default schedules of operations, default occupancy density, and default set points and do not include the effect of actual equipment load, it is useful to compare the end-use estimations of the EPC with actual figures. The EPC profiles and assumption for schools are based on the so-called 'standardised' conditions and, as such, the EPC estimations for fixed building services could arguably be used for comparison purposes. Figure 3 compares the results of TM22 energy assessment in-use and the EPC estimations for end-uses based on the energy end-use classification used in the National Calculation Methodology (NCM). It should be noted that the EPC estimations provided in this graph (and other similar graphs in this report) include the 'Equipment' load used in the calculation engine to estimate the heating and cooling demand under 'Non-regulated end-use' category. This load is subsequently excluded from EPC rating but it is useful to compare this with the actual equipment load to have a better understanding of the assumptions behind EPC assessment and their relevance to actual loads.



	EPC (kWh/m²/annum)	TM22 (kWh/m²/annum)
Heating	12.1	73.3
Cooling	0.01	6.4
Auxiliary	2.8	22.3
Lighting	15.4	15.7
DHW	2.8	20
Non-regulated end-use	20.3	29.2

Figure 6.3: EPC vs. In-use TM22 energy analysis for Loxford School[2]

While actual lighting consumption is close to the design estimation, the rest of the fixed building services have consumed significantly more. The major issues are related to the following energy end-uses:

Heating:
The base heating schedule set up for the School in Building Management System is a 7:00-18:00 profile that is very close to the profile used for Schools in National Calculation Methodology (5:00-18:00) if an allowance for pre-heating is also allowed. However, the temperature setpoints in classrooms are often higher than the standard 18 °C used for classrooms in National Calculation Methodology. A general conclusion drawn from this study and another project Aedas team carried out on three academies is that the heating estimations produced in building compliance and energy performance calculations for schools tend to be optimistic.

The majority of spaces in Loxford are naturally ventilated and, therefore, operable windows and vents are critical in achieving BB101 fresh air and CO_2 requirements. Consequently, it is important to take into account the effect of operable windows and vents on heating loads. Site surveys revealed that a number of motorised vents facing the courtyard were faulty and stuck open in winter. The temperatures detected in the classrooms linked to these vents were often lower than temperatures in other classrooms. Furthermore, lack of training for the use of ground level corridor door external crash pads led to the doors being left wide open in winter and, consequently, high heat loss.

[2] Auxiliary energy includes fans, pumps and control. Individual components of auxiliary energy have been listed in Table 6.1.

Figure 6.4: Motorised vents stuck open regardless of CO_2 level and temperature, Classroom F21 (Photo taken on 15/01/2013)

The contribution of ground source heat pumps to heating has also been less than expected. The evidence collated from the Building Management System suggests that ground source heat pumps are often disabled in heating mode and the gas-fired boilers take the lead. Flow temperatures as high as 80 °C will be required to combat the heat loss from open doors and vents in winter and this could be a likely cause for low contribution of ground source heat pumps to heating as they are not suited to provide this temperature[3].

In summary, excessive heating consumption could be curtailed by reviewing and lowering winter temperature set points, limiting heat loss and reinstating the ground source heat pump.

Cooling:

Comfort cooling to the ICT enhanced classroom is provided by chilled beams fed from the ground loop via a heat exchanger, providing free cooling. In addition to ICT enhanced spaces, the server room and data hub rooms are also cooled. The cooling to these units is provided by DX split units. The server room load allowed in Building Regulations and energy performance calculations is based on default values that are often significantly lower than actual loads and this leads to underestimation of cooling loads. It would appear that school server room W/m² are closer to the NCM figures set for 'data centres', which is over ten times that of the 'Misc24Hr_ITEquip' activity type of the NCM profiles. Yet anecdotal evidence suggests that

[3] Feedback from the controls specialist suggests that system flow temperatures had to be raised (VT slope adjusted) in May 2010 due to cold temperatures in some building areas.

Misc24Hr_ITEquip activity type is often being used in thermal models to estimate cooling loads in school server rooms.

Auxiliary (fans, pumps and control):
As illustrated in figure 6.3 the auxiliary electricity consumption is approximately 8 times that of the EPC calculations, the majority of which is attributable to pumps.

Mechanical ventilation is provided to core spaces of the building and fan frequencies logged by the Building Management System reveal that demand-controlled ventilation is effective leading to absorbed powers as low as 12% of the fans' ratings. There is, however, scope to optimise the kitchen ventilation profile; the profile set up in BMS is 6:00-23:00 that seems excessive.

Out of hours use of pumps seems to be the main root cause for higher than expected auxiliary consumption. Pumps tend to work in tandem with other services. Any out of hours operation of these services would inevitably activate the corresponding pumps. If the control regime does not allow for this then additional pumps are activated too. Overnight sub-metering of the Energy Centre revealed that the baseline power demand of the Energy Centre is around 40-50 kW. Evidence collated from the BMS shows that most pumps are working outside normal occupancy hours leading to this high baseline demand.

It should also be noted that the pump rating assumed in Building Regulations compliance calculations is not altered to reflect vertical closed loop ground source heat pump installed in Loxford School and therefore under-estimates energy consumption by the pumps. Therefore, the EPC value illustrated in Figure 6.2 cannot be considered an estimate of the as-installed auxiliary energy use.

Figures 6.5 and 6.6 show the annual electrical power demand for the school based on half-hourly data sourced from the utility supplier.

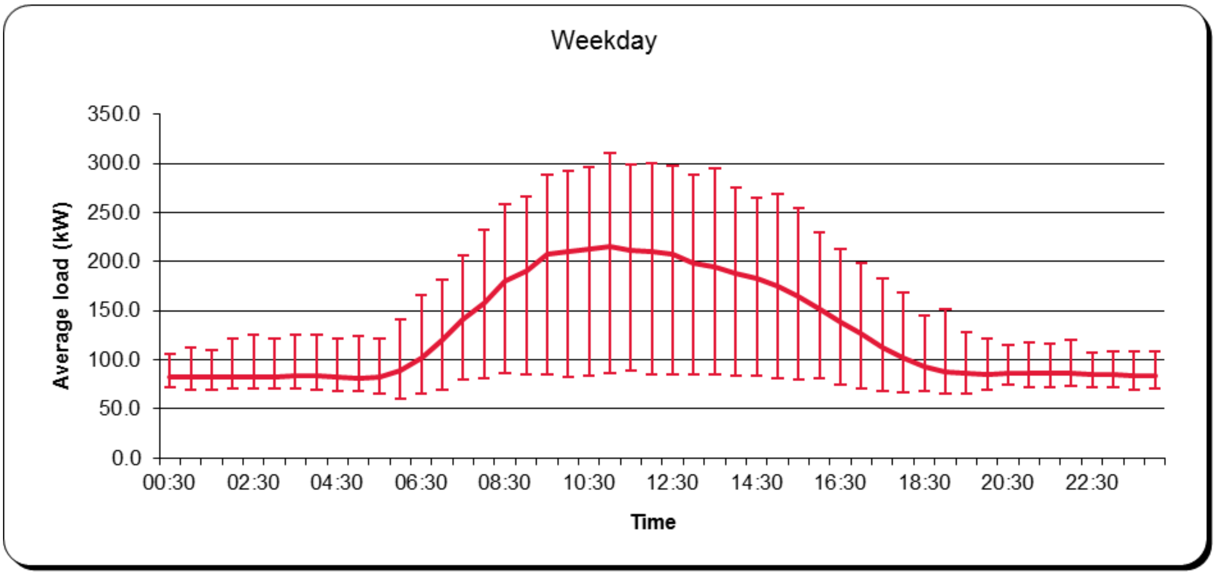


Figure 6.5: Average annual electrical power demand for Loxford School over weekday (kW). Baseline power demand for the building is 80 kW; sub-metered data for the Energy Centre reveal that 40-50 kW of this load is related to the Energy Centre.

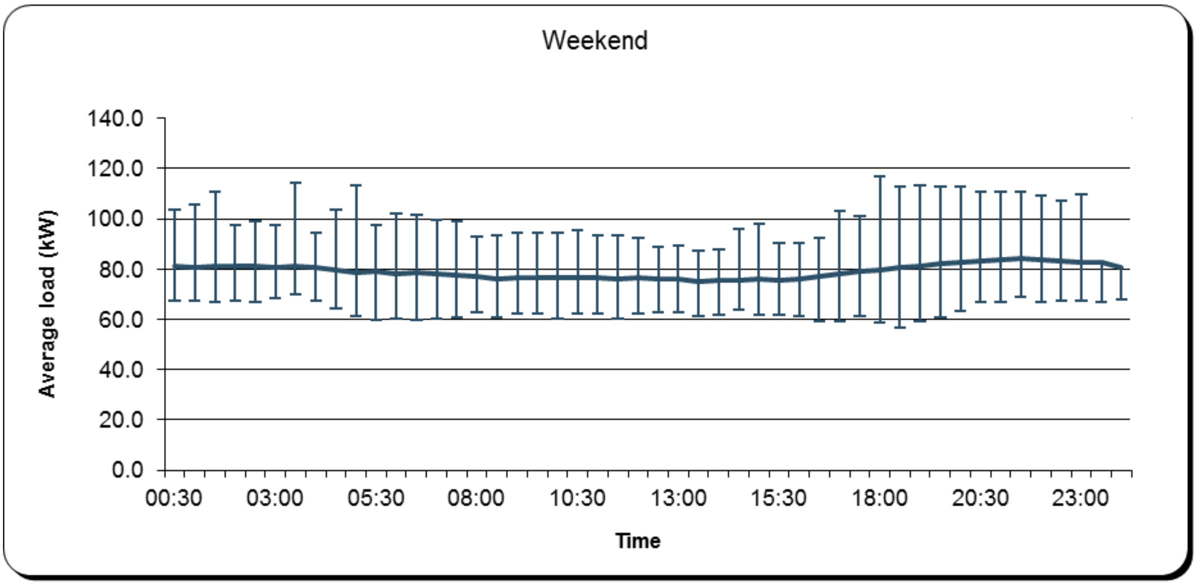


Figure 6.6: Average annual electrical power demand for Loxford School over weekend (kW)

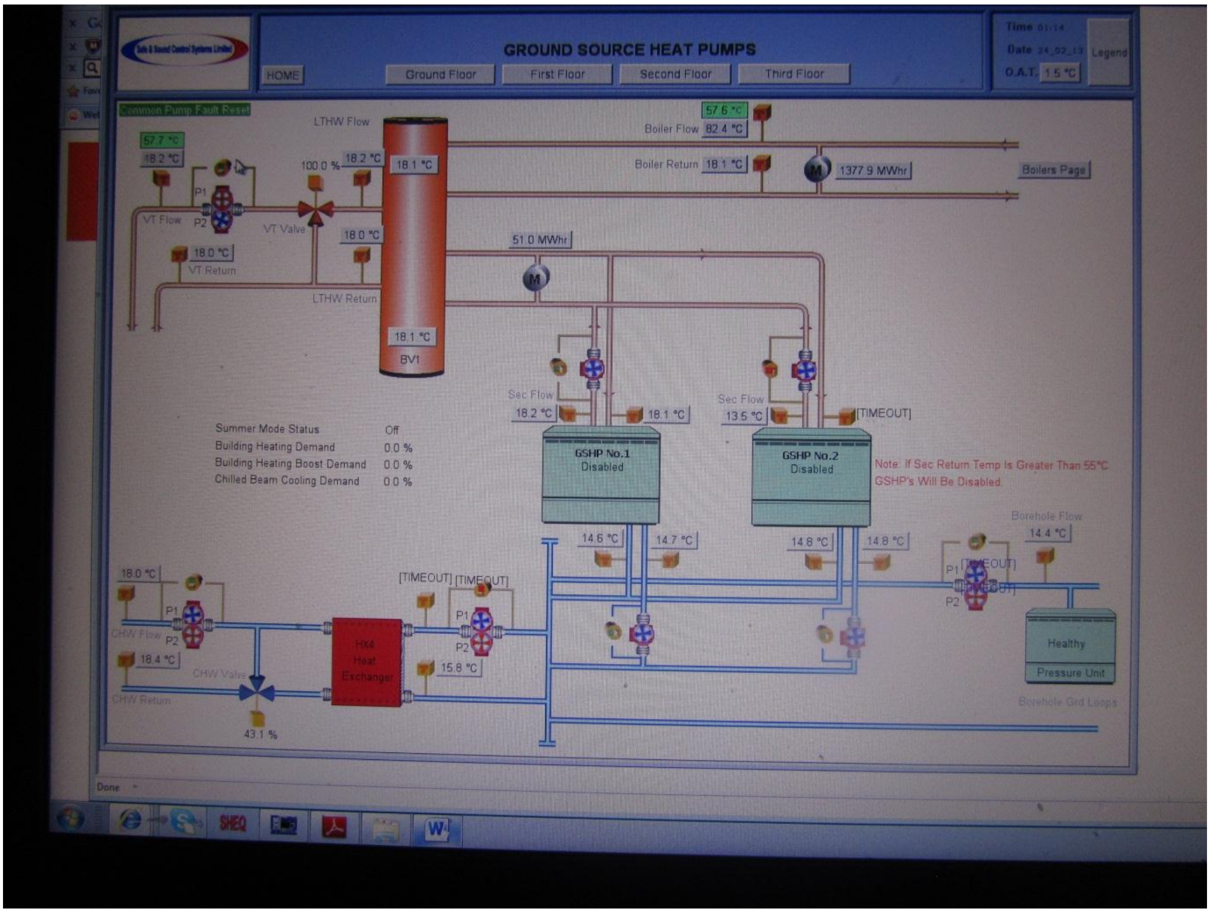


Figure 6.7: Out of hours use of pumps: the blue colour indicates pumps are running. The GSHP pumps and the VT pump are in operation (Sunday 24/02/2013, 01:04 am).

DHW:

A 24/7 profile is set up for domestic hot water. This leads to higher than expected boiler and hot water pumps usage (Figures 6.8 & 6.9).

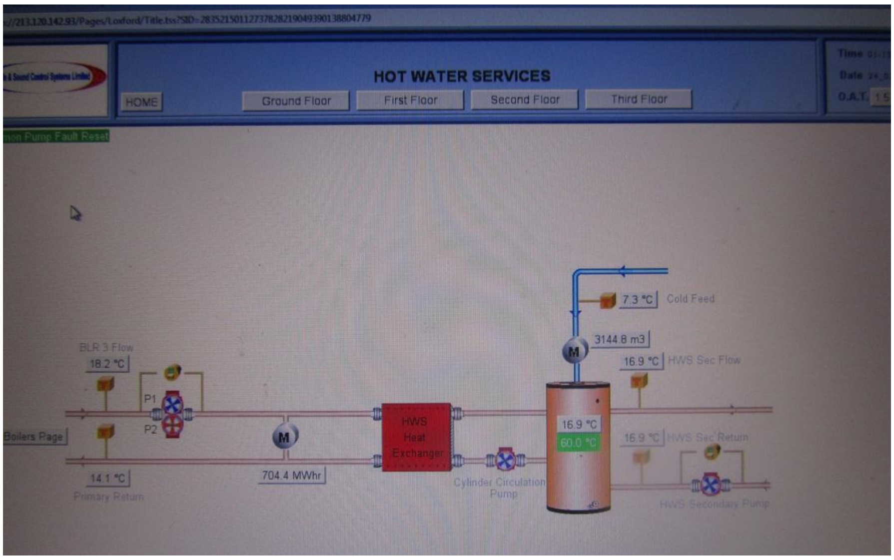


Figure 6.8: Out of hours operation of pumps: The blue colour indicates pumps are running. All hot water pumps in operation (Sunday 24/02/2013, 01:04 am).

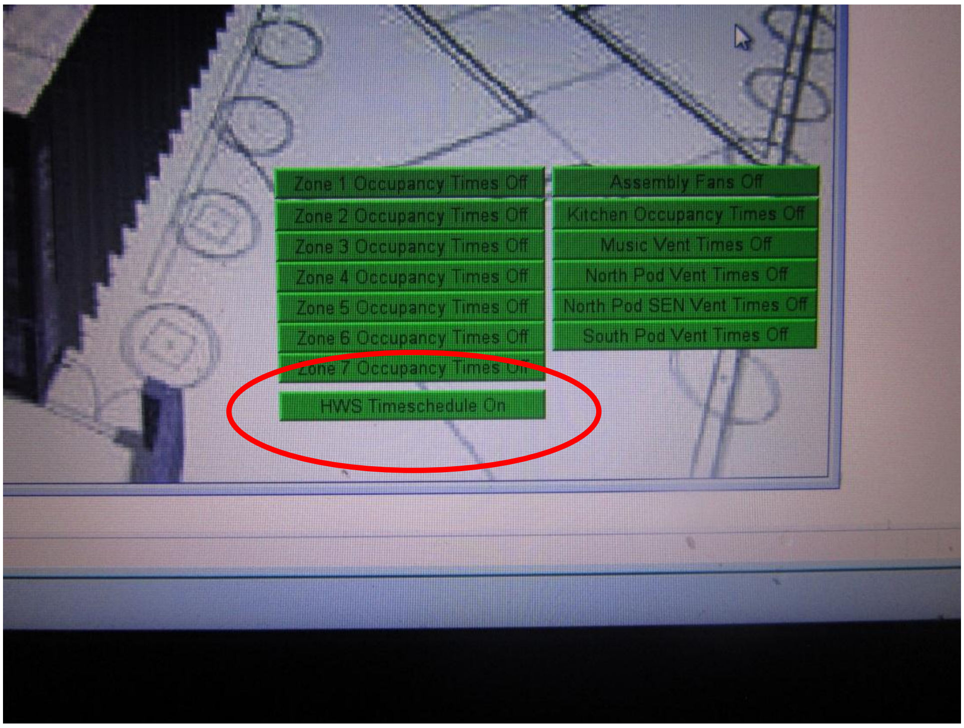


Figure 6.9: All time schedules are OFF except HWS that triggers the out-of-hours operation of pumps (Sunday 24/02/2013, 01:03 am)

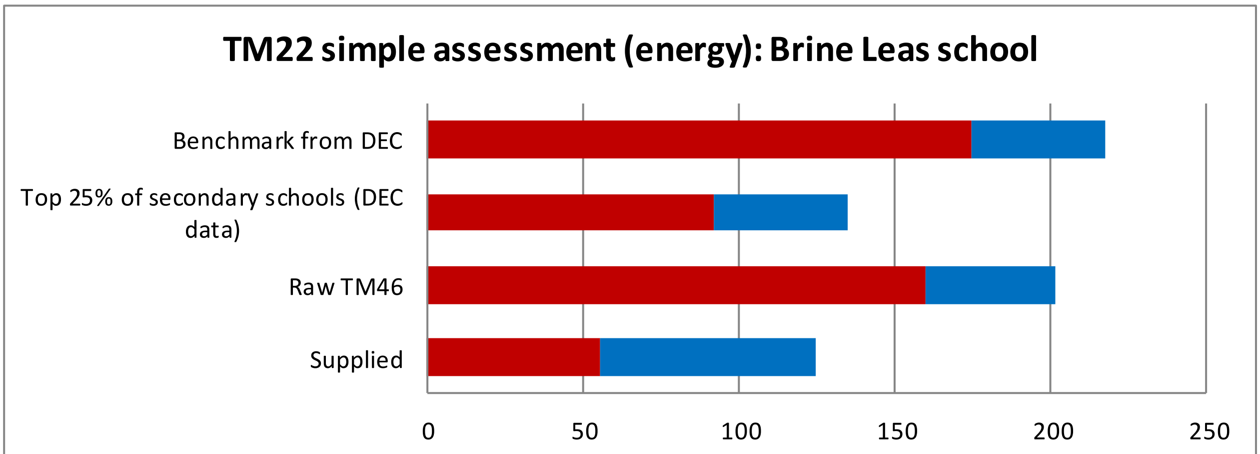
6.2. Brine Leas Sixth Form

The metering strategy designed for Brine Leas School could have provided good quality data for TM22 assessment. However, a number of meters on the LV panel were faulty from the start of the study and could not be used, notably one of the plant room sub-meters was not in use (Figure 6.10).

Figure 6.10: Examples of faulty sub-meters in Brine Leas School: Section 7 Plant Room DB (left) and Section 14 Lift (right)

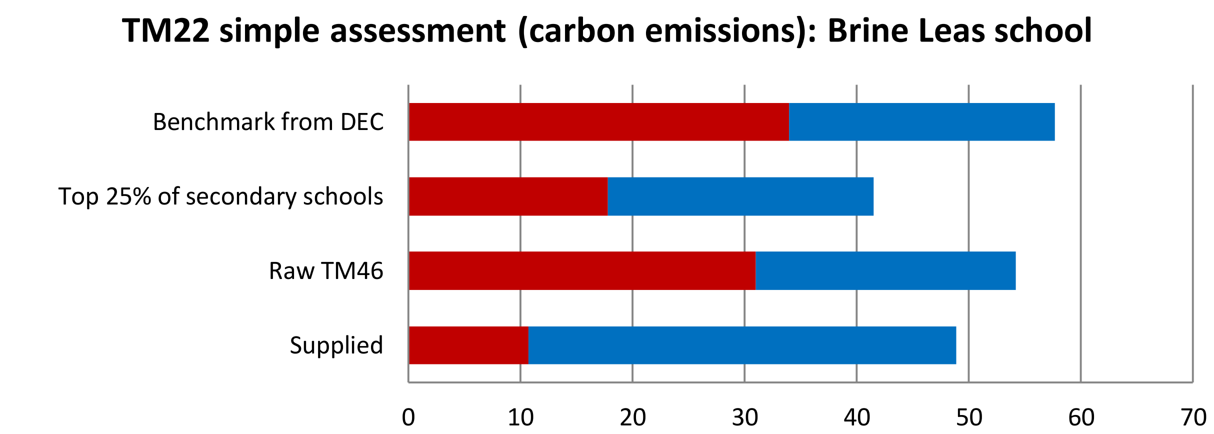
Good quality data was available for lighting, power, and catering facilities. A bottom up approach was used to reconcile end-uses with the metered data.

The following Figures provide the outcomes of TM22 simple analysis.



	Supplied	Raw TM46	Top 25% of secondary schools (DEC data)	Benchmark from DEC
Fuel/thermal (kWh/m²/annum)	55.2	159.8	92	175
Electricity (kWh/m²/annum)	69.4	42.2	43	43

Figure 6.11: TM22 simple assessment for Brine Leas School: energy supplied



	Supplied	Raw TM46	Top 25% of secondary schools	Benchmark from DEC
Fuel/thermal (kg CO_2/m^2/annum)	10.7	31	17.8	34
Electricity (kg CO_2/m^2/annum)	38.2	23.2	23.7	23.7

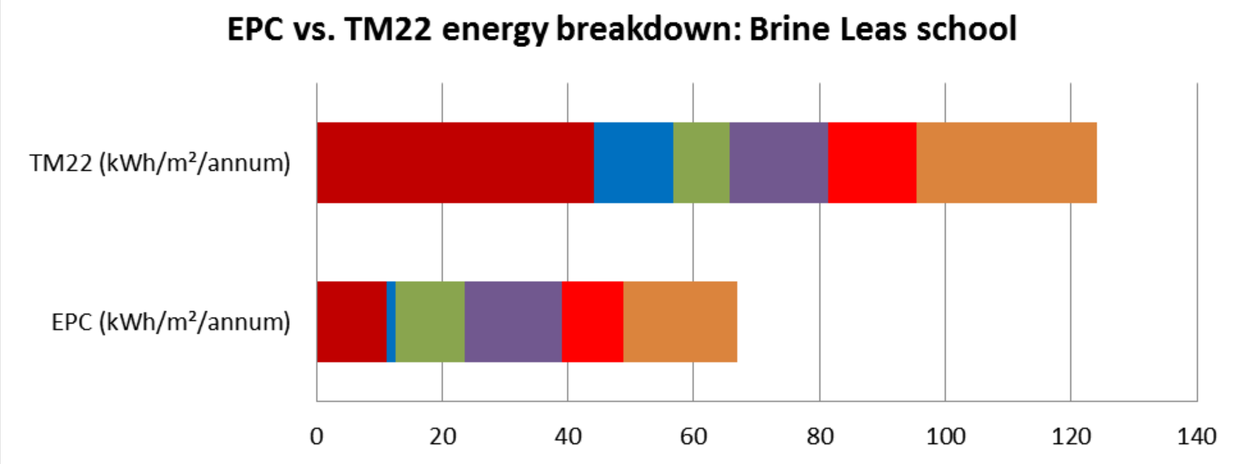
Figure 6.12: TM22 simple assessment for Brine Leas School: carbon emissions

These graphs show that the School's gas consumption is considerably lower than all benchmarks whereas the electricity is higher. The School total performance is better than DEC/TM46 benchmark when the CO_2 metric is used. However, it falls short of the Top 25% of secondary schools. The building does not have a Display Energy Certificate but the estimated DEC is D rated. The end-uses reported in Table 6.2 were reconciled with the mains electricity in the TM22 detailed analysis.

System	Fuel/Thermal demand (kWh/m^2/year)	Electricity (kWh/m^2/year)
Space Heating	41.1	3.1
Hot water	14.2	0.0
Refrigeration	0.0	12.5
Fans	0.0	2.6
Pumps	0.0	4.5
Controls	0.0	1.8
Lighting (Internal)	0.0	15.7
Lighting (External)	0.0	1.3
Small Power	0.0	6.8
ICT Equipment	0.0	13.6
Catering - Central	0.0	6.8
Total	**55.2**	**69.1**

Table6. 2: TM22 energy assessment for Brine Leas: detailed analysis

The EPC produced for the School following the completion of the building is B rated. Figure 6.13 compares the outcomes of In-use TM22 assessment with EPC results.



	EPC (kWh/m²/annum)	TM22 (kWh/m²/annum)
Heating	11.2	44.2
Cooling	1.5	12.5
Auxiliary	10.9	8.9
Lighting	15.4	15.7
DHW	9.9	14.2
Non-regulated end-use	18	28.5

Figure 6.13: EPC vs. In-use TM22 energy analysis for Brine Leas School[4]

The School performs significantly worse than EPC estimations in the following end-uses:

Heating:

The heating consumption of the building is lower than TM46 and the Top 25% of secondary schools. The stair cores and circulation areas located at both ends of the building are not directly heated. The main heating terminal in the majority of internal spaces is radiant panels. Where comfort cooling is provided, to office and ICT enhanced classrooms, heating is also provided by variable refrigerant flow (VRF) system. The school runs a night school on Tuesdays and Thursdays that extends the heating profile from 17:00 to 20:30 on those days. There are also some weekend drama and ICT classes that constitute further heating consumption. However, consumption of this building is lowest in the sample of educational buildings Aedas research team have investigated. In fact, the feedback from building occupants reveal some people are not entirely satisfied with heating and feel cold in winter. Temperature gradient between unconditioned common areas and classrooms along with radiant heat transfer mechanism may have contributed to this. Apart from a mal-functioning VT valve that led to unexpected operation of the system in Winter 2012 and was subsequently fixed, the only issue the research team came across related to heating was that the low temperature hot water loop flow temperature always seemed to be in excess of 80 °C even under moderate outdoor temperatures. Consequently, the condensing boilers installed were operating in non-condensing

[4] Auxiliary energy includes fans, pumps and control. Individual components of auxiliary energy have been listed in Table 6.2.

mode at a lower efficiency than what was anticipated in Building Regulation compliance calculations. High flow temperatures might have been triggered by constant temperature hot water loop or excessive demand of the radiant panels next to atrium operable vents. Based on the efficiency quoted for 80 °C flow – 60 °C return operation by the boiler manufacturer, the non-condensing mode of operation brings actual efficiency 5.6% lower than the level used in Building Regulation compliance calculations (87.4% vs. 93%).

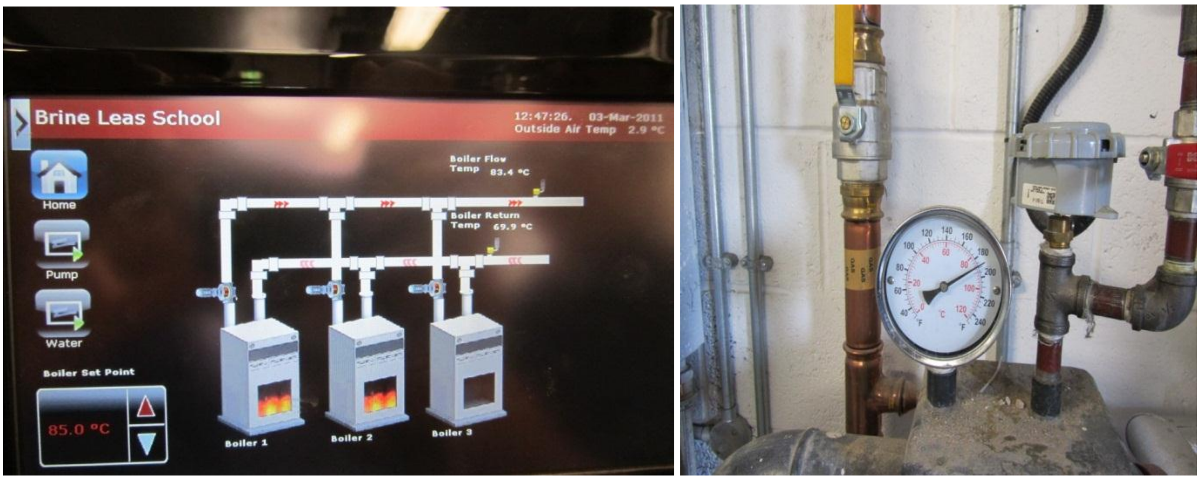


Figure 6.14: LTHW flow temperature of 85 °C (03/03/2011, 12:47)

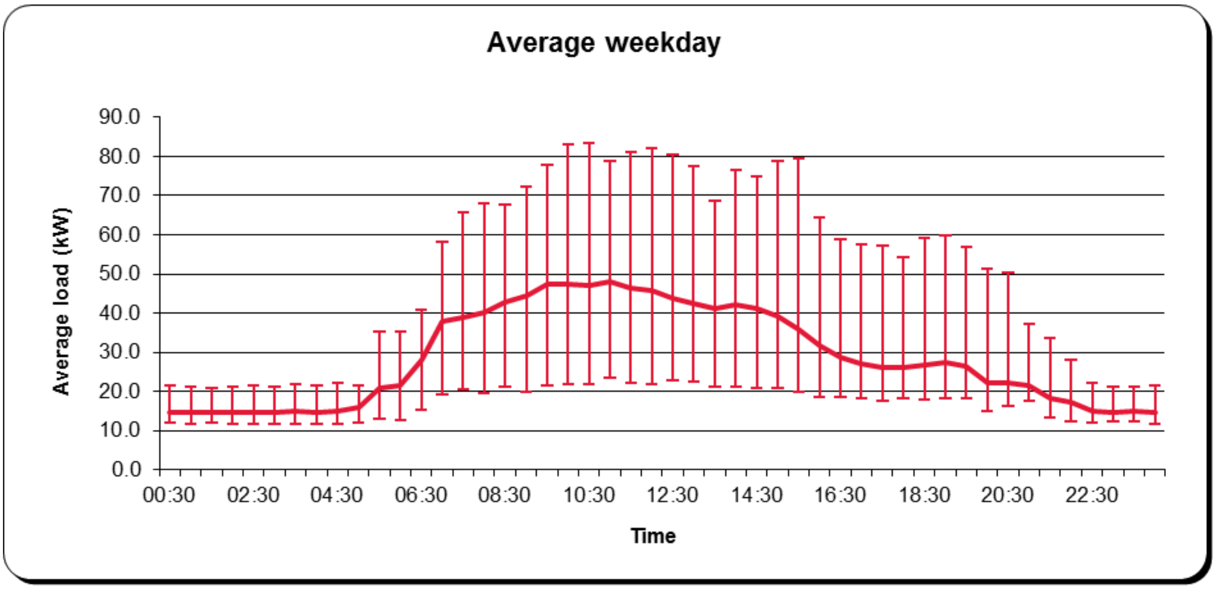


Figure 6.15: Average annual electrical power demand for Brine Leas School over weekday (kW). The graph reflects out of hours building's operation related to the night school.

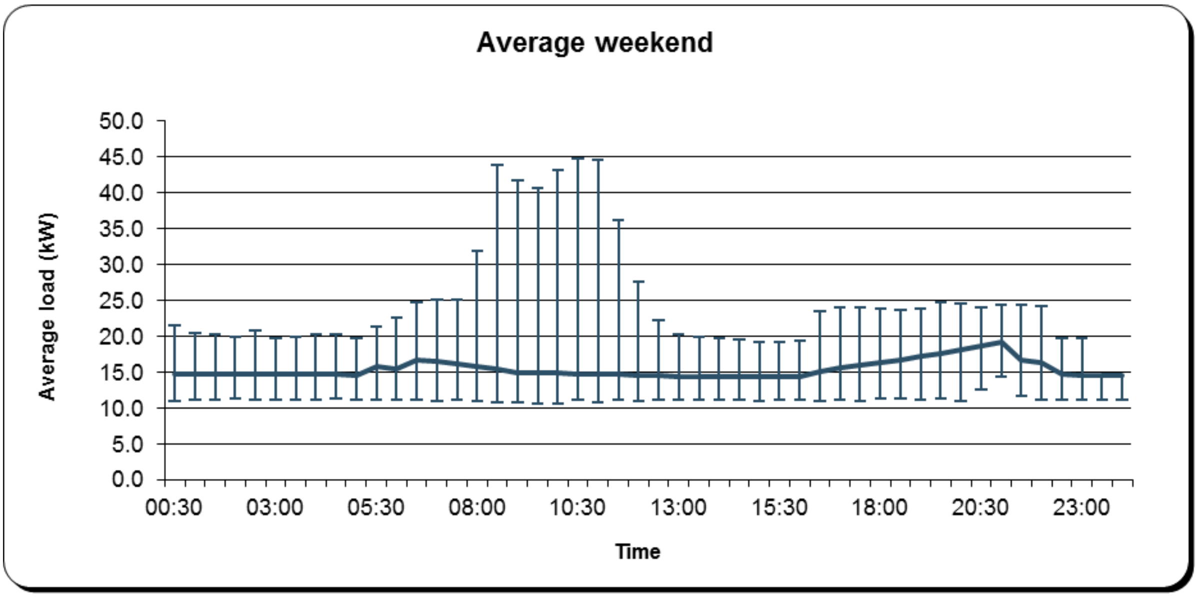


Figure 6.16: Average annual electrical power demand for Brine Leas School over weekend (kW). The graph reflects the occasional use of the building over weekends (9:00-12:00).

Cooling:

The total installed cooling capacity for server rooms, offices, and ICT enhanced spaces is around 80 kW. The Building Regulations and energy performance calculations are based on default IT loads and do not necessarily reflect the cooling demand of server room and ICT enhanced spaces. The TM22 reconciliation exercise and site visits reveal that the building's cooling demand is higher than what was anticipated in EPC calculations with outdoor DX units in operation even in winter to combat the heat gain of offices and ICT classrooms.

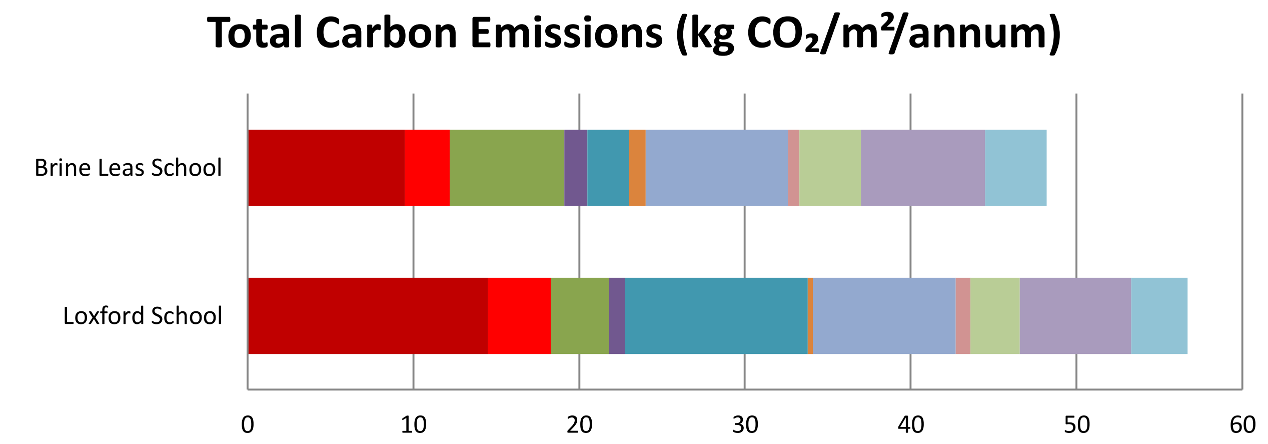
6.3. Conclusions and key findings for this section

Figure 6.17 compares the total carbon emissions of the two schools investigated in this study. The following conclusions could be drawn:

- Heating energy consumption of both schools was lower than benchmarks or on par with top 25% of secondary schools. This is consistent with the low U values and air permeability prescribed by the Building Regulations 2006. However, heating consumption of both buildings was significantly higher than Building Regulations and energy performance calculations. Unwanted out of hours plant operation in Loxford and night school and weekend operation in Brine Leas along with higher than expected LTHW flow temperature that lead to inefficiencies could explain part of this discrepancy. In the case of Loxford School, operable vents stuck open and courtyard exit doors left wide open are causing excessive heat loss. The same problem exists in Brine Leas where the operation of the atrium motorised vents next to radiant panels in winter causes heat loss and excessive heating consumption.
- It is also evident from the Building Regulations BRUKL Reports that there is a major difference in terms of heat loss between the two buildings due to some differences in U values and, more importantly, the extent of exposed surface area. Brine Leas School has a

much more compact form with the total heat loss factor of 0.17 W/m²°K vs 0.51 W/m²°K for Loxford School. This is to some extent reflected in the heating consumption figures although there is much potential for Loxford School to reduce its heating bills.

- Thermal bridges at junctions were treated differently prior to Building Regulations 2010, which may have also contributed to an underestimation of heating loads. However, without a post-occupancy thermal simulation, which was outside the scope of this project, it would be difficult to establish the root causes of the discrepancy between the Building Regulations calculations and the actual energy performance. The evidence presented here, along with other investigations carried out by Aedas R&D on academies, reveal that heating energy is often underestimated in design calculations.
- As explained under section 6.1, actual cooling energy consumption is also often higher than compliance calculations mainly due to the use of default IT loads in these calculations.
- Loxford School is predominately a naturally ventilated building with some mechanical ventilation provided to core spaces. The sub-metered data and TM22 assessment indicate that the ventilation energy use is low and design intent is met. It is a good example of effective demand-controlled ventilation with fan absorbed powers as low as 12% of the ratings, confirmed by recorded fan frequencies. It is also a good example of taking advantage of the free cooling provided by the ground loop that has minimised the cooling consumption.
- There is evidence for out of hours use of pumps at Loxford School that led to a high baseline electrical power demand for the building. The 24/7 profile set for the domestic hot water system, and faulty lighting sensors leading to out of hours use of chilled beams contribute to this problem (chilled beams are activated by PIR sensors).
- Brine Leas School is mechanically ventilated but its energy performance is better than Loxford thanks to effective demand-controlled ventilation and smooth plant operation.
- Even where actual consumption is on par with EPC calculations, there is sometimes scope for further improvement. For example, lighting consumption is close to the EPC calculations in both schools. Nonetheless, a number of opportunities for further reductions have been identified for each building as discussed in the Technical Issues section.
- It should also be noted that the buildings are not of the same scale. Brine Leas is a rather small Sixth Form built next to an existing school. Building occupancy is often less than the nominal level. Extra-curricular activities during half-term breaks and school holidays are minimal. Importantly, the school head has a background in construction with good technical knowledge about building services. All these contribute to the relatively good energy performance of Brine Leas School compared to Loxford School. If the operation schedules are optimised and unwanted out of hours use of the plant room is addressed, the energy performance of Loxford School could be substantially improved. The building's total energy consumption (expressed by CO_2 metric) is only slightly worse than DEC/TM46 figure and could be lowered by adopting simple measures.



	Loxford School	Brine Leas School
Space Heating	14.5	9.5
Hot water	3.8	2.7
Refrigeration	3.5	6.9
Fans	1	1.4
Pumps	11	2.5
Controls	0.3	1
Lighting (Internal)	8.6	8.6
Lighting (External)	0.9	0.7
Small Power	3	3.7
ICT Equipment	6.7	7.5
Catering - Central	3.4	3.7

Figure 6.17: Total Carbon Emissions for Loxford and Brine Leas Schools[5]

[5] Carbon emissions conversion factors used for gas and electricity are 0.19 and 0.55 kg CO2/kWh respectively.

The TM22 process was significantly more arduous at Loxford School, which is a large building with extensive equipment and a complex plant. Extensive discussions took place with the evaluator and TM22 creators relating to the limitations of the TM22 methodology. The end use data gleaned from the TM22 exercise was extremely useful to communicate issues to the client. However, time that could have been spent on client engagement was spent on counting appliances, a process whose uncertainties were inherently greater than compiling the same information form reconciled submeters.

Whilst the team appreciates that the 'counting' approach may sometimes reveal further problems, our recommendation is that TM22 in the future is carried out on a 'graduated response' basis. That means that the counting approach is only extended to end uses and building areas where submeter readings are considered unreliable or where these indicate energy consumption anomalies. A detailed summary of the issues raised were forwarded to CIBSE, which is attached in the Appendix 1 of this report.

It is also worth noting that TM22 does not offer any help with reconciling thermal energy use in buildings and that this is much more accurately done via thermal models. It begs the question that once a thermal model is created that matches a building's as-built properties why anyone would use the complex TM22 spreadsheet instead of profiling electrical loads in the thermal model, especially since the use profiles and load factors are much more accurate and interactive than in the excel based TM22.

The advantage of such a thermal model is that the benefits of potential energy saving measures can be demonstrated and an energy consumption 'baseline' relevant to the as-built and occupied building can be agreed between designers, facilities managers and end users. Such a baseline can be entered into the Log book – or uploaded to CarbonBuzz, where annual improvements can be easily logged once the baseline and energy collection routine has been established.

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. Loxford School

7.1.1. Ground Loop

Symptom: Out of action, high gas consumption

Cause: Complaints from occupants that building was too cold – it was later established that this is largely related to the atrium and external doors being left open. In response flow temperatures had been raised to 65degC in winter season, this deactivates the heat pump as they operate at lower water temperatures (45degC is recommended as the upper limit for efficient heat pump operation by MF). Heat pumps also found to be turned off at the mains switch.

Action: Heat pumps turned on, design heating profile reinstated with amendments illustrated below (graph scales and curve show ideal design settings, new figures in green show adjusted set points and temperatures). A separate link was created on the BMS main page to allow the school and FM to adjust these should this be necessary. MF suggested that a note could be added on this page to highlight the HP->boilers change over temperature set point.

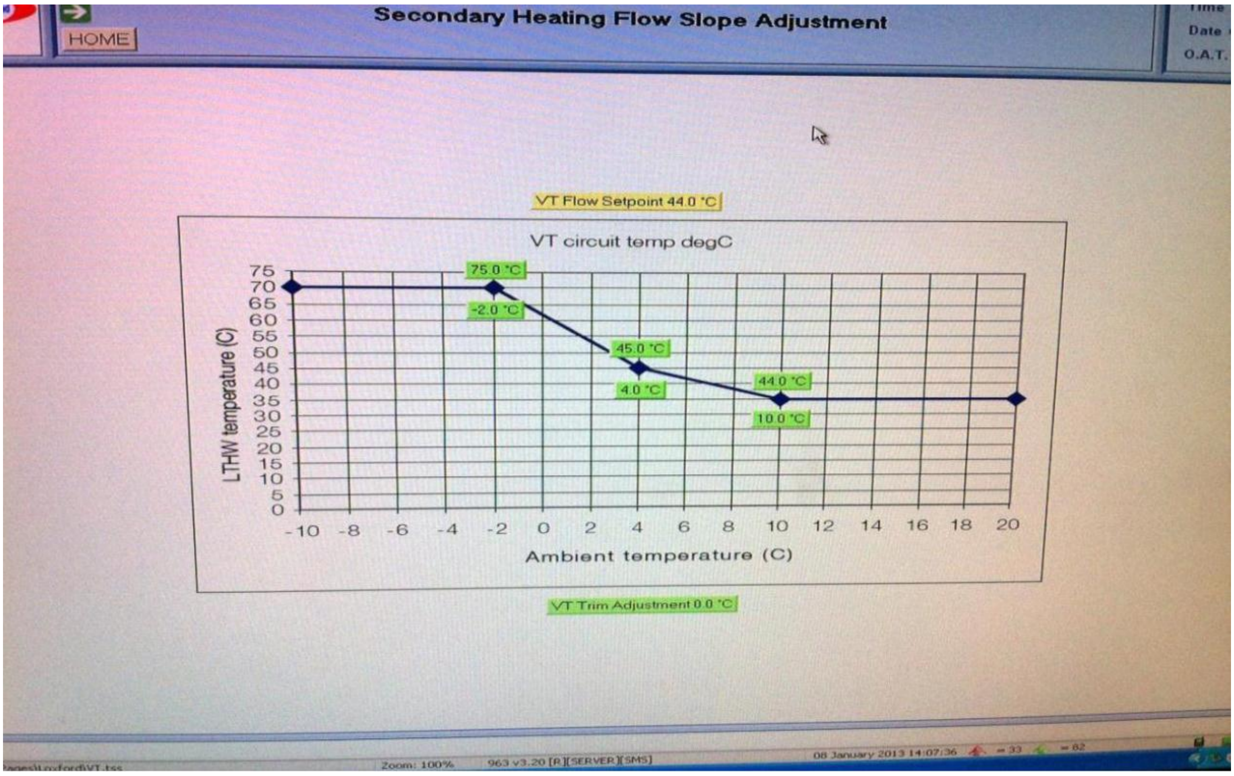


Figure 7.1: Graph from BMS illustrating link between ambient external temperatures and heat flow temperatures

7.1.2. Ground loop out of action even at lower flow temperatures

Symptom: VT Flow Setpoint is 44.9 °C that corresponds to above 4 °C outdoor temperature on the graph. Flow temperatures below 45 °C are consistent with GSHP normal operation.

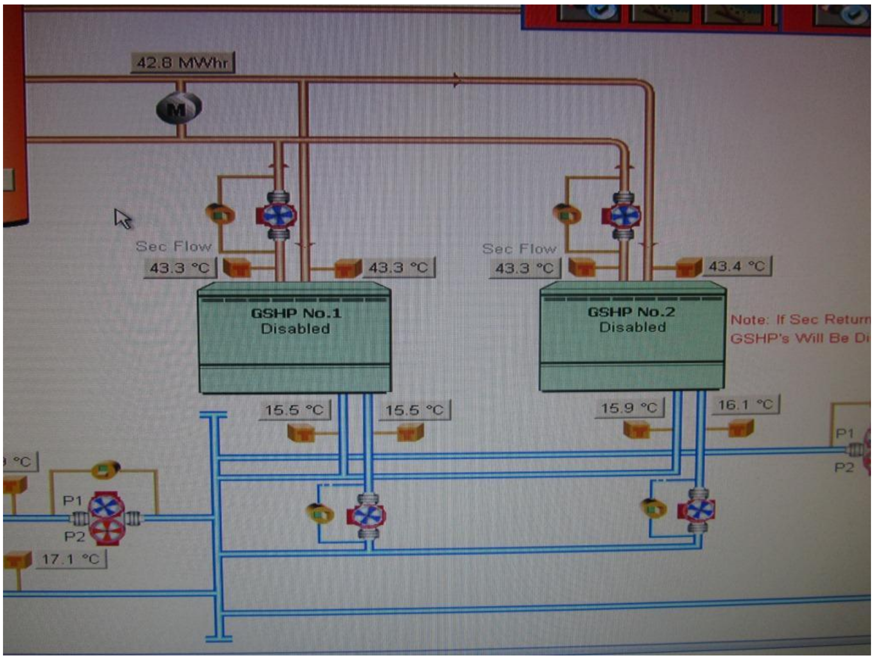


Figure 7.2: Both GSHP units are disabled and gas-fired boilers provide heating.

7.1.3. Main Circulation Doors at ground level

Symptom: These are found to be open during teaching hours in all seasons

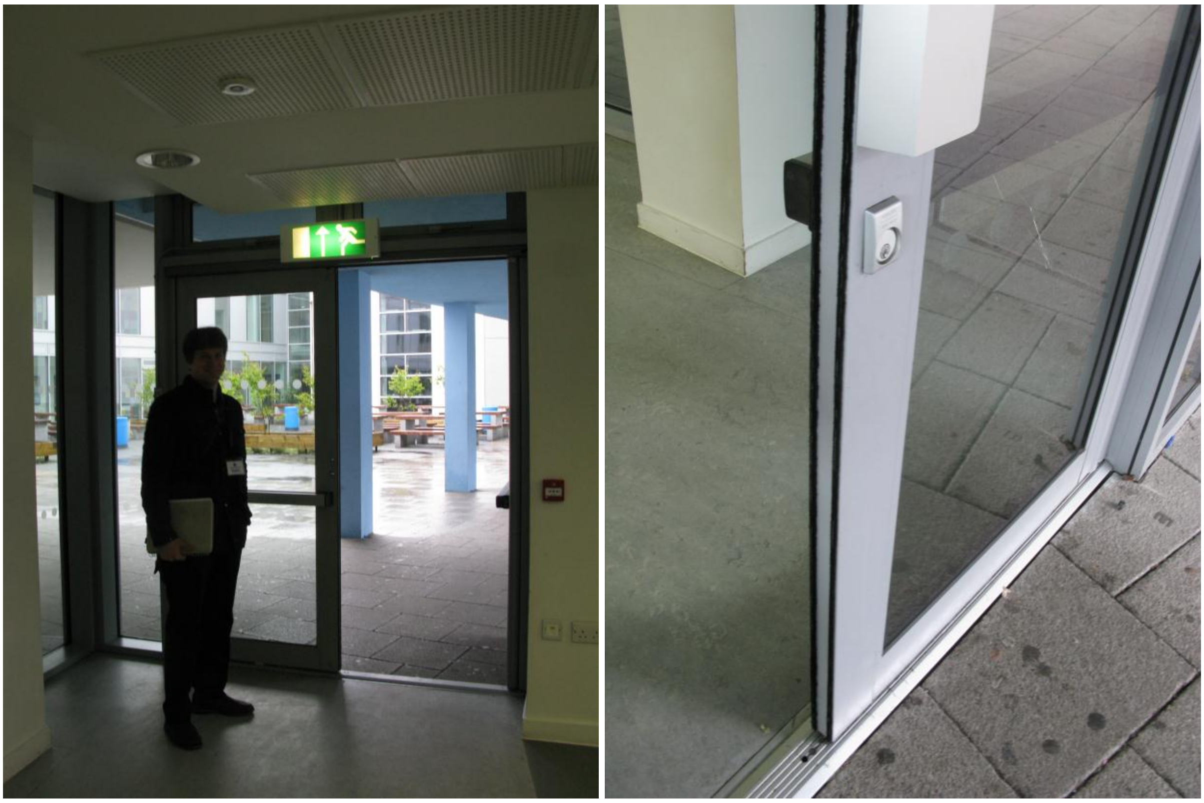


Figure 7.3: The architect of the building scrutinising the ground level circulation doors being open

Figure 7.4: Ground level circulation doors open at both corridor ends in winter

Cause: Caretakers and FM reported that these doors can only be opened using a key from the outside. As these are main circulation doors they are kept open at all times to allow students to pass from one corridor to the next and ensure that teachers can access these corridors from the outside should they need to. The school also found that the escape doors to the courtyard are also used bi-directionally. As a result there is a constant draft in the atrium throughout winter which is all the more uncomfortable as the enclosure around the lobby was value engineered. Heat demand from this zone necessitated the heat flow temperatures to be raised in the first place.

Action: Investigation by Aedas found that a simple no-cost fix was available, which allows the escape/circulation doors (DG025 and DG026), as well as the courtyard escape doors to be opened from the outside too.

Conversation with Adams Wright, the supplier of the ironmongery confirmed that the Concealed Vertical Rod Exit Device 960 series that could have been installed has a ‘dogging device’ which allows the latch to be retracted with a specialist Allen key during school opening hours (at a cost of £2.50 from this supplier or similar). Overnight, the caretakers can release the latch using the Allen key, which will lock the doors from the outside while still leave them operable from the inside via the panic bar. This will allow users to use the doors for entry as well as exit without them having to be left open.

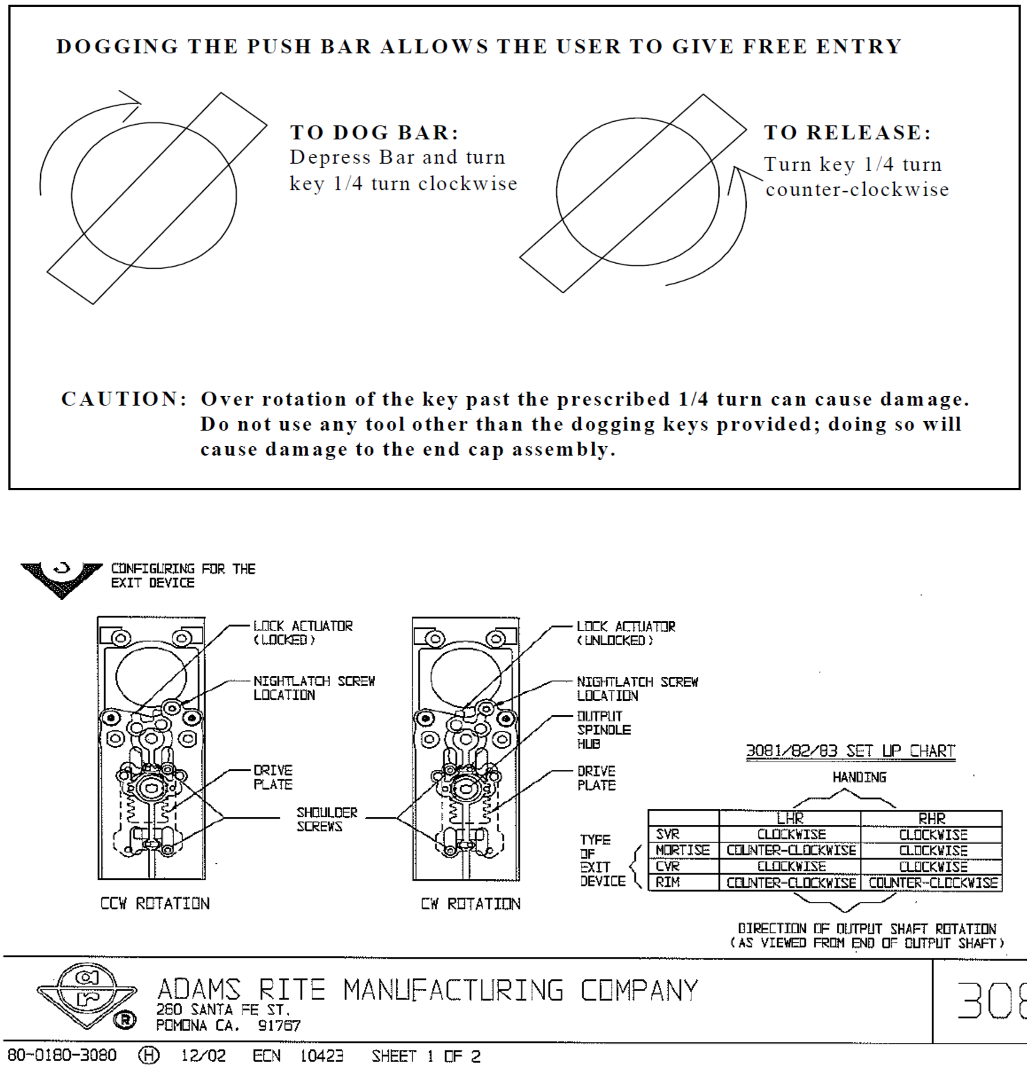


Figure 7.5: Operation of dogging device - diagram from Adams Write manual sent to Aedas by request

7.1.4. Door seals at ground level

Symptom: A walkaround early into the second year of the monitoring by the architects highlighted problems with ground level doors. Several courtyard doors were leaking, not closing properly and brushes were seen to be damaged or peeling off.

Figure 7.6: Inadequate door seals at ground level

Cause: As highlighted by Hydro, the curtain wall supplier, doors have not been 're-hung' after the first year of operation. It is not clear whether a dispute between the school and WD caused this or whether this was not in Solaglass' contract in the first place.

Action: Aedas recommended that Solaglass were asked to return to rehang the doors and provide some training to the school and demonstrate correct operation. Following a discussion with Aedas, the curtain wall supplier Hydro kindly offered to help train school staff. The visit by Hydro took place on 12th February 2013.

7.1.5. Zoning

Symptom: Radiators observed to be on outside the scheduled hours in a particular zone during site visits. Heating zoning not clear from BMS and lack of effective building manual means that the school and FM are uncertain about the impact of out of hours timer settings for different zones. Upon checking by S&S, BMS indicates 7 building zones – which can be heated independently.

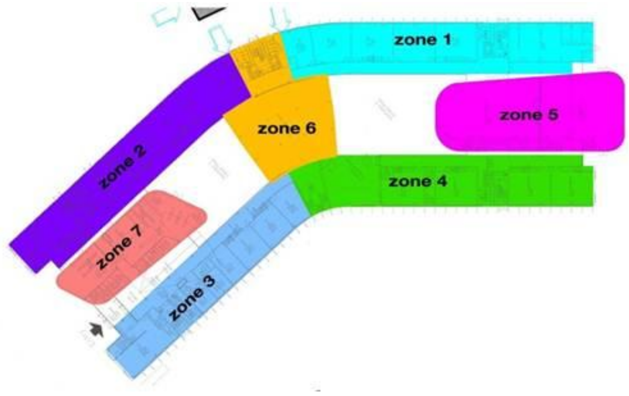


Figure 7.7: Heating zones for Loxford School

Cause: suspected BMS programming issue

MF comment: MF can re-issue the original zoning diagrams to clarify the design intent. Heat supply to zones is scheduled via BMS. Heating demand is reduced when zones are in off-mode as hot water circulation to these zones is physically off which means that there is less water for the system to heat. At the end of the heating season, during mild/warm weather, the boilers will still be used to heat up domestic hot water in the plantroom, but will not circulate hot water in the building (i.e. the space heating hot water circulators will be off and the radiators should not feel warm).

During the heating season, the heating will be off outside occupied hours (subject to frost/building low temperature protection routines). There is a need to warm-up the building to a comfortable temperature ready for start for occupation. This warm-up is normally achieved by starting the heating system in advance of the start of the occupation period. MF suggest that to maximise the efficiency of the system, this warm up will ideally be done on flow temperatures compatible with the heat pumps (max 45C).– i.e. the building would be pre-heated with heat pumps as the lead source. This will require a separate LTHW temperature curve to be set up for use outside occupied hours and linked to the time schedules.

Action: Aedas recommended that Safe and Sound were asked to review timings for zones with school, which took place on 8th January 2013. A discussion between Willmott Dixon and Max Fordham's design engineer took place to refresh WD information regarding design intent zones and warm-up strategy. However, during the intensive monitoring week that took place in February 2013, the monitoring team found that radiators were on in several zones that were scheduled to be off. Aedas recommended that the school invited S&S back to verify that the zoning and related schedules were fully functional. During the last conversation with S&S, they did not think that they would be able to return to the building without further payment.

7.1.6. Temperature control in classrooms

Symptom: It appears that thermostats have no gauges and feedback from school is that teachers only use these as an on/off switch as a result. Consequently, classrooms often overheat. Thermostats are also often left on.

Figure 7.8: Classroom thermostat and location – diagram extracted from Max Fordham presentation to school

MF comment: The thermostats have gauges from 1-5 and are able to increase or decrease the amount of heat provided to the classroom similarly to a TRV on domestic radiators.

<u>Action</u>: Thermostats are frequently left on in classrooms – if the zoning and schedules do not shut off heating as expected, excessive heat consumption occurs. Aedas checked that the thermostats do vary the heat supply to the radiators.

7.1.7. Plenum flaps, rooflight and atrium damper controls

<u>Symptom:</u> Rooflights and plenum flaps are open during winter. Feedback from occupants is that corridors are cold in the winter and rooms and atrium overheat in the summer. Atrium dampers perceived shut on hot summer days. Night purge not working.

Figure 7.9: Winter and summer snapshot of West Wing and Classroom Pod showing 30% and 100% open plenum flaps respectively.

Cause: During S&S's visit in January 2013, the programmers pointed out that plenum flaps, rooflights and dampers are not activated by temperature, only by CO2 levels. These are set as constant with the only difference between summer and winter being that in the winter season opening % is only 30%. This is still causing heat loss to the corridors (and potentially the atrium) but doesn't improve CO2 levels unless windows are opened, in which case the heat loss is too high. In the summer, flaps only open when CO2 levels rise but temperatures rise quicker than CO2 levels. CO2 triggers also mean that night purge strategy is not working as dampers would not open at night when the classrooms are unoccupied and therefore have low CO2 levels. These would explain complaints around summer overheating.

MF: MF propose to limit the opening of the flaps (closed/cracked open) during the winter to reduce unnecessary heat loss if flaps only controlled on CO2. Single sided ventilation (by manual opening of the windows) should still be effective to maintain good air quality (open high level windows first to reduce draughts and promote better air distribution/mixing). The amount of air flow required to maintain CO2 levels in the classrooms is much lower than what is required to control the internal temperature in the summer. The main purpose of the cross ventilators is to help achieve these higher flow rates in combination with the manual opening of the windows on the façade by the user. In the summer, the flaps are to be controlled on temperature and CO_2 readings whichever gives a higher demand.

In the summer, the atrium dampers are to be activated by temperature and CO2 of adjacent classrooms and temperature of the atrium, whichever gives a higher demand. Given the feedback from the school, in the winter the atrium dampers should remain shut; this will reduce downdraughts and heat loss. If adjacent classrooms are rarely used in the summer then the BMS should still open the dampers for ventilation in response to readings of the temperature in the atrium. This strategy applies to both sides of the building, north and south pods.

During the heating season, the users need to open their windows to control CO2 levels (open high level windows first to reduce draughts and promote better air distribution/mixing).

Actions: Override button set up for atrium louvres on BMS, to be accessed via the front page.
Adjust BMS ventilation controls, monitor for any problems around discomfort. Check if pigeons are still a problem with flaps and cost of coarse bird mesh. Recommendation is that the school schedules S&S to return to set up the temperature controls asap so that the building loses less heat in the winter and night purge is restored to reduce summertime overheating

7.1.8. Plenum flap actuators

Symptom: Some flaps are continuously stuck open resulting in heat loss to corridors and class rooms. At the start of the monitoring, the team received reports that pigeons moved into the West side plenum where the faulty flaps were.

Figure 7.10: Plenum flaps stuck open

Cause: The actuators specified by the architects, initially envisaged to be by the same manufacturers as the plenum flaps, have been replaced by a cheaper alternative from a different manufacturer. The subsequent problems were due to inadequate motor power as well as the poor alignment of the new actuators.

Action: Aedas recommended the replacement of faulty actuators. It is not clear if any of the actuators were replaced but when the monitoring started some flaps were still faulty and pigeon mesh was installed to cover these openings. During the monitoring, these actuators were not fixed.

7.1.9. Specific Fan Power

Symptom: This was observed to be too high during the first year of monitoring. The M&E designers confirmed the as-installed total SFP (excluding catering) as 1.96 W/L/s. This is 40% higher than what was used in the Building Regulations compliance report.

Cause: Feedback from S&S indicates that 3 of fans were running at almost double speeds but were changed in August 2012. Cause is unknown.

Action: School to follow up with FM that SFP is set back to 1.4 W/L/s if possible.

7.1.10. Frost Coil in AHU

Symptom: The frost coils observed to be in use in AHUs when outside temperatures are in excess of 6-7 ° C; therefore, the heating top-up valve is being used to heat incoming air. With this set up, the heat exchangers are less effective (heat exchanger does not take priority over heating system). The image below shows that the temperature setpoint off the frost coil is 16.0 °C. This means that the majority of AHU heating is provided by the frost coil before taking advantage of heat recovery; this is questionable. A more reasonable and lower temperature setpoint off the frost coil will result in more effective use of heat recovery with the remaining heat provided by the heating coil down-stream the heat recovery unit.

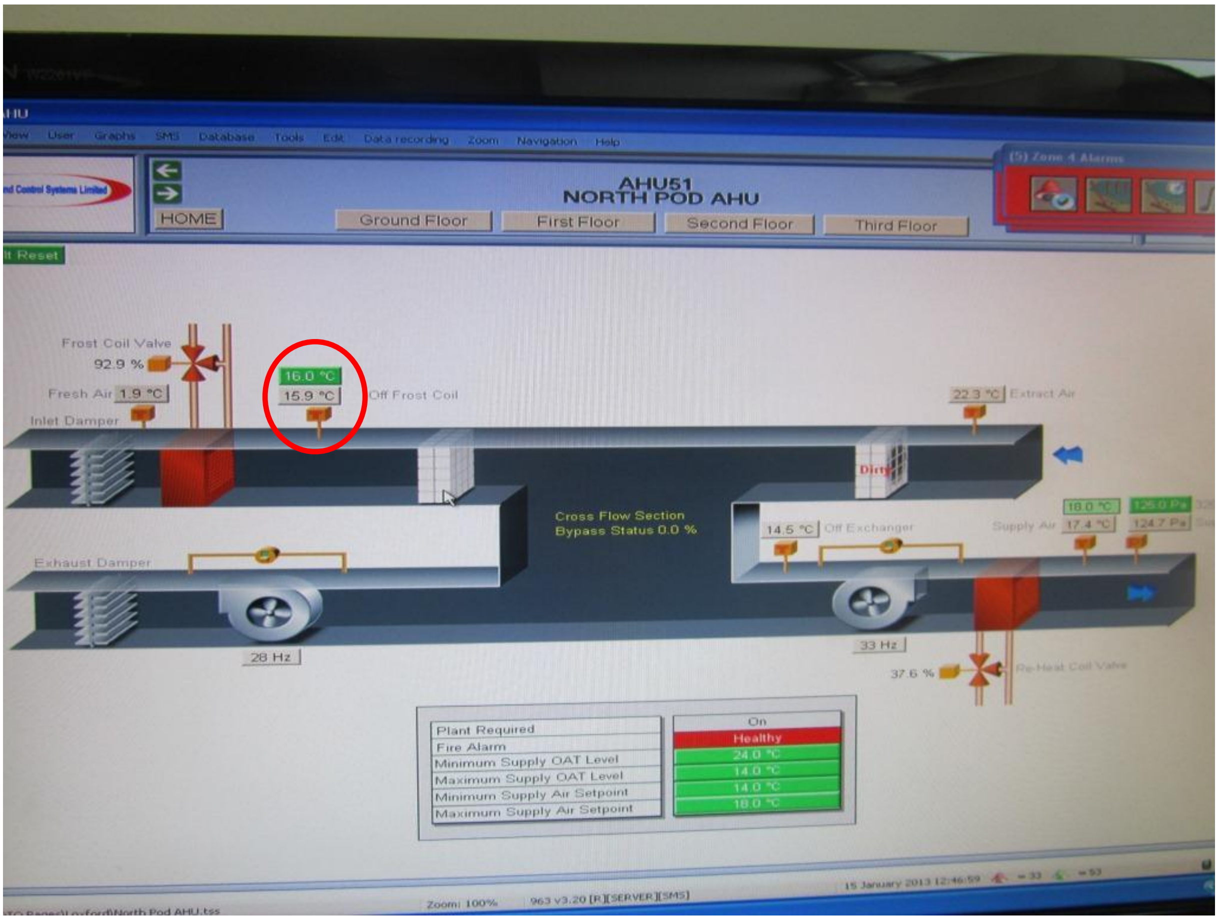


Figure 7.11: Temperature setpoint off the frost coil is 16 °C. This compromises the heat recovery strategy.

Possible cause:
Frost coil set point settings not activated/optimised.

MF comment: Frost coils are normally active at ambient temperatures below 3degC.

Action: Aedas recommended that the school checks temperature sensors via BMS before and after frost coils and heat exchangers when external temperatures are above 3degC degrees. Due to exceptionally cold winter weather this was not possible to verify during the intensive one-week technical study.

7.1.11. Meters

Symptom: Early on in the project heat meters were highlighted to show different figures from BMS, but these were subsequently fixed. However, there is faulty flow meter for the boiler which needs changing. This costs approximately £800.

GSHP does not have electricity meter –annotated space for this is left on the LV panel but no meter is installed. Without this, it is not possible to directly establish how much the heat pump is contributing to the heating and whether it costs less than the boilers.

Figure 7.12: Heat pump electricity meters marked on LV panel but missing

Incoming cold water, electric and gas meters showing zero. Recently, some gas meters show non-zero figures but the mains meters do not appear on the BMS anymore.

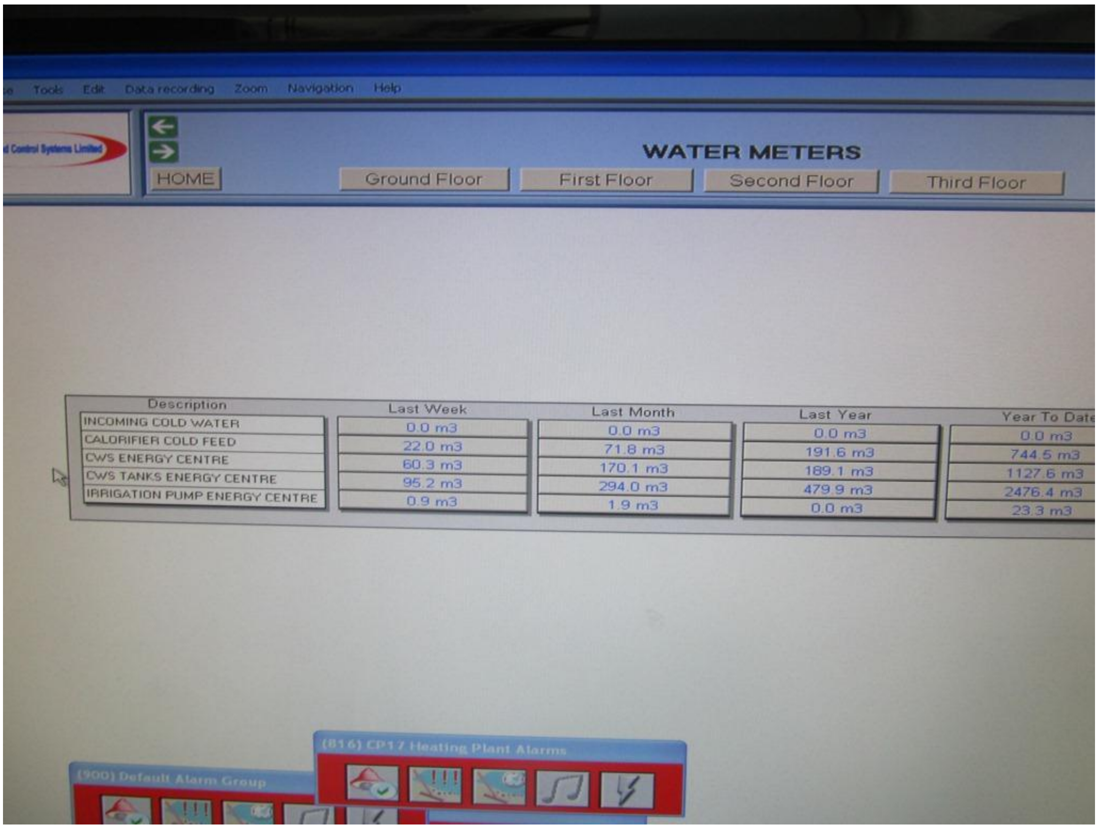


Figure 7.13: Incoming cold water: zero

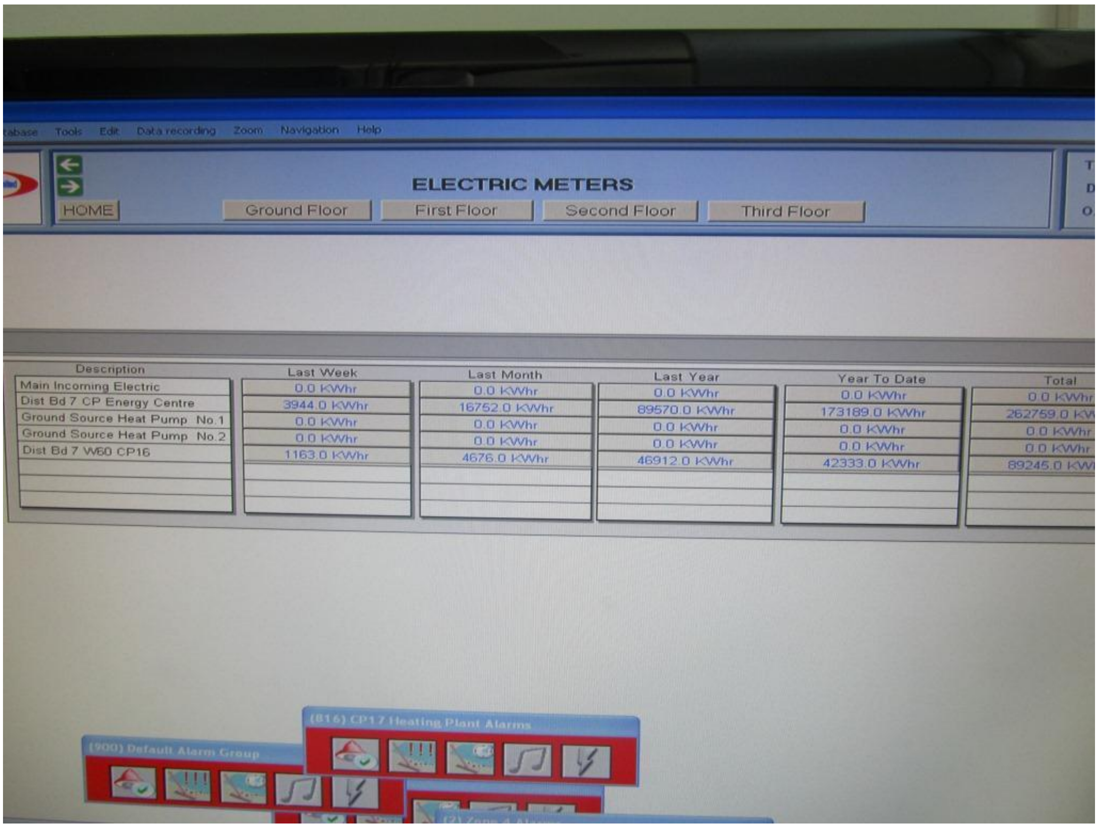


Figure 7.14: Main Incoming Electric: zero

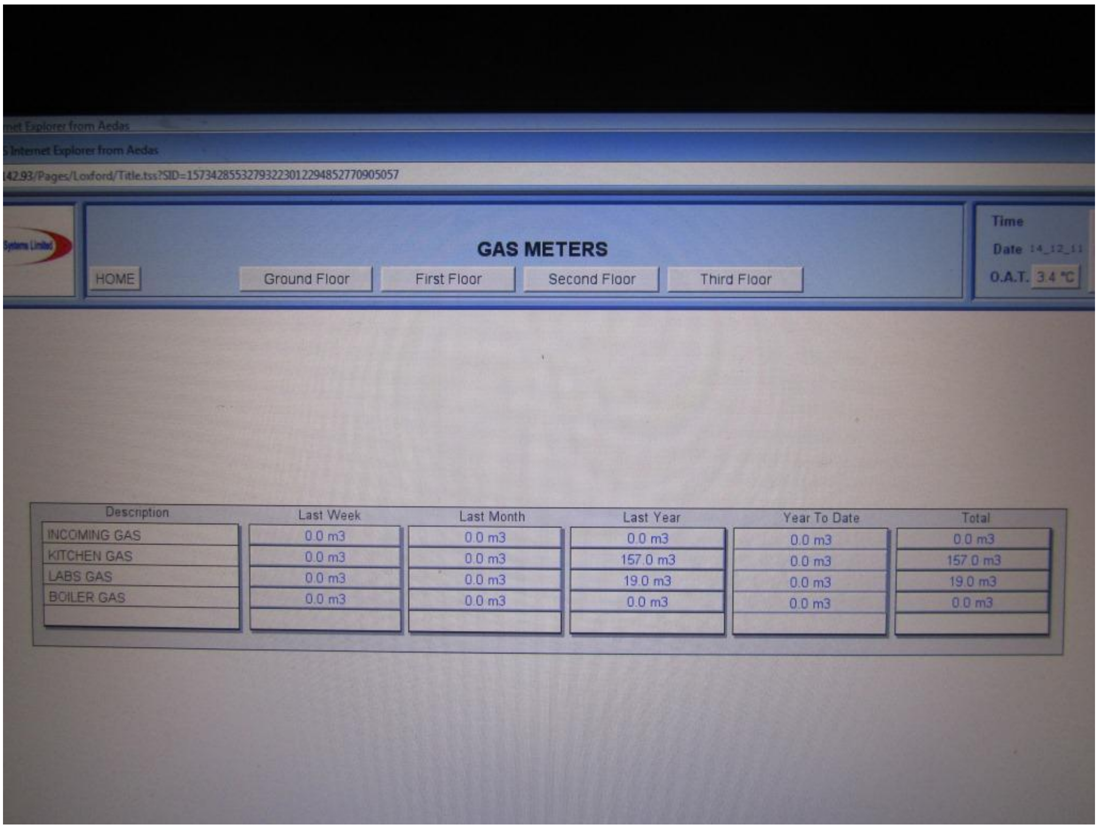


Figure 7.15: All gas meters: zero

<u>Cause:</u> Faulty and missing meters not spotted during defects liability period

<u>Action</u>: School to agree with Halsion to install these.

7.1.12. BMS logs

<u>Symptom</u>: The school and its FM were unable to set up logs for different building areas to diagnose any issues. Remote login details were shared with S&S.

<u>Cause</u>: Limited and unintuitive BMS interface, lack of training and continuity, lack of energy performance targets and monitoring in FM scope. Little overall awareness of the scale of operating cost increases associated with poor building performance.

<u>Action</u>: Recommendation to school and WD that all future training should include this and highlight to end users the importance of including energy targets and monitoring in the FM scope.

7.1.13. Lighting

Symptom: All common area lighting is on the same generic zone, which means that if any of the zones are activated all the common area lights are on resulting in excessive energy consumption in a very well day-lit building.

Classroom perimeter dimming does not work in many classrooms

Cause: The school reported problems early on with common area lighting, particularly the inability to switch off common area lights. The then Deputy Head was the only person who understood the use of the remote lighting controller and it is not clear whether the lights were ever correctly zoned or whether the commissioning settings were overridden at some point. By the time the monitoring started, the lighting settings were in default mode and no documentation was found describing zoning and set points for daylight and PIR settings for sensors.

MF: Specification and building manual describes system that should be capable to achieve perimeter dimming and zoning of common areas on occupancy detection.

Action: Aedas has demonstrated through a conference call/workshop with Ex-Or at the school how the lights were intended to work on a small corridor segment on the second floor. It has been agreed that the school would ask Ex-Or to return and programme in the zoning, lighting level & PIR setpoints. Further discussion between Aedas and Ex-Or clarified that, beyond the defects liability period, Ex-Or charges £600/day to carry out any programming of the lighting system. Approximate savings have been identified as between £600-1200/yr based on installed light fittings and their current hours of use.

7.2. Brine Leas

7.2.1. Ventilation

Figure 7.16: Dirty air filter alarm

Symptom: Dirty air filters.
The main air handling unit was displaying dirty filter alarm for a large part of the study. Dirty air filters create large pressure drop across the filter, using more energy to push air through the system.

Cause: When questioned, the school had not taken out a maintenance contract for any of the plant as they were of the understanding that this was not necessary during defects liability period. They also reported that they were missing portion from the O&Ms that lists the contact information of the product installers. The following excerpt was found upon inspection of the Willmott Dixon section of the O&Ms:

Maintenance callout procedure at Brine Leas:
For maintenance/repairs during the 12 months defects liability period the following procedure should be followed:

- Initially consult this building manual or the Mechanical/Electrical manuals handed over during the handover process.
- If the manual cannot help, contact Willmott Dixon Construction Customer Care Manager to discuss the problem.

As previously mentioned, the mechanical and electrical information was missing from the O&Ms and staff at Brine Leas reported difficulties in communication with Willmott Dixon. This may have been affected by the additional difficulty that the owner – Cheshire East Council – is not the occupant of the building.

Action: the O&M section was recovered from Willmott Dixon and the academy has since signed a cyclical maintenance contract for this.

7.2.2. Lighting

Symptom: Circulation lighting in atrium on throughout the day

Cause: Circulation lighting is controlled using presence detectors without the use of daylight dimming. This results in circulation lighting remaining on throughout the day due to constant traffic in the corridors somewhere in the building. The lighting circuits are zoned floor-by-floor which precludes the option of using a manual override for lighting in the atrium. It seems that daylight dimming was the design intent as an excerpt from the logbook on the energy efficiency intention confirms;

… *'The lighting controls system installed incorporates daylight dimming which reduces lamp energy consumed and presence and absence detection has been installed to all transient spaces ensuring lighting is not in use when nobody is present…'*

Action: Due to the way the lights are circuited, there are no low cost solutions to the issue. Calculations for savings show a potential £700/yr saving if this had been properly zoned:

Recommendations for future projects:

- Detailed control specification and zoning to be produced at design stage
- Specification and zoning to be revisited at detailed design and installation in order to ensure bespoke, suitable strategy and control
- Include zoning, parameter set-up and remote controller training in the contract when commissioning the lighting installation and provide documentation with instructions that can be signed off at commissioning
- Ensure that (at least one) remote controller is issued with the kit upon handover

7.2.3. BMS

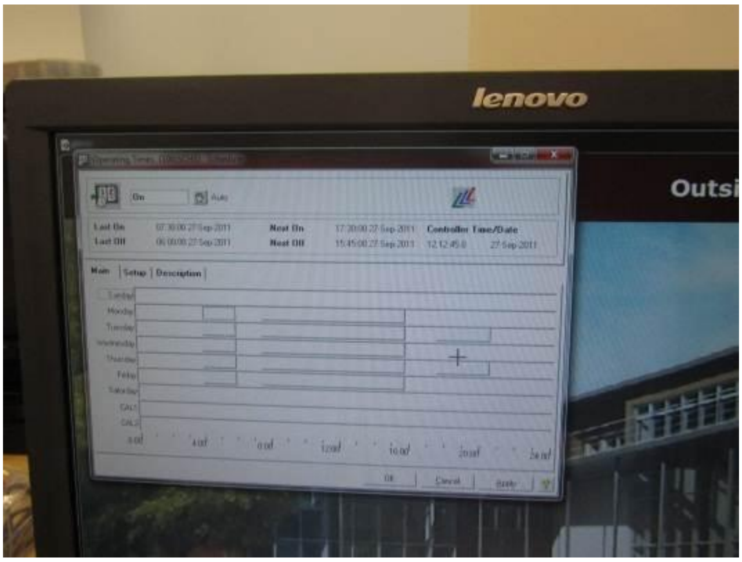


Figure 7.17: All systems on the same profile. There is no other available profile to facilitate more bespoke control.

Symptom: Interface is not suitable for optimal building management. Upon first interrogation of the BMS, some eccentricities were discovered:

- Mains gas does not appear to be linked.
- The boiler set point was 30 °C. It's unclear as to what this might be referring to; the flow temperature, return temperature or something else. This could be manually overridden but in Building Management's experience, it would reset overnight. Furthermore, we were shown that the boilers weren't communicating with the sensors and firing intelligently until the outside temperature was manually set to -5 °C.
- The mains water meter and the kitchen water sub-meter do not seem to correlate in terms of water consumption when viewing the day-by-day and weekly consumption screens.

Cause: The preferred system, 'Trend' was not installed. BMS interface was specified as 'Trend or similar' in the performance specification. The current Delta system does not provide the same functionality as a Trend system making it more difficult to interrogate from a building user perspective. In addition, there is no alarm facility to allow users to investigate issues.

Action: Take out a controls maintenance contract or commission a control specialist to tailor the interface to the school's needs and train the relevant staff members – always more than once to prevent knowledge gaps due to staff turnover or sickness.

7.2.4. Solar hot water panels

Symptom: Contribution not measurable

Cause:
At the initial kick-off meeting on site, it was confirmed that there was no sub-meter for the solar hot water panels. Communication with the contractor led us to believe that access to this information would be through the BMS interface, but there was no evidence of the contribution here either. It was later discovered that the solar hot water panels had not been properly commissioned.

Action:
The subcontractors visited the site at the end of August 2012 for re-commissioning. A re-commissioning report was received, when asked, dated October 17th 2012. This means that the solar hot water system was effectively not in use in the first two years of building's operation.

Recommendations:

- Ensure that all renewable technologies are specified with a sub-meter. Where these systems are sub-contracted, ensure that relevant sub-meters are cross-checked with, and included on main sub-metering drawings.
- Employ or appoint individual for the responsibility of checking all metering is in place, functioning and communicating with the relevant kit.
- Ensure the handover and commissioning portion of the programme does not get dropped under time constraints – this process is no less essential for the delivery of a sound building

7.2.5. Conclusions and key findings for this section

Early on in the project, the monitoring team set up a matrix format to document technical issues and related actions/recommendations. This made tracking and evaluating findings much easier across the five education buildings covered by two TSB projects. The majority of the problems could be traced back to systemic issues – the Design & build procurement route does not facilitate the coordination and design integration required for building occupiers to receive a building that is fully operational.

There is little awareness of how such systemic issues affect operational and maintenance costs and there is no incentive built into current procurement procedures to quantify and address these. In many cases the cost of prevention would have been nil or low in the context of a multi-million pound investment. At Loxford School, installing the thermal triggers for the automated vents would have added little in terms of work load at the time.

S&S's fees for the building commissioning were reportedly over a quarter of a million pounds without seasonal commissioning, which was not added to their scope of works. A verbal quotation put the missing commissioning costs at £10-£15K. However, seen in the context of a school's budget for maintenance, this figure is high even if the payback on such investment is only a few months. The cost of addressing the problems post-completion is also higher because a substantial number of person hours are needed to re-trace problems to their causes and re-mobilise the expertise required to fix these.

Given the design and build procurement route, neither the project managers EC Harris, nor Max Fordham were given the time and opportunity to check for such commissioning problems, especially as seasonal commissioning was omitted from the scope of S&S and MF.

The defects liability period is critical – but if contentious relationship arises it is not in either party's interest to take action. Schools reported that they 'can't wait' for the defects period to end so that they can go ahead and fix what they can themselves without further disputes and legal challenges.

Without energy consumption being of a higher priority it is easy to see how buildings with inherent technical faults would get sign-off from project managers who simply do not have the expertise to detect such detailed but critical problems. It is clear that by engaging further with commissioning and after-care, architects have a perfect opportunity to grow their role as 'integrators' – of fabric, space, technology and occupants.

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. The Challenge of Complexity

One of the most important conclusions of the studies is how important it is for well-trained facilities managers, well versed in the electronic control of school buildings, to represent end users' needs from the start of the project. The monitoring team sees a great opportunity for architects to increase their scope in design integration via the Soft Landings Programme. It is the traditional role of the architect to balance the complex factors of context, building fabric, technologies and occupants so that energy saving measures match the long term needs of occupants and investors.

System configurations that do not take into account end user expertise not only result in excessive energy costs but can affect the effectiveness of the day-to-day running of the school, staff productivity, well-being and absenteeism. The pursuit of energy consumption data from the early days of a building's operation exposes issues affecting long-term management and operation and ensures that these are addressed during the defects liability period. Finding such problems early on is as critical as the expertise required to deal with them. As seen in the case of both Loxford and Brine Leas Schools, once a contentious relationship arises it is not in either party's interest to take action during the defects period.

8.2. The Role of Performance Contracts

When undertaking a new building or refurbishment it is critical for end users to understand the complexity and maintenance requirements of the building systems. Most education end users will not have the skills in house to undertake this and need expert advice on how to procure such service externally. Putting in place a performance contract for managing these systems is the first logical step to take. However, there is currently NO pro-forma issued to schools for the procurement of facilities management services for building controls and management and Aedas R&D have been actively lobbying CIBSE as well as BSRIA to make such a document available to their respective members.

If reporting on energy performance is tied into the FM scope with embedded incentives to reduce consumption, it is much more likely for FM/BMS contractors to take an interest in optimising the BMS and collate data from the expensive submetering for diagnostic purposes. Having to meet energy use targets would encourage greater familiarity with aspects of the design specification that are related to energy performance and comfort. If end use energy data is not easy to extract from the BMS then it is the first sign that the building may not have been properly commissioned. Missing or poorly calibrated meters are only spotted if someone takes an interest in what they report, hence the importance of energy performance contracts forming the basis of maintenance.

In the case of Loxford School, the facilities managers employed by the school did not have contractual obligations to meet energy targets and, therefore, did not think it necessary to insist on the thermal profiles being programmed into the BMS to reduce winter heat losses.

A performance contract pro-forma should provide guidance to schools so that the scope agreed covers all energy performance related aspects of the building. At Loxford the maintenance of the GSHP is carried out by a different organisation from the BMS management. Consequently, it is not in the interest/power of the BMS contractor to integrate the GSHP into the school's operation.

8.3. Early Focus on Performance Data & the Significance of the Defects Period

In our experience, schools need help immediately after handover to recognise if systems are not adequately configured or if installed equipment is not in line with what was specified. Many of these issues only emerge if a dedicated person with good knowledge of the building and its design specifications is in charge of pursuing energy consumption data. Every effort should be made for members of the original design team to be involved in the training of facilities managers and the building's aftercare.

Greater design team involvement in reporting the first year's consumption data would mean greater scrutiny of metering strategies – so that these meet legislative requirements and future monitoring needs.

Energy performance data is considered obscure and highly technical. However, building up a CarbonBuzz style energy bar in the first three months of a school operation should not take more than half a day – when done for the first time. For subsequent updates this process can be largely automated. This type of representation of end uses makes it easy to start diagnosing problems and has helped the monitoring team communicate to the school management the scale of the problems encountered. Realistic energy performance baselines documented as part of the log book would greatly support this diagnostic process. In the absence of a building specific measured energy use prediction figure, better and more granular benchmarks would help schools understand what savings can be achieved.

Installing submeters is costly but is potentially a hugely valuable investment allowing end users to benchmark their energy costs and carry out building diagnostics that could otherwise be expensive and potentially poorly targeted. However, the current study demonstrates that neither of the buildings studied had read their sub-meters or carried out any benchmarking exercise before the start of the study. Display

Energy Certificates are due only at the end of the first year of operation, therefore the schools were unaware of how their energy bills compared to those of similar buildings in the first few months of operation when it would have still been the contractor's responsibility to fix problems.

8.4. Targeting Measured Energy Use

Ultimately, it is advised that education clients request a **measured energy use target** from the start of a project and review updates of this as the project progresses. This would ensure that 'occupant related energy use' or 'unregulated' energy use is taken into account, and the impacts of IT and server equipment, special functions, out of hours operation, increased occupancy and building management are planned for from the very start of the project. In turn a building specific baseline would be available to end users against which they can compare actual energy end uses. Such a process would not only ensure that systems are chosen to match end users expertise at design stage but that more attention is paid to handing over usable documentation and carrying out good training so that end users can manage the building and its systems upon completion. This recommendation applies equally to both refurbishments and new build projects.

Aedas R&D currently recommends the following document checks for any education project at handover:

- Building EPC – design and as-built
- Lighting system controllers
- AMR link login and passwords
- Building Log Book, containing:
    - Building Manual (NOT the full O&M but a description of each system and key operating settings with references to relevant sections of the O&M manual)
    - Copy of Metering Strategy
    - Building specific energy consumption baseline/benchmark
- CarbonBuzz energy records for estimated 'measured' energy use

8.5. Design Recommendations

In terms of design issues – the most pervasive question for school buildings is around ventilation strategy. In actual fact even Loxford School, which is primarily naturally ventilated, had some areas of the building mechanically ventilated and cooled. The solution is not necessarily the exclusion of such systems. Instead investors and end users must be informed of the maintenance and operating costs associated with these so that such decisions are made with a full appreciation of the risks involved.

In the buildings studied, heat gains from IT equipment have been one of the key factors in specifying mechanical ventilation. However, low heat gain ICT solutions are becoming more common and should be investigated before a mechanical route is chosen.

Zoning of buildings is another much overlooked area. Most education buildings are used out of hours on a regular basis as well as ad hoc. Keeping only occupied the parts of the building serviced helps save energy and cost. However, the zoning of mechanical services in some of the buildings studied did not allow for such partial operation either because of the way in which the zones were defined or because of inadequate BMS controls. Consideration of out of hours operation should be emphasised during early design stages and incorporated in the buildings spatial organisation and services strategy.

The impact of double and triple height spaces on zoning strategies need to be better understood. This configuration helps passive ventilation in the summer, if the right triggers are installed in the BMS. However, when systems are poorly configured or an entrance atrium is built without a drought lobby, the problems far outweigh the spatial and aesthetic benefits. In the case of Brine Leas, the most important communal area of the building became unusable for the majority of the year ; in the case of Loxford School, four large portable heaters had to be installed behind the reception desk to keep the space functioning. Whilst the knee-jerk reaction may be to remove atria from schools, the feedback indicates that poor mechanical integration and management can compromise seemingly optimal architectural solutions.

In terms of spatial planning, storage is a persistent source of complaints. Successful schools have a tendency to grow rapidly but current funding structures mean that schools do not have spare capacity built in by default. It is worthwhile to include in a school's brief an adequate buffer for success and growth.

8.6. Design Integration – the Architect's Role

There is much on-going discussion about the impact of design on academic achievement with the government taking a stance that design and inspiring architecture does not have a role to play. The feedback from the Building Use Surveys and interviews indicate that where occupants take pride in their building they feel more empowered to deal with operational and behavioural issues. What has been less emphasised in the past is the importance of integrating building services in the building's architecture – ensuring that users can interface with the technologies smoothly.

An impressive looking building can make users more forgiving towards poorly configured building services. Yet one of the key outcomes of the study for Aedas was the need to champion a design approach where a building's architectural composition manifests the full integration of building physics, services and controls with the needs of building occupants.

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.

This study aimed to investigate the causes of the performance gap in two schools, in particular the impact of design and build procurement and current building regulations on building performance. The following paragraphs summarise the conclusions.

9.1. Procurement and controls

Interviews with architects and engineers involved points to the need for contractors to share their cost model with the design team under a design and build procurement route. Without this information architects or engineers are not able to balance different solutions during detail design but have to accept contractors' recommendations. Value engineering decisions are often made in isolation by the contractor or subcontractor without an appraisal/modelling of the effect on other packages or the overall building performance. Without a 'critical items' register, including measures that contribute to comfort, energy performance and maintenance costs, these items often get changed or omitted post-novation. Storage solutions, any openings in the building fabric, sanitary installations, roof build-ups and control systems are the most typical areas to suffer.

In terms of services implementation, the omission of seasonal commissioning and other aftercare services from subcontractors' scopes had the biggest impact on outcomes. Without these, building systems cannot operate at optimal levels, which can reflect on comfort levels and costs valuable occupier time fighting with controls.

9.2. Predicted vs. actual energy use

Neither of the buildings studied had a calculated energy use prediction, the team could only compare measured energy use with the figures extracted from as-built EPCs, which in itself is not a simple process. These clearly cannot be treated as a forecast as the calculations are carried out using standard conditions, that do not reflect actual occupancy patterns, controls, special building functions and do not take into account the actual IT and appliance consumption in the annualised kWh figures. These figures can normally be found in the SBEM main output document or dynamic simulation software output.

Consequently, establishing a 'performance gap' as such is not possible using EPCs as we are not comparing like-for-like values. Consumption figures have, therefore, been compared to other data sources, including benchmarks and the performance of other education buildings studied by Aedas. Using the CarbonBuzz energy bar format has been helpful in communicating similarities and differences.

The energy consumption of the two school buildings is the closest to the CIBSE Raw TM46 benchmark out of all buildings studied by Aedas. Following the trend witnessed at the three Aedas Academies studied in parallel under a different TSB project, heating consumption was lower than the TM46 figure. The savings were, however, taken up by increased electrical consumption. Loxford School performed somewhat worse than Brine Leas due to inefficiencies arising from the BMS and increased heat demand due to doors, windows and plenum flaps being left open. This school also had higher electricity consumption due to pumps running overnight that may be attributed to the 24/7 schedule specified for the domestic hot water system and active chilled beams being linked to faulty PIR sensors.

If compared to the Academies studied by Aedas, both buildings are in the top quartile; Brine Leas because of its size and relative simplicity and Loxford mainly because of the natural ventilation route which leaves less room for errors in larger more complex buildings. The school's head technical background also contributed to the relatively good energy performance of Brine Leas. It is estimated that if the simple problems identified were addressed at Loxford (doors, temperature profiles, lighting) then the CO2 emissions of these two buildings would be around half of those measured for the academies studied. Both buildings have further room for improvement particularly around heating, auxiliary consumption (pumps), and lighting in Loxford, and heating, cooling and lighting in Brine Leas.

The analysis of energy end uses in these buildings demonstrate that the figures set out by the Education Funding Agency for the Priority School Building Programme are realistic and achievable by either mechanically or naturally ventilated buildings:

- Total fossil fuel energy consumption of less than 60 kWh/m^2/annum
- Total electricity consumption of less than 50 kWh/m^2/annum

With the following targets for end-uses[6]:

- Lighting 12-24 kWh/m^2/annum
- Space Heating 55 kWh/m^2/annum
- Domestic Hot Water 10 kWh/m^2/annum
- Fans and pumps 6-15 kWh/m^2/annum
- Server rooms 8 kWh/m^2/annum
- ICT 8-10 kWh/m^2/annum

[6] The total energy consumption figures are based on the lower values given for end-uses.
Source: The Education Funding Agency, November 2012. *Priority School Building Programme Baseline Designs for Energy Efficiency.*

- Miscellaneous and small power 5-10 kWh/m^2/annum
- Catering 6-12 kWh/m^2/annum

Brine Leas is already close to these figures and Loxford School can achieve this level of performance if the issues stated in the report are addressed.

9.3. Unregulated energy use

When comparing the metered energy use against the calculated EPC, there is a two-fold difference in total kWhs for Brine Leas and just over three-fold for Loxford. This difference is smaller than what was logged for the Academies, leading to the hypothesis that simpler and smaller buildings have a lower margin for error. This seems to be reinforced by anecdotal evidence across the TSB programme.

The debate about the effectiveness of regulation becomes more heated when commissioning and building management are included under ‘unregulated’ impacts. It is widely accepted that building fabric and system efficiencies have improved significantly with the introduction of Part L 2006. However, when it comes to education buildings, a pattern of significantly increased electrical consumption seems to emerge from new ‘low carbon’ education buildings.

The question is whether this trend is an unintended consequence of the ‘improved’ building regulations, whereby, buildings are designed and refurbished to include ever more complex services and control systems to meet increasingly stringent regulations. The risks associated with the procurement, commissioning and maintenance of these complex systems is such that they frequently fail to bring the intended energy performance improvements in practice.

In order to gain approval, and a higher EPC rating, engineers need to demonstrate that all HVAC and lighting systems operate at the minimum number of hours needed and in as few zones as possible. Multiple systems are specified to optimise heating, cooling, hot water and fresh air requirements, which means that a BMS is required to control their operation and to get below the SBEM Target Emissions Rate. However, in the five education buildings studied (two of which were part of this project) none of the BMSs were functioning as described by the design specification. In each case, the BMS contributed to substantial performance shortcomings and immense occupier frustration.

The huge discrepancy between the estimated energy performance of fixed building services and their actual performance in most cases is attributable to building management and control issues. Unregulated loads such as IT and small power also contribute to the energy performance of new-built schools. However, evidence collated by Aedas suggests that the effect of these is less than what is generally perceived in the industry; control issues associated with the fixed building services are often more influential (see the energy end-use breakdowns & corresponding diagnostics in Section 6).

9.4. Conclusions and key findings for this section

The monitoring team has recently contributed to CIBSE School Design Group's forthcoming Technical Memorandum based on the lessons learned from the building performance evaluation of the five Aedas designed schools and academies. The following summary recommendations were compiled by Aedas/UCL research team for energy efficient facilities management of educational buildings.

Recommendations for energy efficient facilities management	
Clients (schools / local authorities, etc.)	Consider introducing an operational rating target into design brief (e.g. DEC A rating).
	Ask for specific design measures for out of hours and extra-curricular use of school.
	Ensure energy performance is taken into account during defects liability period. This could uncover some problems that could otherwise go unnoticed.
	Ensure building FM and other personnel involved in day-to-day operation of school are trained adequately (especially in case of staff turnover).
	Appoint someone to own energy consumption. Consider signing a performance contract with the maintenance contractor.
	Commission a Display Energy Certificate 12 months post-occupancy. Compare and contrast the operational rating with the energy baseline defined by designers/contractors. (This is an independent verification of annual performance and not merely a compliance issue).
Designers and Contractors	Opt for simple, passive design strategies that require low intervention so far as possible (schools often do not have the resources and budget for a high intervention building management scenario).
	Schools are seasonal buildings and should be designed and procured as seasonal buildings with flexibility for extra-curricular activities without compromising energy performance.
	Ensure a working draft of building logbook is prepared by RIBA stage D/E (especially for Design & Build contracts).
	Ensure zoning arrangements and control strategy for out-of-hours and partial use of school are properly explained in the building log book.
	Introduce a list of critical energy efficiency measures in building log book. Include tips for facilities manager to ensure these measures are implemented and working as intended.
	Define building energy baseline clearly in log book (total thermal fuel and electricity & estimations for all energy end-uses). Provide the underlying assumptions and help building occupants benchmark their building's performance against this baseline.
	Ensure the metering strategy is implemented as intended and is working effectively. Train building occupants how to use the metering strategy for monitoring and targeting.
Facilities Managers (All activities to start within the first year of post-occupancy and continue thereafter)	Review the building logbook and make sure baselines for energy performance along with underlying assumptions are defined.
	Review the metering strategy in building logbook and other documentation to understand how the strategy works.
	Carry out a meter reconciliation exercise following the methodology explained in CIBSE TM39 to ensure the metering strategy is robust and sub-metered data is reliable. Record any faulty sub-meter in the defects log.
	Implement a monitoring and targeting strategy in early stages of building occupancy. Compare and contrast the outcomes with baselines and make sure critical energy efficiency measures are implemented and working as intended.
	Where a performance contract has been signed with the building maintenance contractor, ask the maintenance contractor for regular updates on energy efficiency measures and building energy performance. Compare energy performance with the baselines defined in the building log book.
	Treat the building log book as a 'live' document. Update the log book with results of energy measurements, M&T outcomes, and any other in-use investigations (e.g. Display Energy Certificates, Air Conditioning Reports, etc.)
	Review the operation of operable windows / motorised vents in naturally ventilated spaces and demand-controlled ventilation in mechanically ventilated spaces regularly. Ensure air quality and thermal comfort is maintained without compromising energy performance.
	Ensure the schedules of operation defined for HVAC systems reflect actual occupancy and the seasonal nature of school's operation.
	Ensure the last person who leaves the school in the evening checks building's demand on the electrical smart meter installed on-site. Investigate overnight operation of building if building's demand is unusually high.

As feedback from buildings in operation is not currently mandated by regulation, such impacts are not quantified and do not inform policy and procurement. Gathering statistical evidence to verify the effectiveness of low-carbon investment is currently costly and in many cases not possible. However, the BPE studies have demonstrated a strong business case for embedding feedback in the procurement of school buildings.

Carrying out a detailed energy survey and illustrating end use data in a simple-to-interpret diagram has been an extremely productive way of 'getting under the buildings skin' and identifying trends.

In all cases the studies have resulted in client intervention that could improve the energy use of the buildings in question. They also point to simple measures that, if included during design stages the cost of such evaluations would drop significantly and the gap between expected and achieved building performance would be substantially reduced.

Individual studies have highlighted systemic barriers that prevent buildings and their occupiers from using less energy in operation. The BPE programme has been successful in educating influential architects, clients, contractors and building performance specialists in bringing together the multi-disciplinary expertise required to propose effective solutions to these. It is important that the recommendations are taken on board by the government so that investment in low energy solutions is more effectively targeted. A key recommendation is to incorporate the requirement for energy consumption 'data drops' alongside 'BIM data drops' in the Cabinet Office Soft Landings Programme implementation. These energy records, submitted online at key project stages, would need to disclose a prediction of measured energy use alongside assumptions behind such a figure.

It is clear that regulatory and procurement processes need to change in order to address the increased technological complexity in new and refurbished buildings, or education buildings must be designed to be less complex to manage. A more integrated approach to low energy refurbishment and new build is required to create more resilient buildings. Architects, who traditionally act as 'integrators', are well placed to lead this. However, the energy literacy of built environment professionals remains a key challenge – government and professional bodies need to work together to harmonise the reporting of energy consumption from design to operation. Disclosure and transparency may be a much more effective way to achieve energy reductions than complex regulation.

10 Appendices

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