Pennywell Academy 360

NOTE This report combines three studies: Pennywell Academy, Stockport Academy, and Petchey Academy

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	450008
Project lead and author	AHR (fornerly Aedas Architects)
Report date	2015
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Schools (secondary)	Sunderland	Design and build	2010
Floor area (TFA)	**Storeys**	**EPC / DEC (2011)**	**BREEAM rating**
10,172 m^2	Various	B / F (146)	Very good

Purpose of evaluation

The evaluation aimed get an insight into performance issues in early to mid-occupation and to offer helpful information on the impact of design approaches to mechanised systems and of procurement on build quality, installed systems and emissions of building in operation. The study also sought to highlight where current design process failed to address unregulated energy use, highlight where further emissions can result through poor commissioning and management in occupation at the early stages, and identify main contributing factors relating to the discrepancy between estimated and actual energy use.

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

Pennywell Academy 360 consists of a cluster of 12 separate structures around a central courtyard. Electricity consumption was estimated at 102 kWh/m^2 per annum, and thermal energy (500 kW biomass and gas) at 145 kWh/m^2 per annum. The CIBSE TM22 assessment showed that the school's gas consumption was better than DEC/CIBSE *TM46* benchmarks but worse than the top 25% of secondary schools. Electricity consumption was higher than all benchmarks. In terms of CO_2 emssions, the school's performance of 84.1 kg CO_2/m^2 per annum was worse than all benchmarks.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	166	107 (65%)

Pennywell Academy received mixed user feedback. The feedback on overall comfort, lighting, noise and image to visitors was average. However, users were not satisfied with temperature and air quality, design (configuration of spaces) or storage and as a result felt that the building didn't meet their needs, lowered their productivity and affected their health. The majority of the comments reported the inadequacy of the open spaces in terms of teaching, noise and behaviour control.

Stockport Academy

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Report date	2015
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Schools (secondary)	Stockport	Traditional	2007
Floor area (TFA)	**Storeys**	**EPC / DEC 2012**	**BREEAM rating**
10,418 m^2	3	B / G (163)	No

Purpose of evaluation

The research was undertaken as part of a wider project in order to provide insight into some of the different issues surrounding buildings in early to mid-occupation, offer helpful information on the impact of design approaches to mechanised systems and of procurement on build quality, installed systems and emissions of building in operation and highlight where current design process failed to address unregulated energy use in school projects. The project identified main contributing factors relating to the discrepancy between estimated and actual energy use.

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

A ground source heat pump (GSHP) of approximately 300 kW installed capacity, a coefficient of performance (CoP) of 4.1 and an energy efficiency ratio of 5.2 was installed to provide heating and cooling to the building. The GSHP was supplemented by a 1500 kW gas-fired boiler system which provided additional heating when necessary. Cooling was provided by the GSHPs feeding chilled beams. The building was mechanically ventilated via 10 main AHUs and extract-fans in areas such as toilets and data hub rooms. Electricity consumption was estimated at 132.8 kWh/m^2 per annum, and thermal energy at 87.2 kWh/m^2 per annum.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper survey	100	75 (75%)

Lack of fresh air within the classrooms/offices was reported to increase incidence of illnesses. Lack of storage space and inadequate staff toilets were also reported. Apart from a below midpoint score on perceived health, the summary results from the BUS were positive. Evaluator note: future users of the survey data need to be aware that BUS survey results are not solely a judgement on design decisions but reflect many other construction-related and management-related influences and inputs.

Petchey Academy

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Innovate UK project number	450008
Project lead and author	AHR (formerly Aedas Architects)
Report date	2015
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	Location	Form of contract	Opened
Schools (secondary)	London	Design and build	2007
Floor area (TFA)	**Storeys**	**EPC / DEC 2012**	**BREEAM rating**
12,186 m² (10,490 m² DEC)	3	N/A / G (199)	No

Purpose of evaluation

The research was undertaken as part of a wider project in order to get an insight into some of the different issues surrounding buildings in early to mid-occupation, highlight where current design process failed to address unregulated energy use in school projects, and highlight where further emissions can result through poor commissioning and management in occupation at the early stages. The researchers also aimed to identify the main factors relating to the discrepancy between estimated and actual energy use.

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

The school is mechanically ventilated with partial air-conditioning and heat recovery. AHUs with heat recovery (including summer bypass) provide supply and extract ventilation to all classrooms, staff areas and changing rooms. The design specification was for four 500 kW air-cooled chillers, but two Airedale air cooled chillers, each with a rated output of 208 kW, were installed. The energy use of Petchey Academy was found to be six times the design projection. Electricity consumption was estimated at 125 kWh/m² per annum, and thermal energy at 109.5 kWh/m² per annum. Note that the initial meter reconciliation was out by more than 20% mainly because some lighting and power section boards were not sub-metered.

Occupant survey	Survey sample	Response rate
BUS, paper-based	106	76 (72%)

The users were largely happy with the configuration of the building but were concerned about the lack of adequate space for the size of school and insufficient storage. Occupants felt that they had inadequate control of temperature and fresh air. Most staff found the winter and summer conditions in Petchey uncomfortable. Air quality was reported to be unsatisfactory. Evaluator note: future users of the survey data need to be aware that BUS survey results are not solely a judgement on design decisions but reflect many other construction-related and management-related influences and inputs.

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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.

Technology Strategy Board
Driving Innovation

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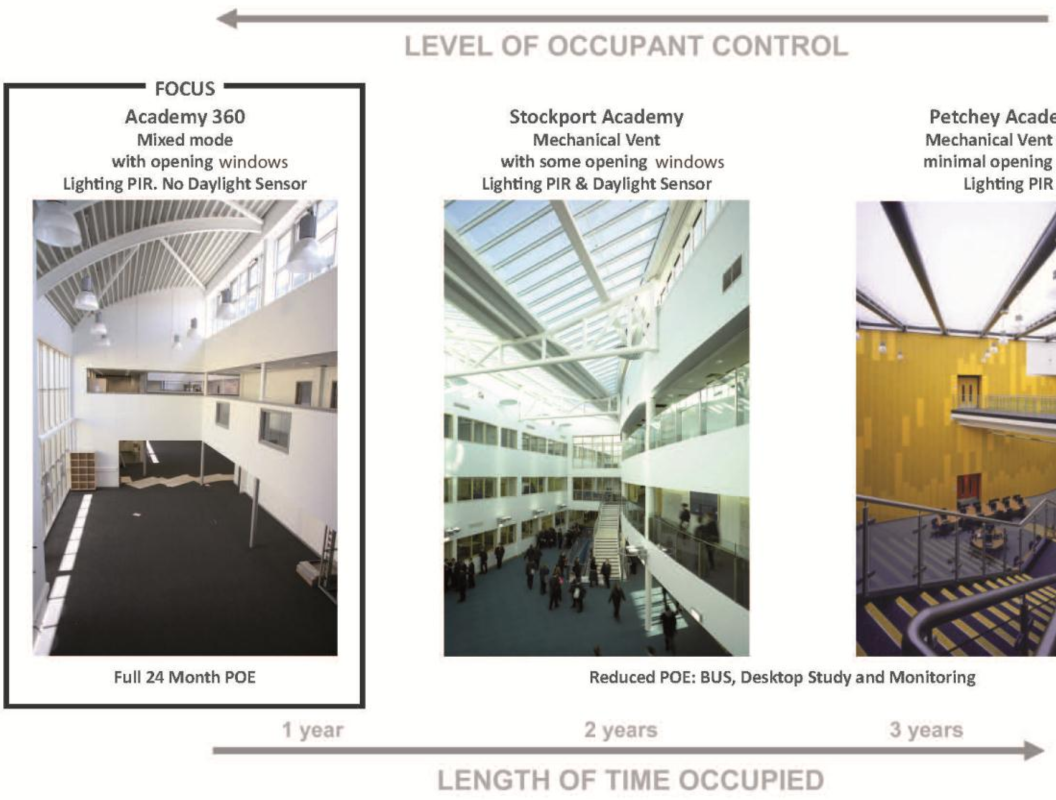
1 Introduction and overview

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



This project comprises the evaluation of three case studies to facilitate a compare and contrast analysis. The three case studies chosen, Pennywell Academy 360, Stockport Academy and Petchey Academy, were designed to meet the requirements of the DfES School Building Bulletins. The buildings were completed over a three-year period and show different characteristics in terms of consolidated use and building management. The buildings are either fully mechanically ventilated or mixed mode – as indicated in the diagram above. The study was set up to review the buildings in use and gather evidence of any performance issues. The report describes recommendations for remedial actions to the building end users as well as feedback to TSB on possible measures to address systemic procurement issues.

Of the three case studies, Pennywell Academy 360 is the most recent and had the highest level of engagement from the facilities manager from the outset; an important attribute for a successful study. It was for these reasons that Pennywell Academy 360 was chosen as the focus case study for the project, where a full two-year monitoring period was undertaken, while a reduced one year study was undertaken for the other two academies.

All studies included: the gathering of design data and metering strategy, inspection of build quality, review of delivery of design intent, sign-off and commissioning plans and procedure, the review of original plans for move in, aftercare, operation management and maintenance, familiarization, and a further review of training for occupants and facilities manager, a desktop review of test results (e.g. air pressure tests, commissioning records), handover data, log book, O&M manuals and user-guides for occupants and management and technical performance. A Building Use Survey was performed to establish occupant de/satisfaction and feedback was gathered from client, occupier, design and building teams wherever possible. As part of the first year's surveys, a review of the FM, monthly and annual energy use and usability of controls and Building Management Systems (BMS) in all three buildings was undertaken. In the case of Pennywell these studies continued through a second year of monitoring to enable more in-depth investigation of issues and to establish the impact, if any, of interventions undertaken by the school. In all the buildings there was an early focus on reconciling meters and gathering energy data.

As well as the compare and contrast exercise, the case studies also had unique areas of interest. In Pennywell Academy 360, the mixed mode ventilation strategy and occupants' control of low or zero carbon technologies (in particular the biomass boiler) were studied. The actual total energy use of Petchey Academy was six times the design projection. The initial DEC rating was G. In Stockport, the efficiency of the mechanical ventilation system installed and the contribution of ground source heat pumps to the building's heating and cooling demand were of special interest as both aspects were critical for the building's energy performance. Detailed energy monitoring was required here to reconcile the actual consumption. The as-designed and as-built buildings were compared with operation to identify the differences imposed by occupant behaviour, management practices, maintenance issues, and to investigate to what extent these design, construction, and operation choices affected, aided or abetted efficiency. In summary, the main scope and aims included:

- Good insight into some of the different issues surrounding buildings in early to mid-occupation,
- offer helpful information on the impact of design approaches to mechanised systems and of procurement on build quality, installed systems and emissions of building in operation,

- highlight where current design process failed to address unregulated energy use in school projects,
- highlight where further emissions can result through poor commissioning and management in occupation at the early stages,
- identify main contributing factors relating to the discrepancy between estimated and actual energy use and communicate these across the design team, client body, broader industry, sponsors and local authorities.

1.1 Key facts, figures and findings

The Building Performance Evaluation (BPE) of Academy 360, Petchey Academy and Stockport Academy has been carried out in parallel with the BPE of two schools 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 Academies 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 all the academies.

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. They are also not warned about the level of expertise and investment required for successful building management. 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.

Personnel running large education buildings cannot be expected to understand the complex building systems without expert in-house facilities management. Our experience points to the fact that the school leadership teams have other pressing priorities and lack the expertise to act on recommendations even when the financial implications of underperformance are quantified and solutions are presented in a step by step manner. This raises the question whether education buildings should be built entirely with passive systems with straightforward controls.

The interviews carried out with school business managers revealed that schools are not routinely issued with a pro-forma for procuring performance contracts for facilities management. As a result management of the building services is often undertaken by an external party at a high cost and no performance improvements.

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. However, the team found that where occupants were happy with the building design, as in the case of Stockport Academy, they were content with comfort levels. In the case of Academy 360, where they were unhappy with the design, the BUS feedback on air quality and temperature was well below average despite CO_2, temperature and humidity readings being similar to those of Stockport. And in the case of Petchey Academy, where users were largely happy with the look and configuration of the building but experienced extreme discomfort, the BUS feedback was overall better than at Academy 360. Such anecdotal evidence points to the important role of design in occupants' overall experience of a building.

It is perhaps important to state that at Stockport Academy, where occupant satisfaction was above average in most categories, the internal conditions were provided with poorly configured systems, which incurred 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.

As documented by other publications, there seems to be little connection between EPC and DEC ratings. It was surprising that despite all of the buildings being built to an EPC rating of B**,** apart from Petchey, the achieved DEC ratings of the buildings were F and G. A B rated EPC is what the industry would recognise as a low-carbon target. This is unsurprising as these are being calculated based on standardised values for occupancy and hours of operation and omitting critical aspects of consumption such as IT, small power and special functions.

Quantifying the difference between predicted and actual energy use has proved contentious. Apart from Stockport Academy none of the projects had a prediction of measured energy use to use as a baseline for comparisons and even in the case of Stockport this calculation was carried out for RIBA Stage D report and did not reflect the as-built building. Current benchmarks clearly do not have adequate granularity to provide a quick estimate of what a building with similar properties should consume. In order to express the value of any remedial action quantitatively an energy model had to be built – a costly process and not part of the original undertaking.

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. All in all a great deal of extra time had to be spent on re-engaging consultants and contractors who were naturally wary about uncovering issues that may have potential liability implications. When a BPE is carried out in hindsight key personnel has often moved on and important information is lost. A key finding of the study was that building performance evaluations are far more costly to carry out if the process is not embedded in the original project contract.

In all cases carrying out the Building Performance Evaluation resulted in remedial action. At Academy 360, the main focus of the study, these actions resulted in measurable reductions in lighting consumption and other end uses. In the case of the other academies such measures were only beginning to be implemented towards the end of the project and the results of performance improvements are not yet available. Future Display Energy Certificates should give an overview of the scale of improvements over time.

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. The BPE needs to be carried out with the original design and contractor team on board so that issues raised can be quickly addressed. It is not always necessary to carry out the full BPE scope. In fact a short and intensive monitoring week preceded and followed by intensive desktop study seems to have been far more effective at achieving results than sporadic quarterly visits.

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.

The findings from the study fed back to other TSB work, including the Aedas-led CarbonBuzz and Metadata projects as well as parallel BPE studies. As such the outcomes were disseminated broadly, in trade journals, web platforms, via dozens of presentations, workshops and scientific journals. The results fed into new CIBSE Technical Memorandum (TM) around more robust methodologies for the prediction of measured energy use, as well as CIBSE Schools Technical Memorandum. It is highly recommended that a metadata analysis of the outcomes is commissioned by TSB and that the project participants are invited to contribute to this.

Since the completion of this project Aedas has dedicated further staff time to carrying out BPEs on recently completed projects. Early on in the project the practice also joined the UBT/BSRIA Soft Landings Group. The practice has successfully bid and won projects where BPE experience has made a difference to the outcomes and has developed an in-house methodology for de-risking performance contracts for design projects. This is currently being trialled on a live project in Bath and Somerset County Council.

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 Stockport Academy

The procurement route for this building was through a traditional contract with the United Learning Trust. Aedas Architects were appointed by the client to produce the planning submission, at which point, Bowmer and Kirkland (contractor) was brought on board to assist with detail design and cost planning. Buro Happold were on board from the beginning as M&E consultants. At stage H, a JCT contract was signed and Bowmer and Kirkland subcontracted NG Bailey for the systems installation.

The new building replaced Avondale High School on 1st September 2007 on the existing site, with a full complement of students transferring into years 8 -11 and a new intake of 180 students in year 7. The Academy provides 900 places for students aged 11-16 with 250 additional places for Sixth Form students, although they have not yet reached full capacity and currently only have 760 students. The Academy is independent of Stockport Metropolitan Borough Council (SMBC). It is fully inclusive, co-educational and free to the local community within the statutory and agreed admission policies.

It is situated amongst the playing field in a mostly residential area and located near the inner city of Cheadle Heath, with good public transport links, although it is reported that only around 20% of occupants utilise them. The school provides 50 spaces for secure, bike parking with shower facilities and 200 car parking spaces. The aspiration for this building was to deliver a 21st century educational facility that met or exceeded planning and design regulation at the time, with an emphasis on renewables. The school sits under the Manchester Airport flight path and is designed to screen the noise of passing planes. The building form responds to this challenge by organising classrooms around a central atrium space in order to ventilate without the need for operable windows. The building was constructed adjacent to the existing Avondale building in order that the school could remain open during the build, uninterrupted. The existing building was later demolished when the new building was occupied.

In terms of building design and fabric, it covers 10496m^2 over four storeys; 3 above ground and 1 below. It is a steel frame construction with suspended ceilings and cavity block and brick facades, designed to an air-tightness of 10 m³/hr/m² @ 50Pa and pressure tested at 9.24 m³/hr/m² @ 50Pa.


Figure 2.1: External façade of Stockport
Figure 2.2: Approach and entrance to the Academy

Figure 2.3: Internal atrium acts as a light well and is an integral part of the ventilations strategy; creating a passive stack effect and helping to draw air through perimeter classrooms.

Description of building elements				
Element	Orientation	Brief description of design	Area (m2)	U value
Facade type 1	More than one	Facing Brick	2803	0.28
Facade type 2	More than one	Sandstone Blocks	182	0.28
Facade type 3	More than one	Composite Cladding Panels	146	0.28
Facade type 4	More than one	Timber faced Wall	0	-
Glazing type 1	More than one	Punch windows	659	1.8
Glazing type 2	More than one	Glazed Curtain Walls	220	1.8
Glazing type 3	More than one	Opaque Curtain Walls	21	1.8
Glazing type 4	Click to select			
Solar shading type 1	Click to select	n/a solar shade in overhangs		
Solar shading type 2	Click to select	n/a solar shade in structural supports		
Solar shading type 3	Click to select			
Solar shading type 4	Click to select			
Roof type 1	Click to select	standing seam roof	3819	0.15
Roof type 2	Click to select	flat roof	0	0.15
Rooflights	Click to select	various small sizes	737	0.35
Ground floor type 1	Click to select	cast slab (to be confirmed)	4459	0.25
Gound floor type 2	Click to select			0.25
External door type 1	Click to select	standard door	18	
External door type 2	Click to select			

Table 2.1: Screen grab of the designed U-values from the Building Information Document

Daylight was optimised in the design by the introduction of a large central atrium to provide daylight to many of the internal classrooms. That said, much of the glazed surfaces, both to the atrium and to the external façade are used as extra wall space, reducing the day-lighting advantage of the atrium space. This is likely to have had an effect on the lighting consumption of the building, which was found to be excessive during the primary stages of the evaluation. See photos below. The internal windows facilitate passive supervision, which has been an important factor in schools design for some time and is championed by many who work in schools. However, some teachers feel that the windows can cause distractions for the pupils in the class, particularly at staggered break times and others can feel a little too exposed. This may explain why the window decorations diminish from ground floor to third floor level.

The external facades have fixed windows with opening fan lights and internal blinds. There is no external shading; some south facing classrooms have been retrofitted with solar film. The lighting control system was designed using presence detection sensors (PIR) with day light sensors, and override switches located locally within classrooms and other areas. Luminaires with dimmable facility were designed to be controlled by photocell daylight sensors to optimise the use of natural daylight to reduce energy consumption; these are utilised in rows adjacent to windows in classrooms. However, it has become clear during the building evaluation that there are some discrepancies in the strategy that may have contributed to excessive lighting consumption. Lighting throughout the circulation areas is operated by one main switch, which causes all lights to come on throughout, even when only a small portion of the floor area is occupied. Photocell and PIR timing are not consistent between classrooms, with some set to a 20 minute time delay.

Figure 2.4: Windows covered with school work

A detailed investigation of the O&Ms was carried out to establish the comprehensiveness of the documentation supplied at handover. The copy used for this exercise was the edition issued to the Academy upon handover, which was overseen by Aedas Architects.
The O&Ms contents list includes:

- Full set of as-built, mechanical and electrical drawings
- Approx. 200 page.pdf of commissioning-related certificates
- Architectural drawings from Aedas Architects

- The security and access control specification and product literature
- The EPC certificate and BRUKL report

The logbook was compiled by Buro Happold and includes a comprehensive description of the main contacts, the overall building design and systems descriptions. The two-page occupant instructions section is also included. The commissioning overview pages are filled out and where certificates are requested, it refers readers to the O&M manual. However, these certificates do not seem to be present. The readers are also referred to the O&M manual under the headings; 'Controls / BMS layout' and 'BMS software hierarchy,' but these chapters are missing entirely.
The building occupier information is also missing as are any comments or signatures. This would mean that the information was not available during handover. This is further evidenced by the fact that the log book was drawn up by the designer, not the contractor, which would indicate that the information was copied across from design stage information and then may not have been updated. As a result the building users do not have an adequate set of instructions for operating the building; for example there is no indication of how demand controlled ventilation should be used.

2.2 Pennywell 360 Academy

Pennywell Academy is the result of the amalgamation of three schools in an area in need of regeneration. The client team was complex, three organisations collaborating on a single brief. Each school had a different specialism; having to cater for these in the new building explains some of the complexities of the layout.

The project was a complete new-build, covering 10,172m^2. Construction began in March 2008 under a design and build contract. The building was fully occupied by June 2009. Nominal occupancy is 1150 persons; currently they number 1120 students with around 150 staff members. The building was designed as a cluster of small buildings around an internal courtyard and is mixed mode with a passive solar orientation and overhanging eave shading. The Academy was sponsored by a social housing provider as part of a regeneration scheme for the local area including a housing element; this may go some way to explaining the numerous envelope build-ups in the design. The building experiences normal levels of weather exposure as it is located inside the wider regeneration scheme. Rooms are designed around large, internal, breakout spaces which form part of the ventilation route for the perimeter classrooms.

The design intent was to create a 'village feel' leading to a series of 2 (and in one case, 3) storey steel frame buildings many with mono-pitch, passive sections facing south. In terms of building fabric, no substantial improvements were made on Building Regulations 2006. A curtain wall solution is employed across the majority of the façade integrating opaque and glazed panels, with brick plinths in places. There are off-white rendered block-work external walls to central strip of school with areas of full render to external faces.(A list of materials used to build the IES model can be found on the Part L report. The airtightness design target was 10 $m^3/hr/m^2$ @50Pa; no as-built information was found during the study.

There are good public transport links available but only approximately 5% use it based on the Building Use Survey. There are also 50 secure bike parking spaces and shower facilities available, along with 130 car parking spaces.

Figure 2.5: View from internal courtyard
Figure 2.6: View from reception through to main building at night with all the lights on.

Description of building elements				
Element	Orientation	Brief description of design	Area (m2)	U value
Facade type 1	More than one	Facing Brick	1075	0.35
Facade type 2	More than one	Metal clad Wall	1556	0.35
Facade type 3	More than one	Timber faced Wall	611	0.35
Facade type 4	More than one	Rendered or ceramic	444	0.35
Glazing type 1	More than one	Punch windows	494	2.1
Glazing type 2	More than one	Glazed Curtain Walls	811	2.1
Glazing type 3	More than one	Opaque Curtain Walls	70	2.1
Glazing type 4	More than one			
Solar shading type 1	Click to select	n/a solar shade in overhangs		
Solar shading type 2	More than one	n/a solar shade in structural supports		
Solar shading type 3	Click to select			
Solar shading type 4	Click to select			
Roof type 1	Not applicable	standing seam roof	5388	0.3
Roof type 2	Not applicable	flat roof	1796	0.3
Rooflights	Not applicable	various number of small size openings		
Ground floor type 1	All	cast slab (to be confirmed)	5865	0.25
Gound floor type 2	Click to select			
External door type 1	More than one	standard door	150	2.2
External door type 2	More than one			

Table 2: Shows a screen grab of the designed U-values from the Building Information Document.

The Operations and Maintenance manuals and the log book were compiled by Interdoc Ltd. Two sets of the log book exist: the first is dated July 2009 and was presented at handover. In this version, the general information pages such as the Overall Building Design section are blank. The BMS interface is well-documented but not in language that could be understood by a lay-person / building occupant.

There is also no description of plant control or BMS settings, alarms or which meters are linked to the BMS. None of the commissioning charts have been filled in and no signatures are displayed. It contains a small amount of occupant information but it is by no means exhaustive. There is a second version of the log book in section 5 of the final O&M pdf and is dated July 2010, which coincides with the end of the defects period. This version, as well as the rest of the O&M manuals, appears to be comprehensive and very thorough. The contractor's engagement in aftercare improved once the BPE project got under way.

2.3 Petchey Academy

Completed in August 2007 Petchey Academy is a new 1200 place secondary school and is sponsored by the Jack Petchey Foundation. It includes a Sixth Form college for 300 students, and has a specialism in Health Care and Medical Sciences. The new academy replaces the former Kingsland School, which was entirely demolished and the new academy opened in September 2007.

There is also a temporary school, for one year group (180 students), which opened in September 2006 for the first year intake. Part of the site has been dedicated to a Child Development Centre (CDC), which has been developed separately from the Academy. Last year a new wing was added to the building which the research team discounted from the BPE study.

The proposal included the provision of associated sports facilities including a multi-use games area (MUGA), all weather pitch with flood lighting, hard and soft play areas, a number of car parking spaces, cycle racks, landscaping, and also temporary accommodation for one year class. A multi-use games area, gardens and a roof terrace at second floor were also provided. The procurement route was Design and Build through the National Academies framework number 1.

The building comprises two triangular wings located either side of a triple-height, top-lit central space covered by ETFE. At the centre sits a drum housing the auditorium, drama space and Learning Resource Centre. The intention was that this part of the building will be used as flexible learning space and will also provide an area for dining. Since opening the space has been used for film sets on a number of occasions.

The school has state-of-the-art training kitchens, a large cafeteria linked to the atrium as well as design and Technology rooms with heavy machinery. The atrium is populated with over 50 computers where timetabled classes take place. Science labs have fume cupboards and there is a large server room and ICT rooms. Petchey Academy started with 150 members of staff which has reached just over 200 recently.


Figure 2.7: External Façade
Figure 2.8 : Atrium

Figure 2.9: Front Entrance

Constructed as a concrete frame at 3.6m floor to floor height with precast slabs and exposed ceilings, the building's external envelope is predominantly curtain wall with solid panels with some rendered facades. The glazing strips are slightly irregular in shape with a single operable window to each classroom. They provide good daylight levels where the blinds are retracted. The research team was keen to establish if the lightweight building fabric with a u value of 0.35 W/m^{2o}K, specified before Part L 2006, would be adequate to prevent overheating. Design air-tightness target was 10m3/hour/m^2 @ 50Pa and 9.78 was achieved.

Description of building elements

Element	Orientation	Brief description of design	Area (m2)	U value
Facade type 1	More than one	Opaque Curtain walling system	2199.7	0.35
Facade type 2	More than one	Louvres	37	-
Facade type 3	More than one	Brickwork	13.6	0.3
Facade type 4	More than one	Sto Render	497	0.3
Glazing type 1	More than one	Glazed Curtain walling system	514	2
Glazing type 2	More than one	Glazed Curtain walling system	330.2	2
Glazing type 3	More than one	Glazed Curtain walling system	216.2	2
Glazing type 4	More than one	Glazed Curtain walling system	133.6	2
Solar shading type 1	S	Aluminium Louvres		
Solar shading type 2	More than one	Internal Blinds		
Solar shading type 3	Click to select			
Solar shading type 4	Click to select			
Roof type 1	Not applicable	Insitu Concrete Roof	2285	0.25
Roof type 2	Not applicable	Lightweight standing seam roof	638	0.25
Rooflights	Not applicable	ETFE 3 layer	553	2
Ground floor type 1	All	200mm concrete slab (reinforcement @ 80kg/m3; 150mm cellcore; 50mm blinding and DPM.	4122	0.25
Gound floor type 2	Click to select	300mm concrete slab (reinforcement @ 110kg/m3; 150mm cellcore; 50mm blinding and DPM.	664	0.25
External door type 1	More than one	Mild steel door sets	inc above	
External door type 2	More than one	Mild steel door sets	inc above	

Table 3: Shows a screen grab of the designed U-values from the Building Information Document.


Figure 2.10: Flexible accommodation; performance space opens out onto the dining area
Figure 2.11: Dance area; borrows daylight from central atrium space but has no daylight dimming on artificial lighting


Figure 2.12: Drama studio with high audio visual and lighting loads
Figure 2.13: Artificial lights remain on despite high daylight levels in corridor

2.4 Conclusions and key findings for this section

Although all three buildings were large secondary schools they greatly differed in configuration, architectural language, building fabric and HVAC strategy. Only Stockport was constructed under a traditional contract, the other buildings both followed a design and build route. Petchey Academy was the only building designed before the inception of Part L 2006. The technical section of the report will analyse the extent to which the different building characteristics, regulatory framework and procurement routes have affected the building performance outcomes.

The monitoring team was able to establish close working relationships with building operators and the original design team to different extents. Client engagement with the two academies, Stockport and Petchey turned out to be much better than initially expected by the end of the project. There was no input by Buro Happold into the Petchey Academy design vs. as built review due to the original project staff having moved on. Instead, this exercise was carried out by an external consultant associated with the commissioning of the building services. Where the original design team was still in place, feedback from consultants was constructive. The architect in charge of Pennywell, although no longer with Aedas, provided informal support to the team as he was greatly motivated to find out more about the building's operation. Continuity at the contractors' was more challenging and the longer a building was completed the more difficult it seemed to re-engage. Mechanical subcontractors supported the monitoring study at Pennywell, as expected, and became more involved towards the end of the study at Stockport. As the majority of the findings were related to mechanical systems, their input proved especially critical to progress. In the final week of the study further evidence has come forward from Stockport Academy regarding appliance energy use management as a direct consequence of the monitoring work.

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 Stockport Academy

The Academy has a Building Emissions Rate (BER) of 21.8 $kgCO_2/m^2/yr$, with and EPC rating of B. It is serviced by grid-supplied electricity and natural gas. A ground source heat pump system with approximately 300kW installed capacity, a coefficient of performance (COP) of 4.1 and an energy efficiency ratio (EER) of 5.2 – is installed to provide heating and cooling to the building. The ground source heat pump system is supplemented by 1500kW of gas-fired boilers which provide the additional heating when necessary. Heating is distributed via low temperature hot water (LTHW) loop through under-floor heating, radiant panels, and wet radiators. Cooling is provided by GSHPs feeding chilled beams via a chilled water buffer vessel. The building is mechanically ventilated via 10 main AHUs and extract-fans in areas such as toilets and data hub rooms. The sports hall and the main hall are ventilated by Monodraught Acoustic wind catcher. Air is supplied to classrooms through ceiling-mounted diffusers and where possible exhaust air is routed back to the AHUs for heat recovery. Hot water service generation and storage is provided by a calorifier vessel fed from the LTHW heating system, all located in the rooftop plant-room. There are also 15, electric hot water, point of use heaters.

Daylight is the main source of lighting, supplemented on dull days with electrical light which is provided throughout the building. Design is based on achieving required general illuminance levels with the provision of socket outlets for task lighting. The typical design light level in classrooms is 300 lux with an installed density of 8-12W/m^2. Luminaries have glare control & provide both direct and indirect lighting. Lighting controls in classrooms are PIR with daylight dimming and local override switch and PIR only in common areas. Classrooms are equipped with absence detectors and corridors are controlled by presence detection. There is a large amount of external lighting serving the car park and open-air sports courts.

Presence detection is provided for internal rooms such as changing rooms, toilets and store rooms. Circulation/ atrium areas are designed with time clock and photocell control where feasible, with central override facilities under staff control. Lighting control to individual offices and plant / ancillary areas is by local light switches. External and security lighting is controlled via time clock and photocell systems as appropriate. Presence detection with daylight sensors is specified for internal/ external security lighting where applicable.

The main systems are controlled by the BMS; the log book states these to be air handling units, pumps, CW booster set and heating plant. The logbook directs the user to the O&Ms for the controls / BMS layout and the BMS software hierarchy; however, these are not present in the electronic O&M copy held by Aedas.

Under-floor heating is provided to heat the ground floor dining room, sports hall, atria, lower ground floor teaching areas and main hall areas. They have wall mounted thermostats to provide control. All laboratory and corridor areas are heated via ceiling-mounted LTHW radiant heating panels, controlled via local room thermostats and zone control valves. Where additional cooling is required in ICT enhanced areas, active chilled beams are provided with heating and cooling coils. These are controlled via local room thermostats and zone control valves. DX units provide cooling for the server room. Where radiators are provided, they are individually controlled by radiator-mounted, thermostatic valves. All terminal ventilation units are controlled by the BMS, although there is a manual override during occupied hours, for occupants to alter the temperature range by +/- 3 degrees C. Re-heat coils served by LTHW are designed to provide zonal control for each room, with a control link to the BMS and individual temperature sensors. The Stage D design specifies that all relevant fans will be variable `speed to allow air volume control. Stockport Academy also has a large catering facility for student meals, ICT loads for offices, library, classrooms and small power loads for teaching equipment such as portable fume cupboards. There is no detailed water management strategy, although low flush cisterns and aerated taps are installed.

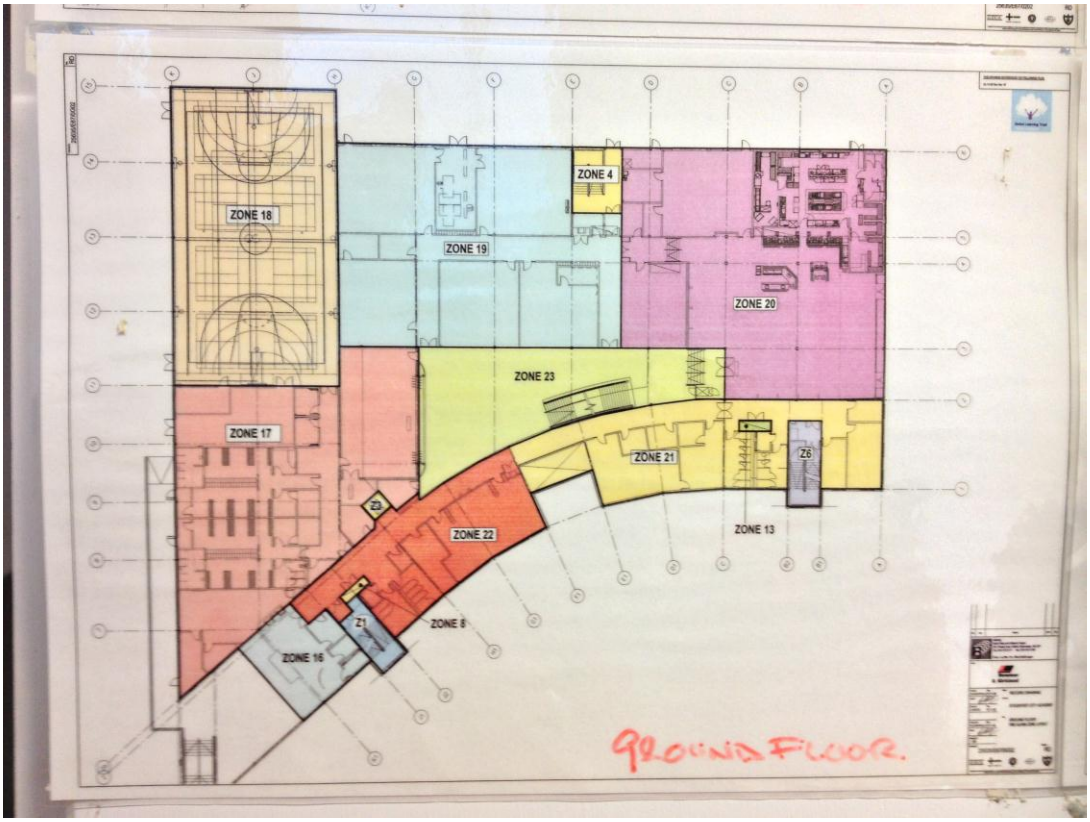


Figure 3.1: Ground Floor Zoning Strategy. The zoning arrangement described in these three images is not reflected on the BMS and therefore the facilities manager cannot take advantage of the systems zoning in out of hours. Due to this, optimisation of energy performance is not possible.

Figure 3.2: First Floor Zoning Strategy

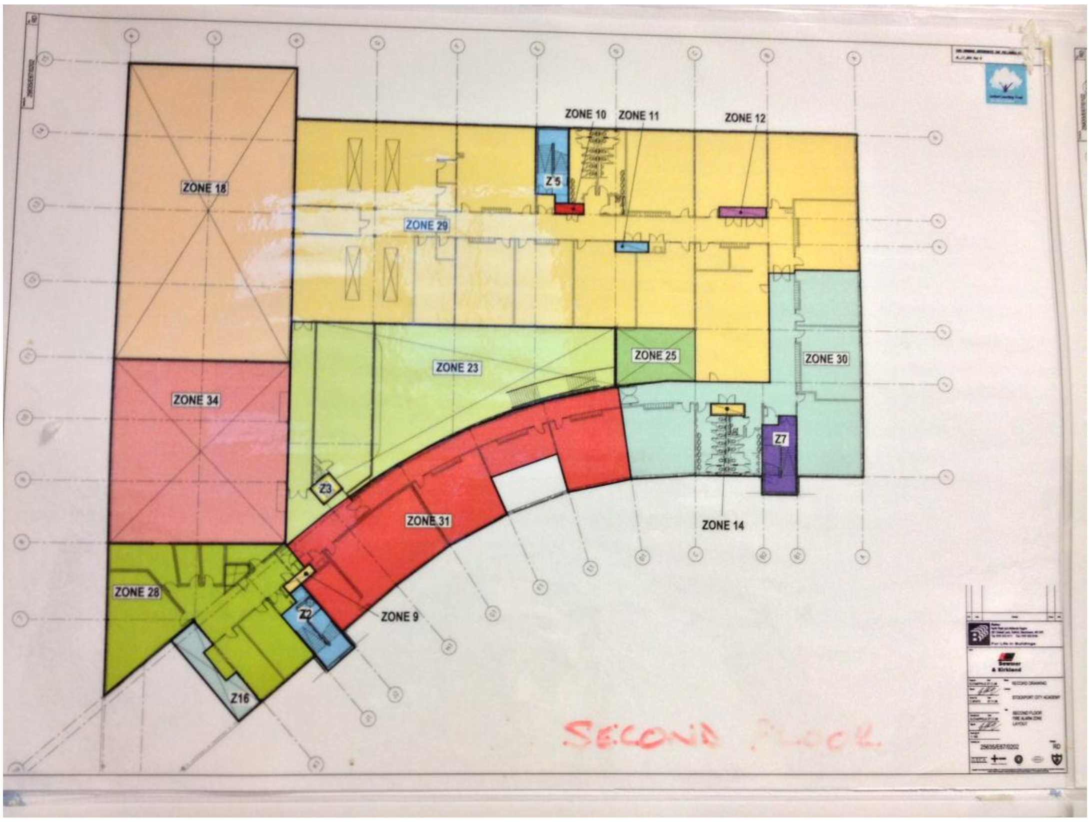


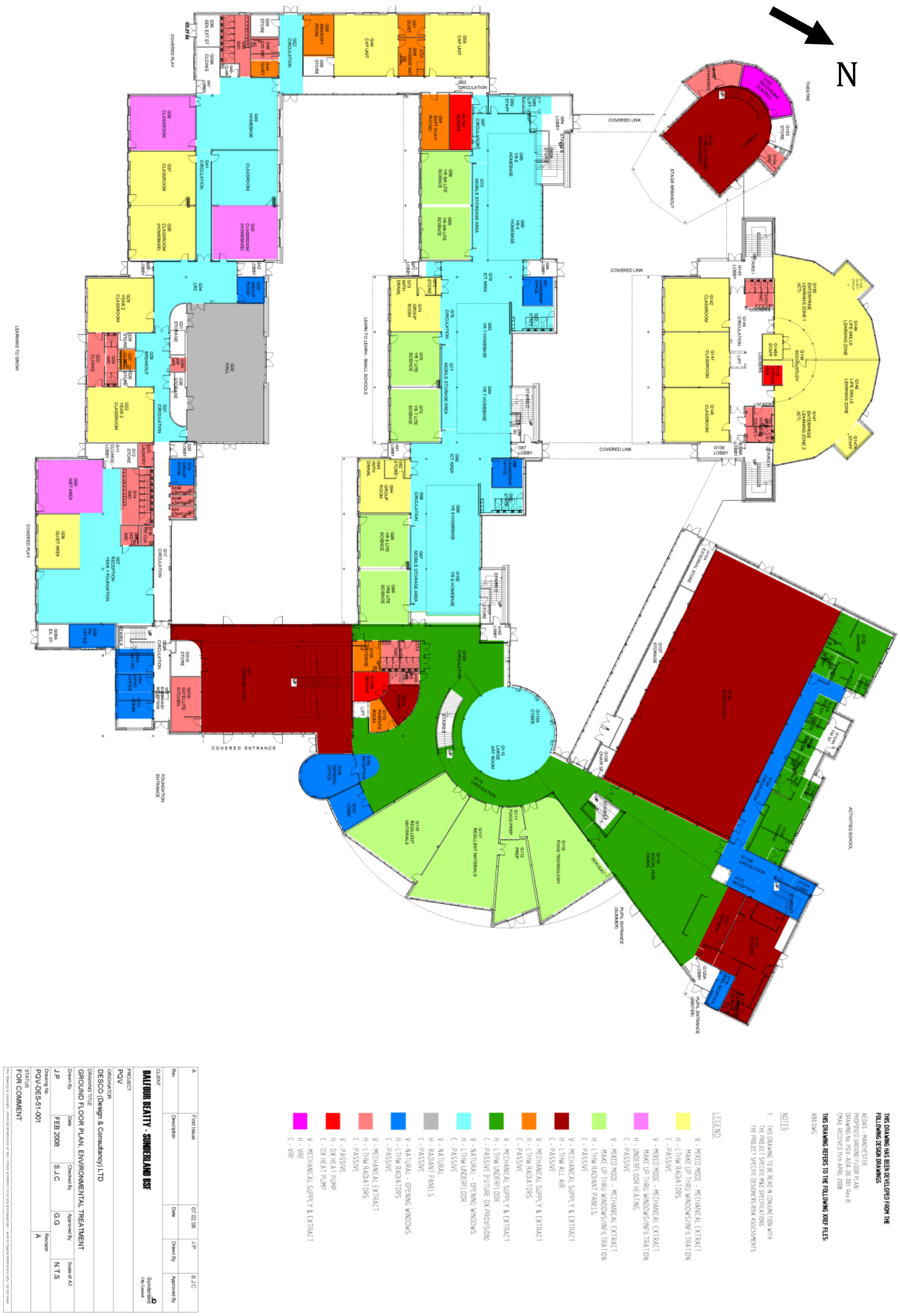
Figure 3.3: Second Floor Zoning Strategy

3.2 Pennywell 360 Academy

The Academy achieved a BER of 14.9 $kgCO_2/m^2/yr$, a BREEAM rating of Very Good and a B-rated EPC. Initially this building was conceived as a naturally ventilated building, but was later altered to mixed mode once the contract was let. This decision was made following an overheating report produced at detailed design stage which reported the single-sided ventilation was inadequate and there was a need for extra booster fans in these spaces. Extract booster fans triggered by manual switches in classrooms were installed to facilitate cross ventilation and mitigate the risk of overheating under extreme weather conditions. These booster fans are operated by the teachers, locally. The building is serviced by grid-supplied electricity. A 500kW biomass boiler is sized to supply low temperature hot water (LTHW) and is supplemented by 2 gas-fired condensing boilers – each capable of meeting a nominal 50% of the design heating load. These serve both constant temperature and variable temperature heating loops; constant temperature serving air handling units and hot-water plate / storage vessel. Where there is mechanical ventilation, it is provided by 7 air handling units; all supply and extract systems. These are controlled by the BMS with control set by Astral.

The two subsequent drawings illustrate the different HVAC strategies across the ground floor and the first & second floors. The zoning and HVAC strategies were developed at concept stage by AECOM. Desco used these as a starting point and further developed these concepts to achieve what had been agreed with Sunderland City Council at concept stage. In areas of the building that didn't meet the BB101 overheating criteria, Desco specified extract booster fans to comply.

The heating strategy was developed to accommodate partial operation of the building during out of hour activities. However, the downside of multiple zones is that it can be difficult to operate and may incur additional maintenance cost. It should be noted that there is no direct correlation between the heating and ventilation strategies, i.e not all rooms with under-floor heating are naturally ventilated, due to the comment above.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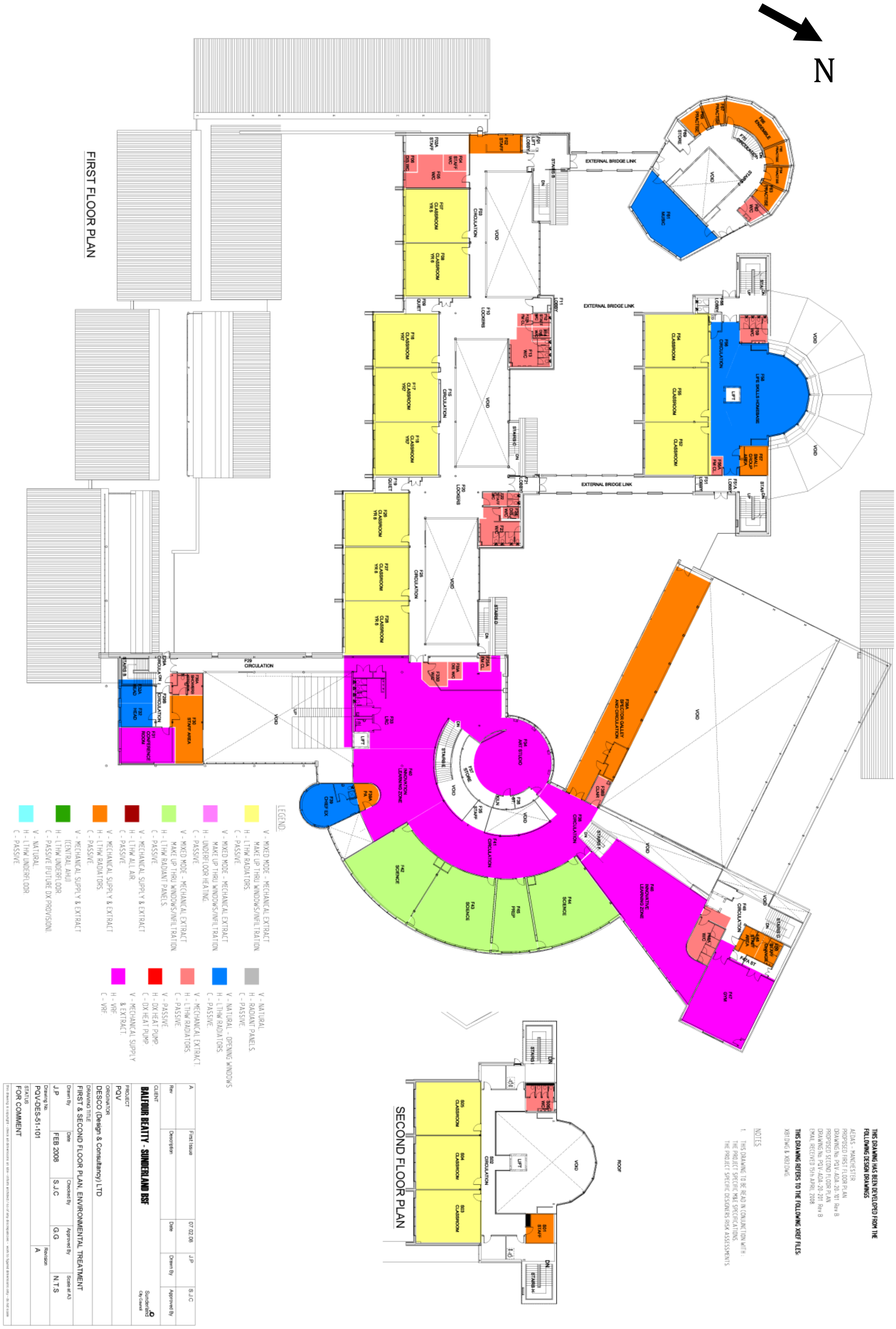



Figure 3.6: Internal break-out space

The large internal breakout spaces form part of the ventilation route for perimeter classroom areas. In order to ensure ventilation is available at all times, the internal areas are serviced by earth ducts. The system uses below ground ducts to deliver fresh air through low level air terminals. This strategy enables air to be preheated by surrounding ground material during winter months and pre-cooled during the summer. Passive stack ventilation is utilised to vent exhaust air through high-level operable vents in the double height spaces. The majority of perimeter classrooms which surround the break out spaces are provided with single-sided opening windows; providing cross ventilation alongside the passive stack. Extract fans are integrated into the classroom system to offer a “boost” facility to ventilation rates for peak summer months.

Generally, automatic lighting control is by means of presence detectors and/or daylight sensing photocells. Manual lighting controls are also provided in each room by means of a local light switch. Installed lighting efficacy is 57 lumens per watt. In areas of low occupation such as circulation spaces, breakout areas, toilets and changing rooms, control is by automatic presence detection only. Low energy, high frequency fluorescent lamps are used throughout the installation with a range of common lamp types to simplify maintenance and rationalise the stock of spares.

In teaching spaces with natural daylight available from side windows, electric lighting is arranged in rows/banks of lighting parallel to the window which incorporate an integrated solution with combined day lighting control and microwave movement sensors within rooms that provide good levels of natural lighting and also maximise energy efficiency. Manual over-ride facilities are provided to any automatic controls in classrooms giving staff the flexibility required for presentation work. Other spaces that contain daylight sensing controls are occupied spaces that have external windows such as offices and learning bases. There are various external lights around the perimeter of the building and throughout the car parking areas that are controlled by the BMS and set by the facilities manager.

Additional loads include 4, 6-person lifts across the building, stage, car park and sports flood lighting and teaching kitchens.

Mains cold water is metered, with cold water storage tank (two compartments), low usage taps and dual flush WCs installed across the Academy. Pennywell Academy 360 provides lunch for all its students, daily, and also has food technology classrooms. It also has a significant IT and small power load.

3.3 Petchey Academy

Due to concerns over road noise, Buro Happold (BH), the design M&E engineers opted for a fully mechanically ventilated system with partial air-conditioning and heat recovery. Aedas argued against this at several meetings as the architecture team felt that the acoustic test figures were borderline BB93 requirements and this approach was overly cautious in a predominantly quiet residential area. There was also concern that the mechanical systems would be too complex and difficult to manage for the school. The building was designed prior to Part L 2006 and a full SBEM calculation wasn't carried out. No EPC was produced for Petchey Academy. However, a parallel research study carried out by UCL MSc students put the potential EPC rating at C, which is in line with Part L 2002 and design strategies.

A central building management system provides central control of the operation, setpoints and scheduling of plant and systems components (such as the air handling units, fans, boilers, overdoor heaters, etc). The interface with the building management system is provided by a remote outstation located within the ground floor admin office.

AHUs with heat recovery (including summer bypass) provide supply and extract ventilation to all classrooms, staff areas and changing rooms. The design specification was for 4x500kW air cooled chillers but two Airedale air cooled chillers, each with a rated output of 208kW, are installed in the second floor plantroom and provide the chilled water to fan coil units and to AHUs serving the Auditorium, Dining Area, Virtual Learning Areas, the Dance Studio, the Main and Training Kitchens.

The ventilation air flow for the boilers is provided naturally via louvered openings in the dedicated boiler housing/glower ground plantroom. Fan coil units serve 6 data hub rooms and 1 server room, 4 ICT rooms, 4 music rooms and some additional classrooms with higher heat gains, such as Maths, Art, Graphics, Sport and Humanities. Each classroom has a single window to supplement mechanical ventilation. This is not enough to allow adequate ventilation for science rooms during simple experiments. Five Monodraught type roof ventilators are installed to provide natural ventilation to the Sports Hall. The roof ventilators are automatically controlled by the BMS based on internal temperature. 17 extract fans provide extract ventilation provision to serve toilets, kitchen, fume cupboards, workshops and training kitchen/food tech.

Heating is provided by three condensing gas-fired boilers with modulating burners (225kW each) located in the basement generating LTHW for the East Wing and the Auditorium, dining, drama, library and presentation spaces. Four additional and identical boilers are located in the second floor plant room supplying heating via LTHW pipework that is feeding radiators in the West Wing only. Electric hot water supply was installed in the training kitchen and admin areas. Under-floor heating serves the sports hall and dining areas which are controlled by wall-mounted thermostats. 2x12kW locally controlled overhead door heaters are installed in the entrance lobby.

Domestic hot water services are provided via a single pipe system by 3 stand alone gas-fired heaters and a packaged booster set located in the lower ground plant room and second floor plant room. A trace heating system maintains supply temperatures.

Figure 3.7: Exposed ceiling with hanging 2D fluorescent fittings

Lighting throughout the building is predominantly T5 fluorescent and compact fluorescent luminaires. A number of 2D fluorescent fittings are installed within circulation areas and some classrooms. Lighting within cellular spaces is generally PIR controlled. Lighting within open plan and circulation is generally manually controlled with retrofitted pull-cords. Lighting systems are linked to occupancy sensors but there is no daylight actuation or dimming. The lighting system was initially designed to be linked to the BMS with no override switches installed which meant that

teachers could not turn them off at will. Target lux levels are typically 300-350 lux for classrooms with an installed power density of 10W/m^2. Corridor light levels are set at 150 lux.
The team had access to the building log book and O&M manuals but, similarly to the other projects, these were lacking detailed information with regard to bespoke BMS settings. Initial visits indicated that a combination of poor zoning, lack of controls, high IT loads, complex systems and lack of management time had led to significant unregulated emissions before the school was even running at full capacity. During later inspections and interviews with the maintenance staff it emerged that the server room and data hub rooms were on the same cooling circuit as the rest of the building which meant that the server room's schedule and set points were activating the cooling system all year round. Whilst the school was keen to address these issues, no changes were made until the end of the study, when a further Energy Audit was commissioned by the school as part of an opportunity to apply for funding.

OR Consulting's energy survey identified 33% potential energy use reductions amounting to 58% of CO_2 emissions resulting in a potential saving of over £70K in utility costs. The survey supported the BPE findings by listing the following issues:

> "The chiller is operating continually throughout the year, regardless of external temperature. Peak AHU energy consumption is occurring during the summer holiday period when the building is largely unoccupied.."

Our study found that a number of fans also worked 24/7 and this observation contributed to the excessive base load of the building, which is in excess of 140KW.

The OR Consulting recommendations related to the installation of a dedicated IT equipment cooling system, re-programming the BMS, retrofitting metering and voltage optimisation and setting up a measuring and monitoring regime.
The monitoring team would not recommend the installation of voltage optimisation as harmonics introduced by variable speed drives could negate the impact of voltage optimisation.

3.4 Conclusions and key findings for this section

Regardless of the specifications of the HVAC systems, all three buildings had complex building management systems installed and this complexity played a major role in the excessive energy consumption recorded in all buildings. Apart from Petchey Academy, where the chilled water system specification caused additional complications, the installed systems would be capable of delivering a good level of comfort at lower energy consumption. The risks associated with these systems are high and not adequately highlighted in either design guidance or the procurement process.

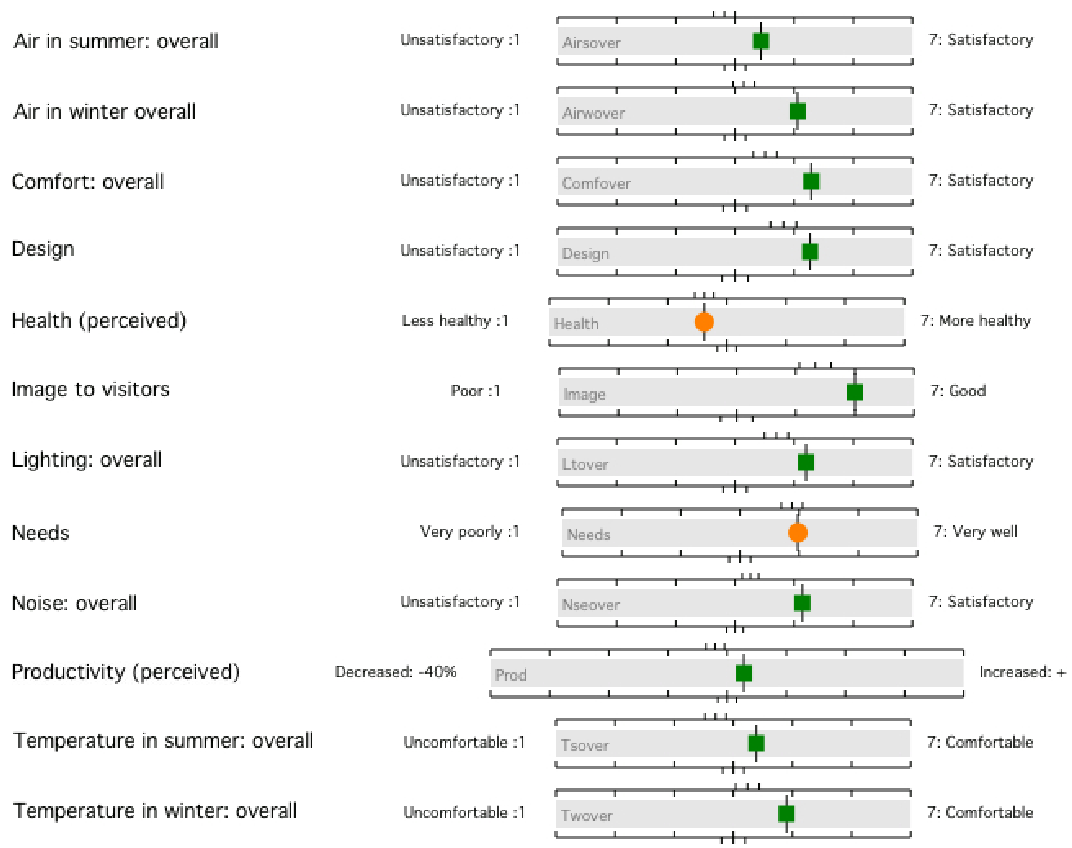
In Pennywell, where dedicated staff was allocated to monitoring the building management system, there were significant improvements achieved as a result of the monitoring. Although many of the symptoms were highlighted earlier in the study, it wasn't until an intensive monitoring week was carried out that the root causes of the problems could be diagnosed.

All three academies experienced problems with the zoning and controls of lighting systems to varying degrees. In Petchey, manual overrides (pull-cords) had to be installed to allow teachers to override the settings as and when required. Common area lights were observed to be on when good daylight was available as no daylight sensors were installed. At Pennywell and Stockport, daylight sensors were not fully enabled in common areas. External lighting controls proved problematic at Pennywell in early stages of post-occupancy.

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 Stockport Academy



BUS Survey Reponses (75 / 100)

Narratives have been compiled for each of 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.

Summary of comments related to individual sections:

Design
On the whole, comments on design of the building were positive. There were a couple of minor access / accommodation complaints but many of the responses in this section were describing noise and temperature issues.

- Bit noisy. Atrium noise reverberates to all areas – difficulties when running exams
- Lower ground floor feels like isolated – like a basement
- Light and spacious
- Most aspects of the building are very good, however there are a few aspects that could have been improved
- Beautiful building, not always practical
- No exit to bin store area
- Insufficient ventilation in main atrium in summer
- Too cold in winter, too hot in summer
- No P.E classroom – have to use rooms all over the building
- Atrium seems to be a waste of space
- Heating and cooling issues, wind tunnel in reception when doors opened

Needs
The general consensus in this section was that the facilities team is very responsive to the occupants needs. The overriding issue reported was of a lack of staff toilet facilities.

- Lack of storage space
- Too few staff toilets and all located on the ground floor
- One issue is the lighting in the hall and sports hall, it's very difficult to deal with faults due to height. A motorised system, maybe?
- Outside areas for pupils, dull
- Large, open plan area, now we use display boards to divide up the space
- More thought should have gone into the D&T rooms
- Sports hall out of use during exams in winter – this is disruptive to lessons

Meeting
The overall thought is that there is not enough meeting space available to teachers and that there is a general lack of daylight in them.

Storage

100% of respondents reported a lack of storage

- Insufficient storage
- Exam chairs and tables stored in PE store – lack of space
- Nowhere to hang coat, keep personal items. Not enough for student work

Space

Almost all of the comments reported a cramped environment. These comments were relating to workspaces.

- I find it ideal
- Have to store things in the staffroom and use that as an office
- Need a hook to hang my coat and a key to lock my desk drawers
- Rooms too small for 6 colleagues to work comfortably. Workplace limited and so feel 'closed in'. Too squashed
- No set area for PE staff.

Comfort

There are very few responses in this section, but one of them repeats the problem of a lack of staff toilets.

Noise

Many responses report noise levels relative to building use. However, the atrium, music rooms and dance hall in particular are problematic. Excessive noise due to air-conditioning was also reported.

- We are a school. It gets noisy in the atrium and outside when windows are open.
- Noise for the most part has reduced well, however some areas such as the dance studio and music rooms do not seem to be adequately soundproofed
- The wind whistles in my room – the students find it distracting
- All satisfactory
- The nature of the job with kids. However, LRC is very noisy (aircon),atrium is very noisy (background)

Lighting

Many respondents say that the lighting is satisfactory, with some comments about inadequate blinds and harsh, artificial light.

- For personal use I find the lighting both natural and artificial to be more than adequate, the only problem perhaps being the cost of the light fitting, but that is a separate issue

- Too many lights on during bright days
- Teaching rooms on playground side have issues using the blinds when sun is bright, students cannot see board even with blinds down.

Health

Lack of fresh air within the classrooms/offices seems to bring on illnesses.

- Picked up more sickness being here in the last 3 years
- Stuffy and poorly ventilated. Lots of bugs / viruses around
- This is not a healthy building. Students and staff are always catching bugs

Problems

The majority of the problems reported were associated with temperature complaints – both too hot and too cold.

- Requests for adjustments are often met with 'sorry, we adjusted somewhere else and it had a knock-on effect'
- Phil and ICT services are spot on
- Temperature too hot or too cold. Reception whiling wind due to doors opening at the same time causing papers to blow about in the office

Behaviour

There are many reports of fluctuating temperature causing problems, children getting into trouble for wearing their coats indoors due to cold temperature and irritable occupants when it becomes too hot.

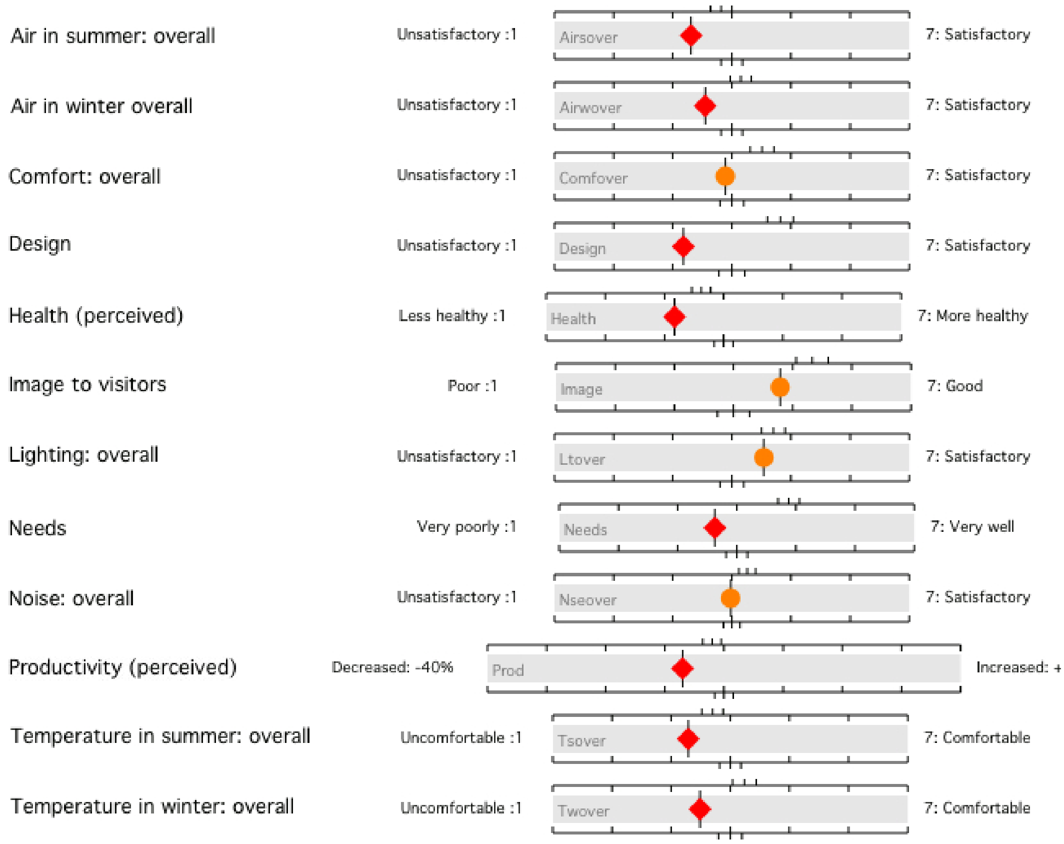
- I try to match what I wear for work to the temperature conditions inside the building but it's very difficult when temperature fluctuates so much.
- Need to leave my coat on in class
- Sometimes can be irritable when too hot

Overall, the results from the BUS are overwhelmingly positive but concerns have been raised with regard to the ventilation system. Some air filters were found to be dirty during the initial inspection and later in the study, during the intensive monitoring study, an AHU serving a stack of classrooms was found not to be operating. Users complained of headaches and stuffiness but no mechanism was in place to expertly follow these up. Once the monitoring team highlighted the issue the problem was fixed.

This case study illustrates that a positive BUS does not necessarily indicate good energy performance. Anecdotal evidence from the BPE workshop held at Coventry University in Jan 2013 shows that a comfortable environment can be provided with sub-optimal control systems but usually at a greater energy cost. People may be happy with lighting and air quality for example but this may have come at the expense of excessive energy consumption; in Stockport by means of poor lighting control and misgivings of the demand-controlled ventilation. Further explanation of these misgivings can be found later in this report.

The mechanical ventilation strategy was specified to meet BB93 acoustic criteria as the academy is located beneath the Manchester Airport flight path. Yet, the evidence reveals ductwork attenuation is not very good and sound levels above 35db have been consistently observed/measured in the classrooms. Yet, despite a couple of negative comments, people seem to be generally happy with noise and acoustic performance of the building. This raises some questions about the relevance and appropriateness of existing BB93 criteria where a poorly implemented mechanical ventilation strategy specified on acoustic grounds has failed and people seem to have no issue with this. Apart from compliance point of view, there may have been no need for the specification of a mechanically ventilated system and they could have gone with natural ventilation strategy instead with far less energy consumption (see the implications of Stockport mechanical ventilation system for energy consumption in Section 6). In this case, the indoor noise levels would have remained under the 35db restriction for the majority of the time.

4.2 Pennywell 360 Academy



BUS Survey Reponses (107 / 166)

Design

The majority of the comments reported the inadequacy of the open spaces in terms of teaching, noise and behaviour control. There were also concerns over storage space and the dining hall being too small for purpose.

- Open teaching spaces not suitable for effective teaching and learning
- Poor layout / wasted spaces
- Too many open spaces, exits / entries for students to enter / exit building
- Rooms are too small, not enough cupboards
- Not enough classrooms / sports hall. Inappropriate playground
- Balconies and open spaces are terrible for teaching and controlling behaviour
- Rooms are odd shapes – e.g. triangular. Difficult to work in
- Cold building. Air bridges are unnecessary. Dining halls are too small and in the wrong place, assembly hall seating not very good

Needs

This section repeated most of the comments from the 'design' section, with the emphasis here being on a lack of storage, staffroom issues and inappropriate outdoor provision for the students. Glare on interactive whiteboards was also of concern.

- Inflexible rooms
- Pupils taught in open areas is not a good idea. Yards are soulless
- No rooms to hold meetings, offices too small
- Small, out of the way staff room. Window arrangement bad for interactive white board
- Not enough provision for lunches and wet breaks
- Too few restrooms, no staff room, not enough storage

Meeting

All comments in the section suggested that there was a lack of meeting rooms. There were also some reports of problems with the booking system.

Storage

Most respondents reported a general lack of storage. Where storage was available, some staff members felt it was located too far away from point-of-use.

Space

Apart from a lack of storage space, the most common comment here was that of provision for the teachers in a classroom.

- No desk space – just a computer
- Fine, just no storage
- Desks are squashed
- A small lectern, no space and with back problems the seating leaves me hurting at the end of the day

Comfort

Reports of bad smells and some temperature issues

- Lovely building but office area noisy and cold. Desks in wrong position in office
- Can't use classroom sinks due to bad smells. Terrible. Corridor stinks and makes you feel sick. Sinks fill up on their own of dirty water
- Have to go outside to get from place to place
- Not enough space / area for pupils at break times – they need things to do and supervision

Have a heater in winter as office gets very cold

Noise

There are many reports of excessive noise, mostly in open areas.

- In open areas noise travels too easily
- Varies at times
- Disturbances come from main hall when pupil activities include loud music. Noise from pupils and parents at end of school day under office windows
- Noise from rooms above – chairs dragging on floor

Lighting

Many reports of blinds having to be used continuously leading to electrical lights being on.

- Blinds good and can adjust
- Lights on all the time. Blackout blinds down all the time glare on computer screens
- Whiteboard is hard to see due to position of windows
- Can’t have natural light as room heats up too much. Blinds always down.
- Fine
- Turn off lights when not needed. Lights come on automatically

Health

There seem to be many reports of health issues, believed to be caused or exacerbated by the building

- I get a lot of headaches and stomach aches. I have stopped drinking the water and bring my own. Usually cold.
- Sickly and light-headed
- Worried about RSI when using mac at podium
- I have problems with my feet and nowhere to rest
- Seem to be catching colds more often

Behaviour

Again, there are many complaints due to open spaces. Temperature is also an issue.

- Had to find other areas to work with children as smell was overpowering
- Open spaces are very challenging and stressful for staff to work in so tend to avoid
- When it’s too hot / cold I get irritable because pupils become irritable

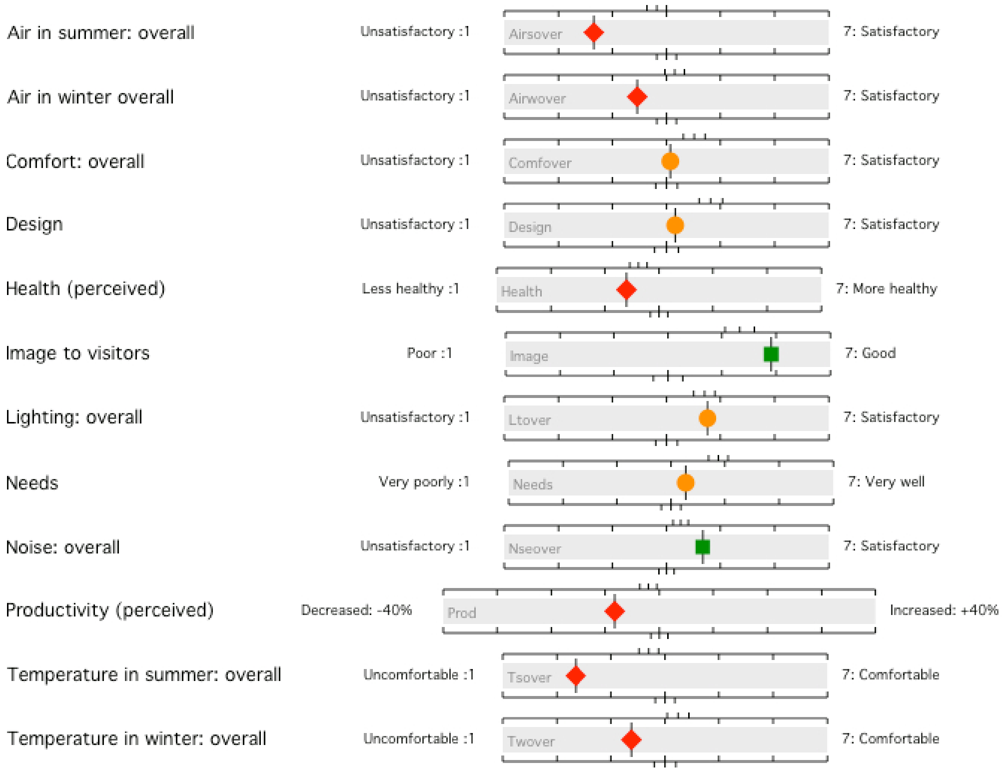
- This building causes people to become annoyed more quickly (due to stress caused by design)

Pennywell Academy received mixed user feedback. The feedback on overall comfort, lighting, noise and image to visitors was average. However, users were not satisfied with temperature and air quality, design (configuration of spaces) or storage and as a result felt that the building didn’t meet their needs, lowered their productivity and affected their health.

In this case study, correlating BUS with post-occupancy observations is a challenge. Comments about complexity of layout, lack of space and small office spaces corroborate with the BPE team’s observations - the case of the attendance officer’s room; room G120 on the architectural drawing for example. Furthermore, the team has witnessed the effect of excessive noise in open plan spaces on the classrooms noise levels such as the noise level from the Life Skills Homebase (F58 on the architectural drawing) on adjacent classrooms and second floor classrooms. As for temperature and air quality, this is predominantly a naturally ventilated building and therefore some degree of variation in these factors is expected but the evidence does not point to any serious problem on those fronts.. Further study is needed to establish to what extent dissatisfaction with the physical building influences occupants' satisfaction with comfort. In this case, the recorded comfort data, such as temperature and CO_2 levels were comparable with other buildings evaluated by Aedas under the funding stream. However, Pennywell occupants reported low comfort levels, whereas other buildings reported higher comfort levels. The most obvious difference between Pennywell and other buildings was that Pennywell occupants were demonstrably unhappy with the complex layout and usability of the spaces.

4.3 Petchey Academy

Summary (Overall variables)



BUS Survey Reponses (76/106)

Design

A number of the staff at Petchey felt that some areas of the building were impractical for a school with the school being too small with corridors being too narrow.

- Odd areas (bubble roof) - pointed corners impractical/atrium waste of corridors too narrow space.
- Too many sharp angles
- Triangular classrooms do not work
- Lovely building but too small.
- Building is pleasant to look at however space is not considered properly in design.
- Sharp corners look nice but vital space is lost.
- Design is good but a little complex to navigate.
- Beautifully designed modern and functional.

Needs

The main concern in Petchey is the lack of adequate space for the size of school.

- Too hot or too cold in certain areas
- Lack of classrooms. Not enough quiet space.
- Labs - not enough. Not enough room
- Not enough staff toilets. Lift. Not enough classrooms.
- Straight corridors were needed.
- More space needed inside. Some cramped offices - MFL.

Meeting
Overall thought is that there is not enough meeting space available to teachers, etc.

Storage
More than 50% of the occupant said there were insufficient storage facilitates to accommodate what is required.

- Not many spaces in department for resources.
- Not enough - broken cupboards etc.
- Nowhere to hang coat, keep personal items. Not enough for student work.
- Not enough on show so looks messy.

Space
Not enough space to accommodate all teachers.

- Cramped.
- I currently share a desk with another member of staff.
- Work area is a bit cramped, as 19 people use an area smaller than a classroom. But I have my own desk to keep my things.
- Sharing a desk with another colleague.
- I have brought my own drawers into the office.

Comfort
Majority of the staff find the overall conditions in Petchey in the winter and summer uncomfortable.

Noise

- Students running outside in the corridor.
- Children, building works.
- Noise transfers through from adjoining classroom all too easily. Students constantly knocking on the office door for us to open the toilet for them.

- Noise levels ok - some colleagues too chatty! Some noise from students above.
- Most of the time we can handle noise of the students on the above classroom.

Lighting

Over 60% of the staff thinks the overall lighting in the school is satisfactory.

- Would be good to be able to control which lights turn on and off in the room.
- I would like to have more of an option instead of on and off.
- No issue about lighting.

Health

Lack of fresh air within the classrooms/offices seems to bring on illnesses.

- Too humid and stuffy.
- No proper ventilation in office, windows do not open. Can get very stuffy.
- Suffer headaches frequently in my opinion linked to stuffy air.
- The air in the office. Feel full of germs - we all get ill all the time.

Problems

Over 80% of the staff reported problem relating to heating and cooling to appropriate members of staff and only about 20% of them were satisfied with the feedback they received.

Behaviour

Majority of the behavioural problems have been due to temperature changes.

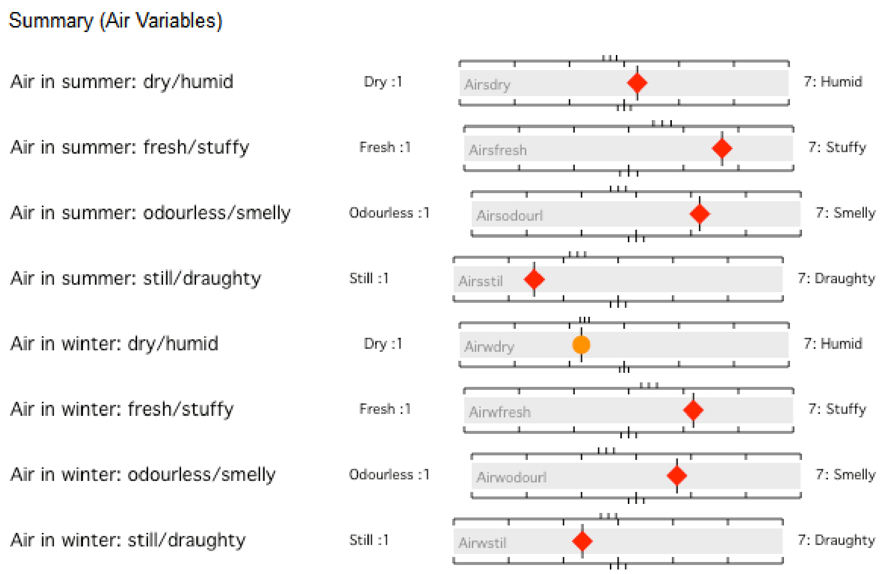
- Kids too hot/too cold creates disruptive atmosphere.
- Heating and cooling issues do irritated when external changes in temperature occur.
- Building is too hot for students and teaching lessons in the afternoon.
- More agitated - as do students.
- The conditions can have an effect on staff happiness.

Travel

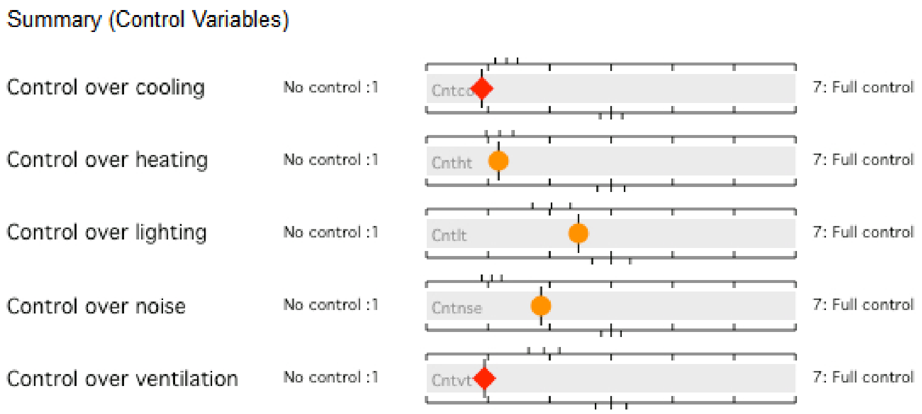
Over 85% of the staff live relative close to the school (< 1 hour).Petchey Academy is a popular secondary school with great academic results in a highly deprived area. There is a vibrant atmosphere with good discipline and enthusiastic teachers and students who are clearly taking pride in the building.

Since the opening of the academy the number of students and teachers grew by a 50% compared to the original design brief which explains the complaints about the lack of space and crammed conditions. Sensitivity about the angled spaces may be more accentuated due to the lack of space.

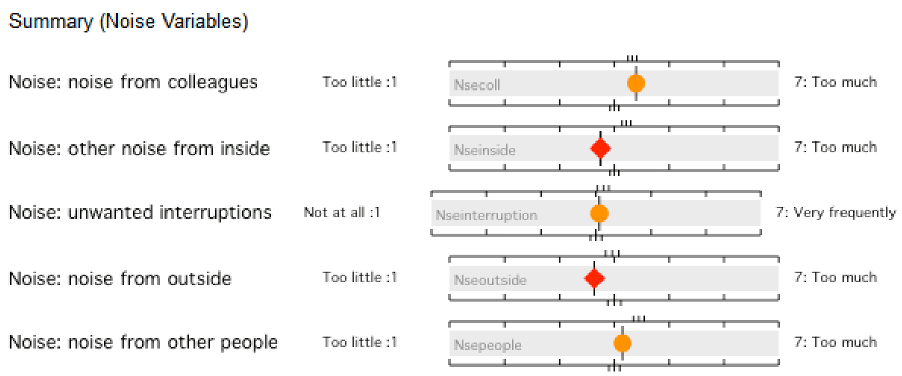
It is compelling to relate comfort issues to the finding that heating and cooling systems are fighting each other all year round. The snapshot of the 'air' page displays that temperature and air quality indicators are nearly always below average. This is one of the occasions where we can state that excessive energy consumption is coupled with serious comfort issues. The fact that such an extreme impact can be the result of such a trivial mechanical issue, i.e. the server room cooling being on the same system as the whole building cooling system with sub-optimal control valves that are letting by, shows that mechanical systems bring very high levels of risks to education buildings. The question is whether these risks are adequately portrayed in current design guidance and standards and the capital and operating costs associated with these risks are adequately highlighted to investors.



Petchey Academy has clearly suffered from multiple shortcomings in terms of the design and implementation of the control of building services. Occupants clearly feel that they have inadequate control of temperature and fresh air and that this affects their health and productivity – further adding to the cost of risk arising from the choice of mechanical systems.



In terms of comments about noise, it is ironic that the decision to go for a mechanically ventilated building was to prevent disruption from noise yet noise from external sources is still a major issue. Both noise from outside and noise from inside feature worse than BUS lower benchmark. The latter may be caused by the hard surfaces and the ETFE roof in the area causing excessive reverberations. This raises the question whether investment in costly mechanical systems was justified at all in this case. It is encouraging that, thanks to the energetic lobbying of the CIBSE School Design Group, the regulations for noise in education buildings have been somewhat relaxed and as a result, hopefully, less projects will be pressured into taking on such a high risk approach to building services.



In summary, occupants are happy with facilities management and support that they get from the school and are proud of their building but are let down by overcrowding and the poor implementation of building services mechanical services.

4.4 Conclusions and key findings for this section

The Building Use Surveys provided an excellent insight into the way occupants perceive the buildings and what they felt was important. In each case we found that most teaching staff were keen to give their comments despite their pressing schedules, even at Petchey Academy, where teachers had very little time to complete the forms. We would have liked to add more questions to the BUS that would allow for further feedback that is more specific to the school environment. A school-focused BUS would be helpful and Aedas has made a recommendation to the CIBSE School Design Group for this to be considered.

In architectural terms, occupants frequently raised issues with storage, spatial organisation and not having had enough input into the design. Fragmented spaces were highlighted at Pennywell with the difficulty to navigate and supervise the space. Stockport and Petchy staff had mixed views on the atria. In Petchey the use of the open space is more successful where it also acts as a timetabled space.

Air quality has been an issue in all buildings, despite the extensive mechanical services. At Stockport, BUS results score higher than the BUS midpoint benchmark in temperature control and fresh air provision. However, user/FM interviews revealed severe problems with the systems in a particular classrooms stack and that many users complained about the temperature control of the atrium. Tempered fresh air is being provided at a great penalty in terms of energy consumption and cost which demonstrates that unless energy data is gathered, collated and benchmarked systems can continue to operate at sub-optimal level for prolonged periods.

One of the conclusions of this study is that the design of mechanical ventilation and cooling of school buildings need reassessment in terms of value for money given the risks and costs associated.

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 Stockport Academy

Site-based personnel in charge of building management consist of the business manager and the on-site facilities manager. The business manager oversees all facilities on-site. She has a member of staff that helps her look after the energy bills. The facilities manager has a team of 4, including himself, and together they look after the day-to-day running of the school, whether that is moving furniture and equipment, ensuring the correct facilities are available during school hours and evening activities, or calling in engineers to assess and address problems with the plant. During the course of the building performance evaluation, the facilities manager has been studying the British Institute of Facilities Management, level 4, funded by the United Learning Trust who commissioned the Academy.

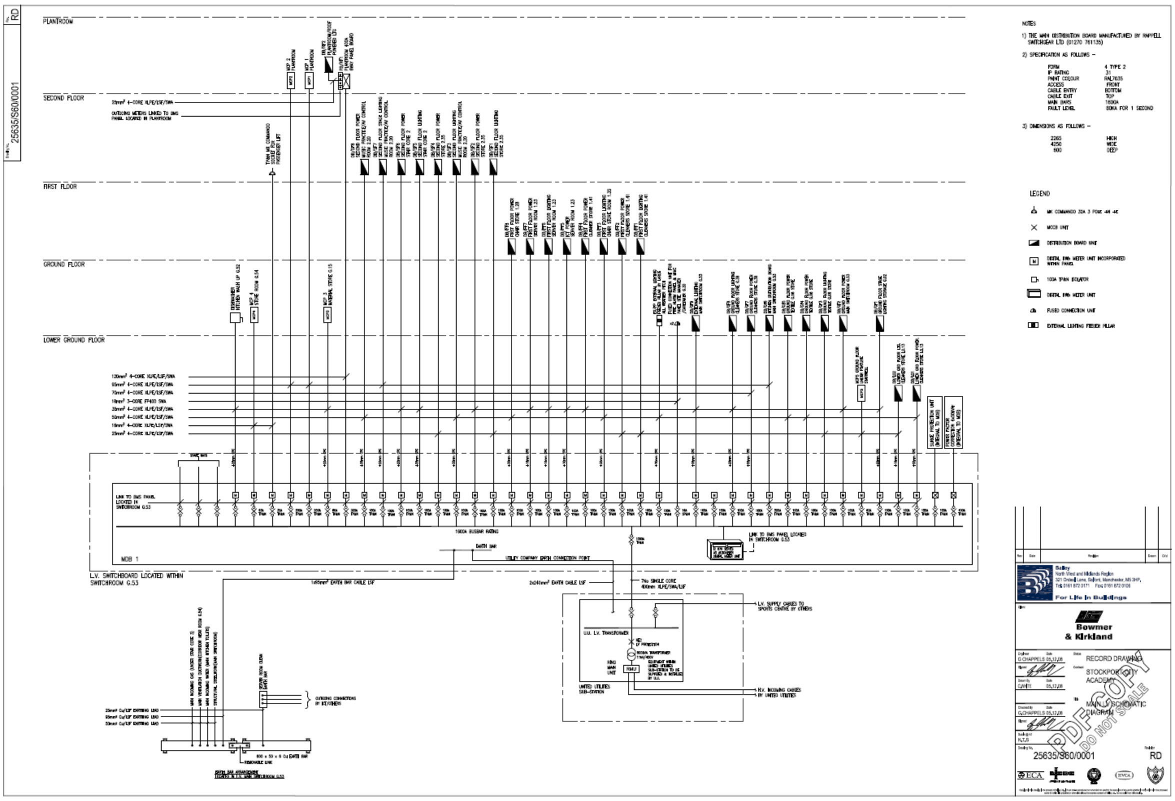


Figure 5.1: The electrical metering strategy for Stockport Academy

An extensive metering strategy underpins the systems in the Academy, as can be seen from the strategy outline, above. The energy consumption of all fans and pumps could also be interrogated from the display units on the inverters; the aggregate figures are consistent with total auxiliary consumption reported on the LV panel & the BMS. This is the best metering strategy of all the case studies, not just for the 3 academies, but for the two schools being evaluated under a separate bid. There is no mention of the meter for the ground source heat pump, nor could any ground source heat pump drawings be sourced in the digital O&Ms received. Further inspection on site, however, revealed 4 meters on the GSHP control panel in the plant room, each reading the contribution of the pumps (4 pumps in total). There are also two heat meters for the cooling contribution of the ground source heat pumps and the heat injection unit installed as the interface between the ground source heat pumps and the gas-fired boilers. These help quantify the heating and cooling contributions of the ground source heat pumps to the building's thermal demand.

NG Bailey was the company that installed the HVAC plant equipment during construction and also have the service and repair contract for the building. They send engineers to site to check systems and carry out regular maintenance of the systems. Their responsibility stops at the ground source heat pump (GSHP) which is carried out by a specialist sub-contractor. The Academy decided to replace the GSHP maintenance contractor following numerous, unresolved issues with the equipment; EnerG have been carrying out the maintenance on this system for the past year. Their remit extends across everything that is part of the stand-alone system including heat pumps, circulation pumps and control valves. The GSHP has its own control panel with meters for each pump but must be enabled by the BMS. Since the beginning of the existing maintenance contract, Matrix installed and set-up the BMS system. They are responsible for setting the controls for the systems and the interface but not directly for the equipment. This includes various control valves on chilled beams and radiant panels as well as heating controls, the temperature of incoming and return air and how the dampers are driven. They also look at the set points and make sure they all set in balance.

At the conclusion of the project, a meeting was held on site in order to discuss issues that had been uncovered during the course of the study; details of these will be covered in Section 7: Technical issues. During the meeting the EnergG representative was not aware of receiving any documentation or instruction as to how the systems should interact with each other. It transpired that none of the other attendees were aware of how their responsibilities overlapped either. It seems, from our BPE activities, that is it commonplace in the industry that various maintenance teams have not met and do not collaborate on arriving at seamless interaction of systems in a building. Equally, there did not seem to be a dedicated member of staff overlooking the energy consumption of the building. What is the purpose of a maintenance contract? Is it the responsibility of the contractors to sift through the log books to ensure that the systems are operating as intended or solely that they are operational? There is obviously a gap here that needs to be bridged.

In conclusion, there seems to be a proactive approach to the day-to-day running of the school and to the maintenance of the systems; this is reflected in the comments from the Building User Survey, which are all very positive about the facilities team's response to issues. However, it is essential that a single point-of-liaison is established in order to achieve the efficient running of the systems and that the contractors work together accordingly.

5.2 Pennywell 360 Academy

Although the Building Facilities Manager had no formal training, she was extremely engaged and proactive from the outset of the evaluation. She has been quick to act upon any findings or recommendations compiled and instructed Astral Maintenance on these bases.

Astral Maintenance have the service contract for the controls at Pennywell academy. Their remit covers the BMS and the temperature sensors building-wide. They have been extremely accommodating in creating extra screens and functionality on the BMS interface – for example by splitting the external lighting from the security lighting and creating separate control over these combined with 'if' statements. They visit the site approximately once every six weeks and have provided the extra screens as part of the contract with no extra costs. Energy benchmarking is not part of their remit, although they can provide a set of screens and functionality, including the ability for students to use them as a learning resource, for a set-up cost of around £2,500. In the absence of this, it falls to the facilities manager to keep track of how the building is performing.

The maintenance contract for the gas boilers in held by Gentoo who also visit the site around once every 6 weeks for preventative servicing and maintenance. They provide a similar service on the AHUs. Arcol service the manually operated, standalone air conditioning DX units. Armstrong is the company that installed the energy centre, and is called out as and when needed but hold no cyclical maintenance contract.

No service agreement has been set up for the biomass boiler, which hasn't been run properly since commissioning. The Academy has experienced multiple parts failures with the system, which has been very expensive to fix. The biomass boiler was eventually run for three weeks in November 2012, until the fuel ran out, in order to establish if this would indeed save any money. At present, they don't believe that it is financially feasible to run this system.

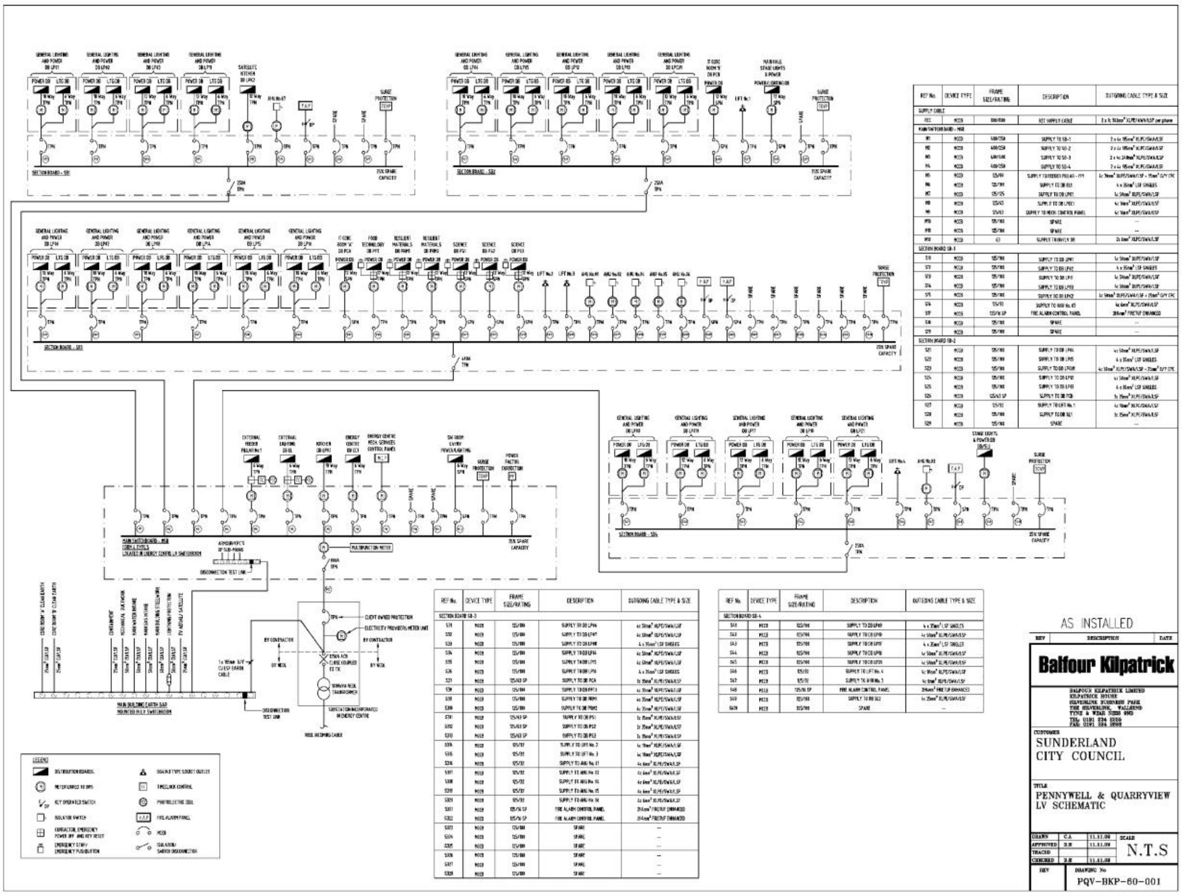


Figure 5.2: The electrical metering Strategy for Pennywell Academy

A detailed metering strategy is installed for the academy that separates internal lighting, external lighting, power, pumps and control, ventilation, IT infrastructure, and the catering facilities.

A reconciliation exercise was carried out in the early stages of the project to ensure the metering strategy is robust for monitoring purpose. The aggregate figure for sub-metered energy end-uses was within 1% of the mains electricity. Pennywell Academy's metering strategy also has its successes. Each of the 7 main air handling units (AHUs) is sub-metered, making robust quantification of mechanical ventilation possible. Lighting and small power are separately sub-metered and, therefore, good quality data can also be gathered for these. One major short-coming of the strategy is that the solar thermal panels are not sub metered, making it impossible to assess their contribution to the hot water demand. Furthermore, the hot water meter is not well wired up to the BMS and, therefore, it must be checked physically in order to ascertain the correct consumption. This meter is located in the ceiling void of the Attendance Manager's office and is not readily accessible. This is a major issue.

Figure 5.3: Poor placement of Hot Water meter. NB: All Health and Saftey points were observed during this activity!

5.3 Petchey Academy

No Soft Landings was carried out at Petchey Academy. The full-time site caretaker has repeatedly requested additional BMS training to deal with the problems of the systems. BMS maintenance was at times contracted out and one of these contractors found the issue with the server room cooling controls in year 3 of the building's operation. Teaching staff were complaining of cold temperatures to the point that they brought electric heaters into the rooms to counteract the effect of the cooling system during the winter. By the time the BPE team started on the project in 2010 the BMS had been handled by different agents. In the absence of a bespoke, BMS manual and commissioning records it was impossible to establish the original settings of the BMS and the causes of the poor profiling, operating schedules and set points. However, without separating off the server and data hub rooms' cooling system it is clear that further investment in recommissioning parts of the BMS will be thwarted by the cooling system working in overdrive.

The BPE study was hampered by poor electrical metering in Petchey – the initial meter reconciliation was more than 20% out mainly because some lighting and power section boards were not sub-metered. Subsequent reconciliation, carried out as part of the TM22 detailed study, discounted the meters that were malfunctioning and interpolated from other meter readings and end use analysis to achieve a good reconciliation of energy end uses. With regard to heating, the submetering was one of the best we have encountered. Metering for the chillers is indicated in the as-built metering strategy. However, these meters were never adequately installed (wired in) to the point that the display unit is blank.

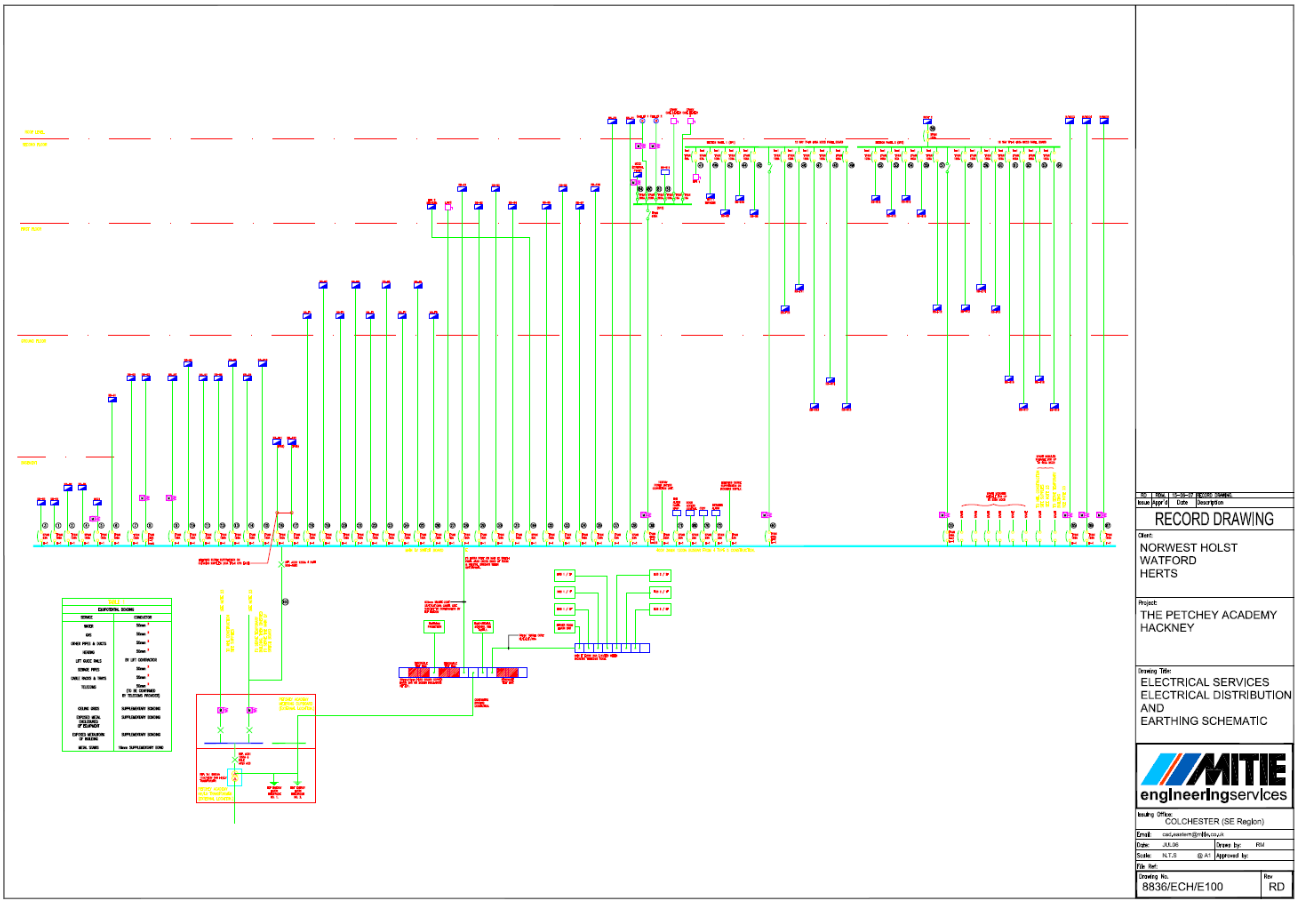


Figure 5.4: The electrical metering strategy for Petchey Academy

Figure 5.5: Sub-meters installed for chillers in Petchey academy are not wired up and do not report the electricity intake of the chillers.

5.4 Meter reconciliation

A meter reconciliation exercise was performed for all case studies and this formed the basis of the evaluation going forward. Each case study was visited at least once per quarter, during which all individual sub-meters would be checked and their values recorded. The aggregate figures were compared with the mains incoming energy. Overall, with the exception of electricity consumption in Petchey , all case studies showed good meter reconciliation. The TM22 exercises were then based on these results.

Cooling, both for the server rooms and for comfort cooling, is not well sub-metered.
In many buildings there is one server room and many data hub rooms. Where separate server room sub-meters exist, the metering strategies are often unclear as to what portion of the total load is covered by these; hub room loads are often embedded into small power. There exist similar problems with comfort cooling loads. A best-practice metering strategy would incorporate a sub-meter that gave a true value of the server and data hub rooms' loads.

For ventilation where there is variable speed control, separate sub-metering is preferable in order to confirm the efficiency of the system. Separate sub-meters for this were included in Stockport and Pennywell metering strategies and enabled the Building Performance Evaluation (BPE) team to ascertain the presence / absence of inverter driven ventilation. A good practice metering strategy would include such a meter which would aid the estimation of load factors for the inverters / AHUs.

That said, the occupants in these case studies had not engaged with the metering themselves and one must question the point of such a detailed strategy in this case. There seems to be a lack of understanding and education around this subject and therefore this needs more emphasis during training and handover. Moreover, how can the industry as a whole encourage building occupants to take ownership of this and use the facility to perform their own forensics and manage their building correctly? The engagement of the Facilities Manager seems to be an important factor in the energy consumption of the building but the studies are not conclusive when it comes to the relationship between the quality of facilities management and thermal comfort.

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.

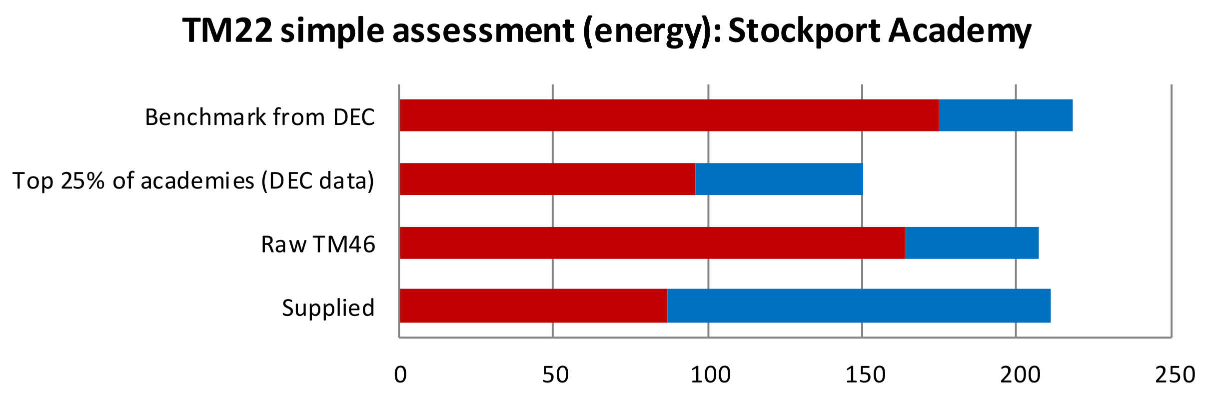
6.1 Stockport Academy

Stockport academy's comprehensive metering strategy provided good quality data for TM22 analysis. Following the simple analysis for total gas and electricity, a bottom up approach was used to reconcile end-uses with the metered data. The following Figures provide the outcome of the TM22 simple analysis.

The user specified benchmark used is the median of the data available for the top 25% of academies based on the study done by Godoy-Shimizu et al. (2011)[1]. The sample used for academies in this study includes 38 buildings. The sample size is not large partly due to the relatively low number of academies (mostly new-built) with valid DECs. However, these benchmarks reflect the energy consumption trend of modern school buildings; these buildings tend to have lower fossil fuel consumption due to higher insulation levels and air tightness. Electricity consumption, on the other hand, tends to be higher partly due to ever-increasing use of ICT equipment.

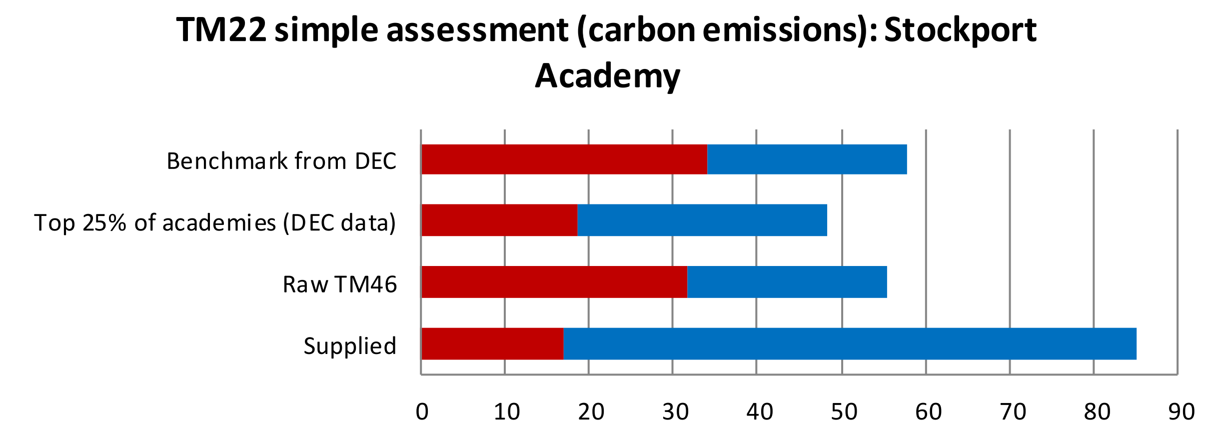
These graphs show that the academy's performance is significantly worse than all benchmarks when CO_2 metric is used. The latest lodged DEC for the academy is also G rated.

[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.



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kWh/m²/annum)	87.2	163.9	96	175
Electricity (kWh/m²/annum)	124.1	43.2	54	43

Figure 6.1: TM22 simple assessment for Stockport Academy: energy supplied



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kg CO_2/m²/annum)	16.9	31.8	18.6	34
Electricity (kg CO_2/m²/annum)	68.2	23.7	29.7	23.7

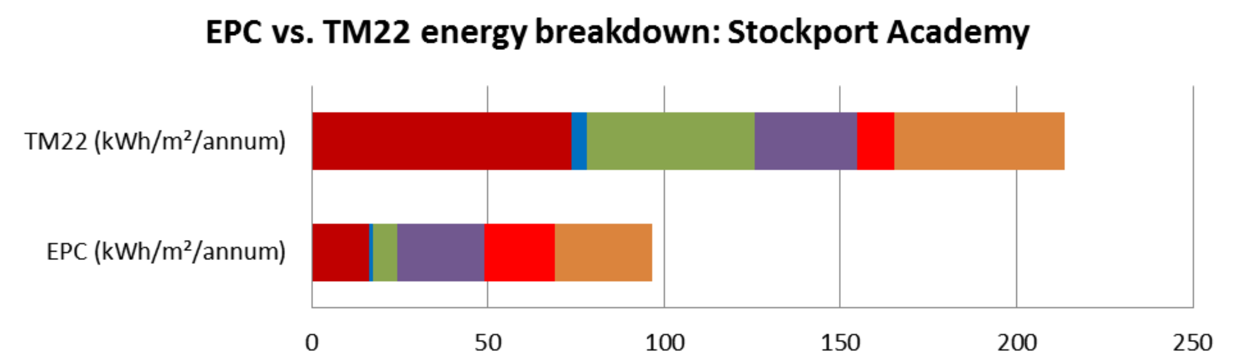
Figure 6.2: TM22 simple assessment for Stockport Academy: carbon emissions

The end-uses reported in Table 6.1 were reconciled with the mains electricity within 2% in the TM22 detailed analysis.

System	Fuel/Thermal demand (kWh/m²/year)	Electricity (kWh/m²/year)
Space Heating	69.3	4.4
Hot water	9.8	0.6
Refrigeration	0.0	4.5
Fans	0.0	35.4
Pumps	0.0	10.8
Controls	0.0	1.3
Lighting (Internal)	0.0	29.0
Lighting (External)	0.0	4.6
Small Power	0.0	8.9
ICT Equipment	0.0	18.6
Catering - Central	7.9	5.6
Catering - Distributed	0.0	2.8
Vertical Transportation	0.0	0.2
Total	**87.0**	**126.5**

Table 6.1: TM22 energy assessment for Stockport Academy: detailed analysis

The EPC certificate produced for Stockport Academy 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 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 benchmarking purposes. Figure 6.3 compares the results of TM22 energy assessment in-use and the EPC estimations for end-uses based on the energy end-use classification of 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 made for EPC assessment and their relevance to actual loads.



	EPC (kWh/m²/annum)	TM22 (kWh/m²/annum)
Heating	16.5	73.7
Cooling	1	4.5
Auxiliary	7	47.5
Lighting	24.5	29
DHW	19.9	10.4
Non-regulated end-use	27.7	48.6

Figure 6.3: EPC vs. TM22 in-use energy analysis for Stockport Academy[2]

The academy preforms significantly worse than design estimations in the following end-uses:

Heating

The academy runs a night school between 18:00 and 21:00 on Tuesdays and Thursdays and, therefore, its heating demand is higher than that of a typical 5:00-18:00 profile used in SBEM calculations. Furthermore, the estimated heating consumption in EPC calculations is based on the assumption that ground source heat pumps will satisfy 40% of heating demand.

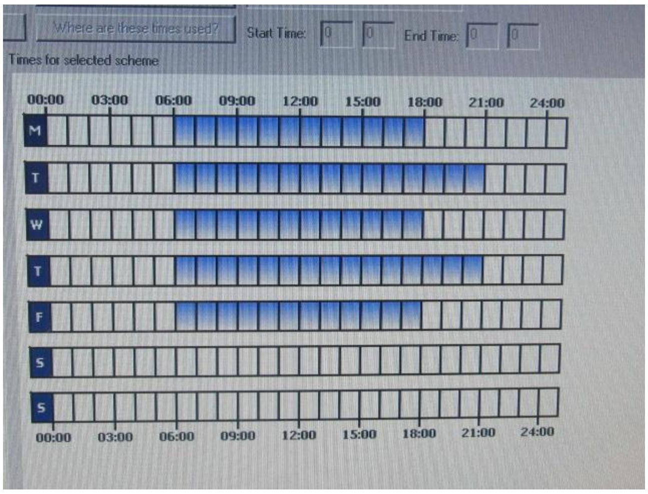


Figure 6.4: The heating profile for Stockport academy from BMS; there is extended operation on Tuesdays and Thursdays for night school.

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

The metered data for the ground source heat pumps' distribution board (electricity intake) and chilled water heat meter could help estimate the contribution of these units to the building's heating demand. Actual contribution of the GSHP system using the heating COP given by the manufacturer (4.1 in accordance with EN 14511) is estimated to be less than 19% i.e. less than half the design target. A likely root cause for this may be the control strategy adopted for ground source heat pumps. There is no buffer vessel between ground source heat pumps and the gas-fired boilers for heating. Heating and cooling to the secondary circuits are provided from a 'sliding' header arrangement with motorised valves that modulate according to the heating and cooling demand. The control system provides priority control for the cooling demand, with the injection circuit from the LTHW primary boiler plant to provide any additional heating required. As the ICT enhanced spaces within the academy may have cooling demand in winter due to equipment gain, it is likely that the cooling biased control strategy and the setup of heat injection result in gas-fired boilers taking the lead for heating. Maintenance issues, happened quite often throughout the measurement period, are another contributory factor. The research team have informed the GSHP and BMS contractors to look into the interaction of ground source heat pumps and gas-fired boilers. An integrated approach to energy performance and concerted action from all contractors is required to ensure the heating system performance is optimised. The fragmented nature of building maintenance where there are different systems in place especially advanced low or zero carbon technologies seems to be an issue in the academy.

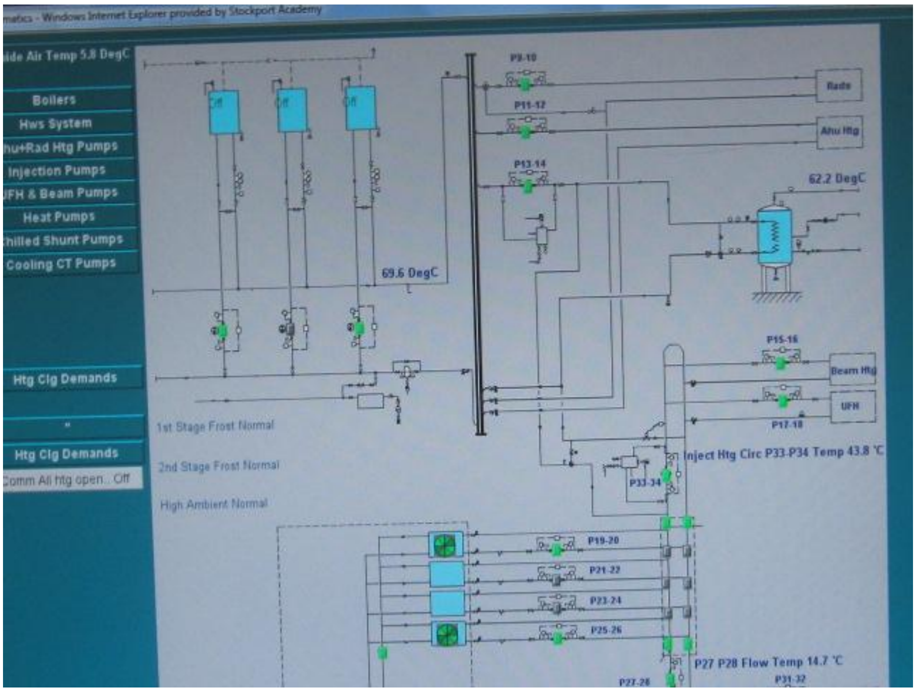


Figure 6.5: Sliding header arrangement and heat injection circuit between ground source heat pumps (below) and gas fired boilers (above, left).

Auxiliary (fans, pumps and controls)

the main root cause for excessive auxiliary consumption is mechanical ventilation. The design intent was to have demand-controlled ventilation in place. Inverters have been installed on all supply and extract fans of the main AHUs. However, the research team's intensive focus studies in February 2012 revealed that the inverters were not enabled. The fan status was always 99-100%

(even at 8 pm on Tuesday and Thursday when there were only few occupants in for night school) and full fresh air was supplied to empty classrooms. This problem is exacerbated by the fact that the air handling units are in full operation during half term breaks and school holidays. The research team discussed this issue with the maintenance contractors and the response was inverters were used at commissioning to balance the system and there is no CO_2 sensor installed in the extract ductwork to trigger demand-controlled ventilation. This is not consistent with the design intent; M&E designers of the building have confirmed that demand-controlled ventilation was indeed part of the design strategy. The mechanical ventilation strategy was adopted to meet BB93 acoustic criteria as the academy is located under the air path of Manchester airport. However, demand controlled ventilation and optimised schedule were critical to minimise the fans' energy consumption. The evidence suggests neither did happen. Furthermore, the efficiency of ventilation system at full load is less than design target. The M&E designers' design vs. as-built review confirms the as-installed specific fan power as 2.78 W/L/s. This is worse than the maximum allowable SFP in Building Regulations that was used in compliance calculations (i.e. 2.5 W/L/s).

Following the TM22 tree diagram concept, it is possible to explore how shortcomings in individual system parameters are compounded and lead to actual ventilation energy consumption that is almost three times what it should be (Table 6.2).

Stockport Academy	Ventilation rate	Efficiency	Ventilation density	Management factor	Annual hours of use	Ventilation energy
Actual Building:	2.59 (L/s)/m²	2.78 (W/(L/s))	7.2 (W/m²)	1.42	3454 h	35.4 (kWh/m²/annum)
System benchmark	2.21 (L/s)/m²	2.5 (W/(L/s))	5.5 (W/m²)	1	2521 h	13.9 (kWh/m²/annum)
Actual/ Benchmark	1.17	1.11	1.31	1.42	1.37	2.55
Notes	Actual figures are based on the final specification, commissioning results, and sub-metered data. Actual Management factor: Actual Ventilation energy/(Ventilation density ×Annual hours of use) Benchmark for Ventilation rate is based on nominal occupancy times 8 L/s/p fresh air in accordance with BB 101, and the BB 101 specified rates for toilets, shower rooms, and kitchen. Benchmark for efficiency is based on maximum allowable specific fan power in Building Regulations 2006. Benchmark Management factor = actual Management factor × 0.7 to allow for demand controlled ventilation Benchmark Annual hours of use takes into account the school break times and holidays i.e. 38 weeks per annum × academy's weekly profile					

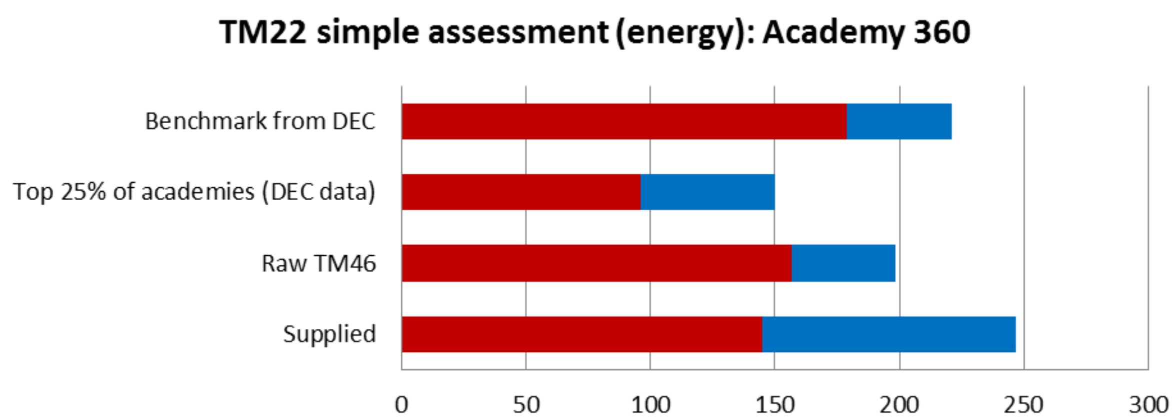
Table 6.2: System level benchmarking for Stockport Academy's mechanical ventilation system

Lighting

Whilst the installed lighting density in classrooms seems reasonable, ranging from 8 W/m² in typical classrooms to 12 W/m² in labs, the installed lighting density in common areas is rather high. Lighting densities around 15-16 W/m² have been observed in the academy. The energy calculations carried out at design stages are often based on notional values used for classrooms. Another major issue is the zoning of lighting in common areas. It appears that all lights in common and circulation areas on each floor are controlled by one switch which makes it difficult for the building FM to manually switch off the unnecessary lights. Given the tendency toward open-plan school design, a common feature in all buildings surveyed by this research team, better understanding of lighting density and control features in common spaces are necessary to optimise lighting use. Zoning, time offs and sensitivity of PIR sensors and zoning and setup of daylight sensors are often not properly addressed at the commissioning stage. The research team witnessed inconsistencies in time offs and sensitivities of the PIR sensors in the academy and could not find any commissioning document explaining the setup of these sensors. The TM22 analysis reveals that the usage factor of most lighting fittings could safely be assumed as 1 during the normal occupancy. This is consistent with our observations on-site.

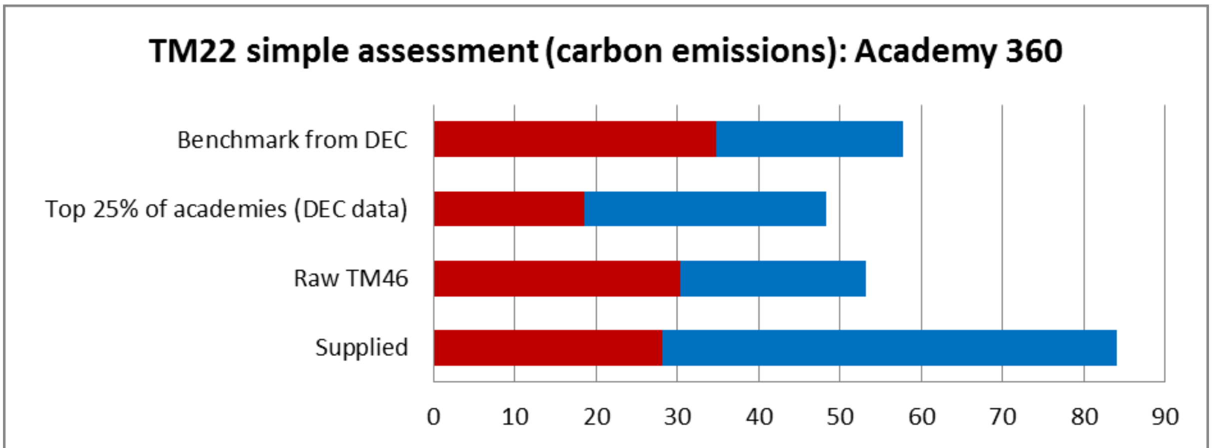
6.2 Pennywell 360 Academy

Figures 6.6 and 6.7 show the results of TM22 simple assessment for Pennywell Academy for energy supplied and carbon emissions.



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kWh/m²/annum)	145	156.8	96	179
Electricity (kWh/m²/annum)	102	41.5	54	42

Figure 6.6: TM22 simple assessment for Pennywell Academy: energy supplied



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kg CO_2/m^2/annum)	28.1	30.4	18.6	34.7
Electricity (kg CO_2/m^2/annum)	56	22.8	29.7	23.1

Figure 6.7: TM22 simple assessment for Pennywell Academy: carbon emissions

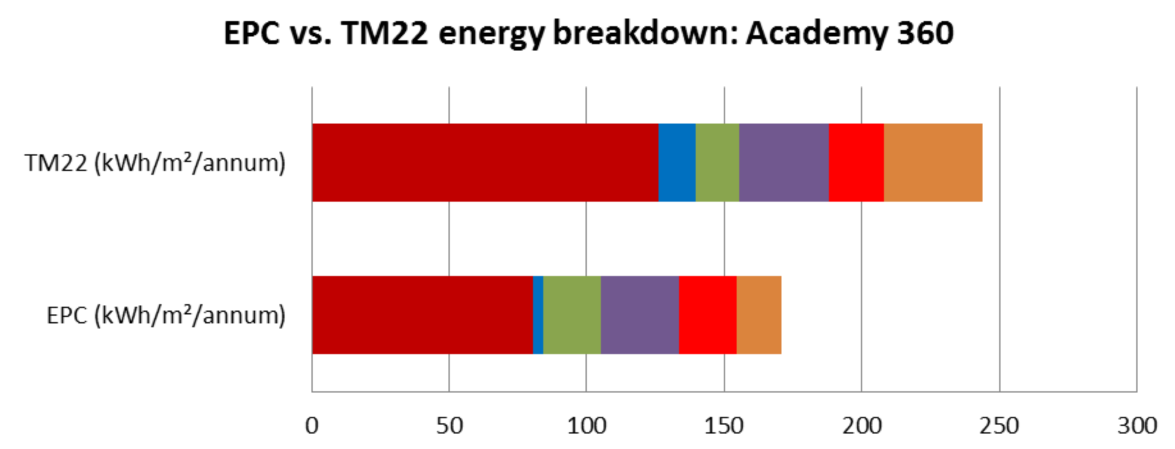
These graphs show that the academy's total performance is significantly worse than all benchmarks when CO_2 metric is used. The latest lodged DEC for the academy is F rated.

The end-uses reported in Table 6.3 were reconciled with the mains electricity within 3% in the TM22 detailed analysis.

System	Fuel/Thermal demand (kWh/m^2/year)	Electricity (kWh/m^2/year)
Space Heating	123.5	2.6
Hot water	20.0	0.0
Refrigeration	0.0	13.6
Fans	0.0	5.0
Pumps	0.0	10.2
Control	0.0	0.5
Lighting (Internal)	0.0	32.5
Lighting (External)	0.0	2.3
Small Power	0.0	9.5
ICT Equipment	0.0	15.5
Catering - Central	1.3	7.0
Catering - Distributed	0.0	0.3
Vertical Transportation	0.0	0.2
Laboratory Equipment	0.1	0.0
Total	**145.0**	**99.3**

Table 6.3: TM22 energy assessment for Pennywell Academy: detailed analysis

The EPC certificate produced for Pennywell Academy following the completion of the building is B rated. Figure 6.8 compares the outcomes of in-use TM22 assessment with the EPC results.



	EPC (kWh/m²/annum)	TM22 (kWh/m²/annum)
Heating	80.4	126.1
Cooling	3.8	13.6
Auxiliary	20.8	15.7
Lighting	28.4	32.5
DHW	21.1	20
Non-regulated end-use	16.4	36.2

Figure 6.8: EPC vs. TM22 in-use energy analysis for Pennywell Academy[3]

The academy preforms significantly worse than design estimations in the following end-uses:

Heating

There is evidence of out of hours use for the heating system probably due to an interlock problem between the BMS and the heating system. The heating system is scheduled to kick in at 4:30 am on Mondays and at 6 am during the rest of the working week to preheat the building. The building FM introduced another heating profile for Sundays (19:00-22:00) to boost the preheating. The logged boiler flow and return temperatures show that the system is actually running continuously over the weekend (Figure 6.9).

[3] Auxiliary energy includes fans, pumps and control. Individual components of auxiliary energy have been listed in Table 6.3.

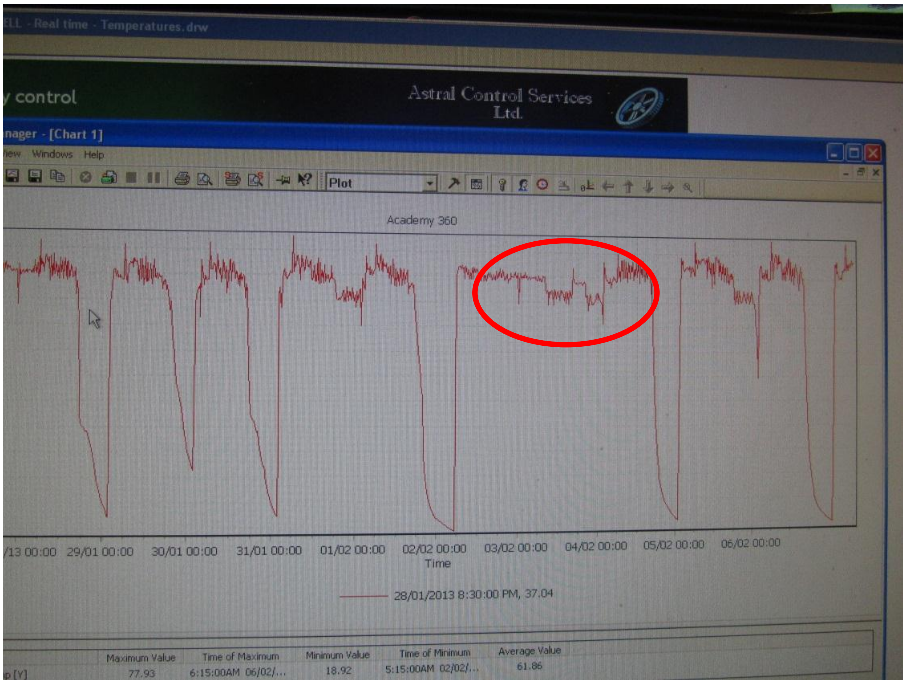


Figure 6.9: Weekly data for boilers flow temperature from the Building Management System; Boiler flow temperature is around 70°C over the whole weekend indicating out of hours and unwanted boiler operation.

It should also be noted that the lead biomass boiler sized to satisfy 50% of building's heating demand was not actually in operation throughout the measurement period. Consequently, the carbon emissions associated with heating far exceeds design expectations. In early stages of post-occupancy, a number of maintenance issues compromised the contribution of the biomass boiler to heating (the augur section stuck, the tree port valve busrt, and the main pump had sprung a leak). The research team gather that the maintenance costs and the price of wood pellets discouraged the academy from using the biomass boiler. A full backup system in form of gas-fired boilers is installed and it seems building management tends to utilise this system rather than the biomass boiler. Recently, the academy received a letter from Balfour Beatty, the building contractor who fitted the biomass boiler, containing health & safety warning about the risk of carbon monoxide generation within the storage unit for wood pellets. This has also been used as another reason not to run the biomass boiler. Apparently, only one batch of wood pellets (9 tonnes) was ever purchased for the biomass boiler that was used in November 2012 following boiler maintenance. Since then, the academy management have decided not to order new biomass fuel and use the gas-fired boilers instead.

Cooling

In addition to one server room and two data hub rooms that are air conditioned 24/7, there are a number of outdoor DX units that provide comfort cooling and heating to parts of the building. Total cooling capacity of these units is approximately 180 kW. The evidence from Pennywell Academy and other modern school buildings investigated by this research team suggest that cooling loads of these buildings are systematically underestimated in Building Regulations and EPC calculations.

Notably, actual server room loads are not taken into account in these calculations and this can lead to underestimation of cooling loads. The equipment gain assumed for IT rooms with 24/7 operation in National Calculation Methodology is 50 W/m². There is another profile for data centres, which gives an internal gain figure of 500 W/m². Given the total server and data hub rooms area in Pennywell Academy, this equates to 1.8 kW or 18kW depending on the profile used to carry out the Building Regulations compliance calculations. The installed capacity is around 40 kW or around 1100 W/m², more than twice the assumption for the data centre.

Lighting

Lighting consumption was higher than the design estimation during the measurement period for TM22 assessment (30/03/2011-29/03/2012). One of the issues witnessed in early stages of building performance evaluation was that the PIR sensors were too sensitive. For example, very often the lights in empty classroom turned ON when someone passed the adjacent corridor. The time offs for PIR sensors were also inconsistent and in some paces longer than expected.

Having a proactive building FM who engaged very well with the building performance evaluation led to the optimisation of lighting control. The lighting control system DD-LCDHS Direct Dim, PRM and MWS7 Handset was used by the FM to optimise the lighting control in January-February 2012. All units are set on sensitivity of 7 (9 being most sensitive), minutes are set to 10 minutes with a few at 15 minutes (ranges from 00 – 99). Furthermore, the schedules for external and security lights were optimised. External lights used to be ON throughout the night but now external and security lights come ON if the light level sensor drops below the setpoint (set at 300 lux) AND the following time schedules are ON:

- External lighting: 6:30-9:00 & 14:45-21:15 (Monday-Friday), OFF (Saturday-Sunday)
- Security lighting: 15:00-24:00 (Monday-Sunday)

Figure 6.10 shows the effect of these new schedules on electricity consumption of external lights:

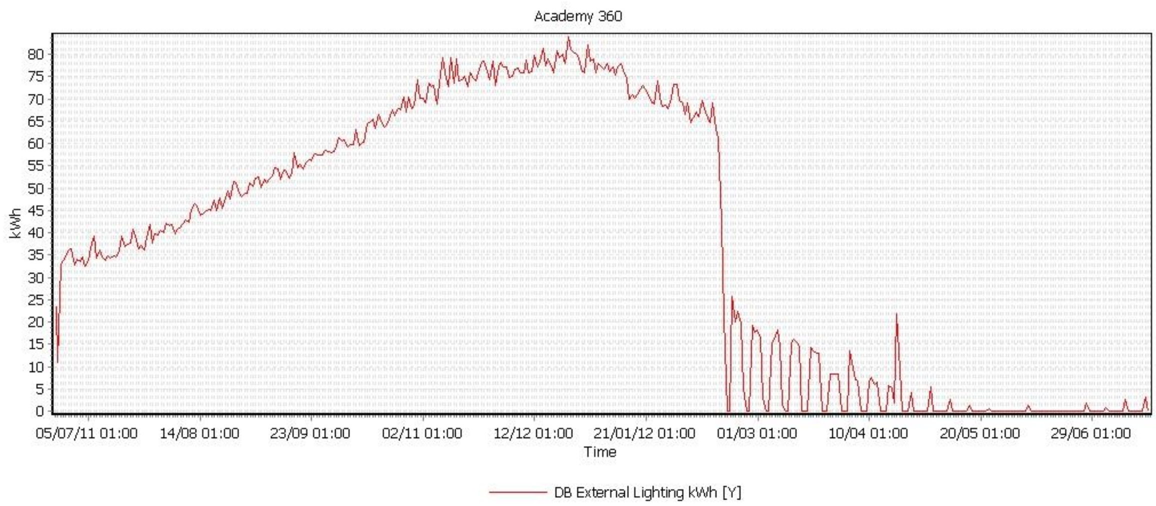


Figure 6.10: External light energy consumption for Pennywell Academy: since February 2012 the new schedules for external and security lights have been used.

Another initiative taken up by the building FM was labelling the light switches. This was done for all classrooms and offices.

Figure 6.11: Light switch labels installed by building FM

All these changes also led to behavioural change among staff. The research team witnessed the improvement in lighting automated and manual control in the recent visits.

Energy consumption measurements carried out over the period 08/02/2012-07/02/2013 confirm the following figures for internal lighting, external lighting, and mains electricity:

- Internal lighting: 26.1 kWh/m²/annum (20% saving over the previous year)
- External lighting: 0.85 kWh/m²/annum (63% saving over the previous year)
- Mains electricity: 81.2 kWh/m²/annum (18% saving over the previous year)

Internal lighting consumption is now slightly better than the EPC estimate. The last site visit, however, revealed some unexpected out of hours use that could be addressed to further reduce the electricity consumption (Figure 6.12)

Figure 6.12: Last occupants had left the buildings but internal lights in the Innovation Zone on the first floor were ON (Friday 08/02/2013, 17:56).

6.3 Petchey Academy

The reconciliation exercise for Petchey academy revealed that a number of lighting and power section boards were not sub-metered. This is consistent with the metering strategy; some section boards are sub-metered and some are not. Furthermore, the as-built metering strategy indicates sub-meters installed for chillers. However, in practice, the installed meters are not properly set up and do not report the energy consumption of the chillers on the meters or via the Building Management System. Therefore, a decision was made to use total electricity consumption reported on utility bills, cross-checked with the main LV panel intake, and estimate the end-uses using TM22 energy assessment methodology.

To address the issue of high level of uncertainty in end-use energy estimation in the absence of good quality metered data, half-hourly data was used to establish the night-time energy use and reconcile it with end-uses first before making an attempt to reconcile the day time usage. The academy's baseline power according to the half-hourly data supplied by the electricity supplier is around 140 kW.

The following figures show the average annual electrical power demand of the academy based on the half-hourly electricity data.

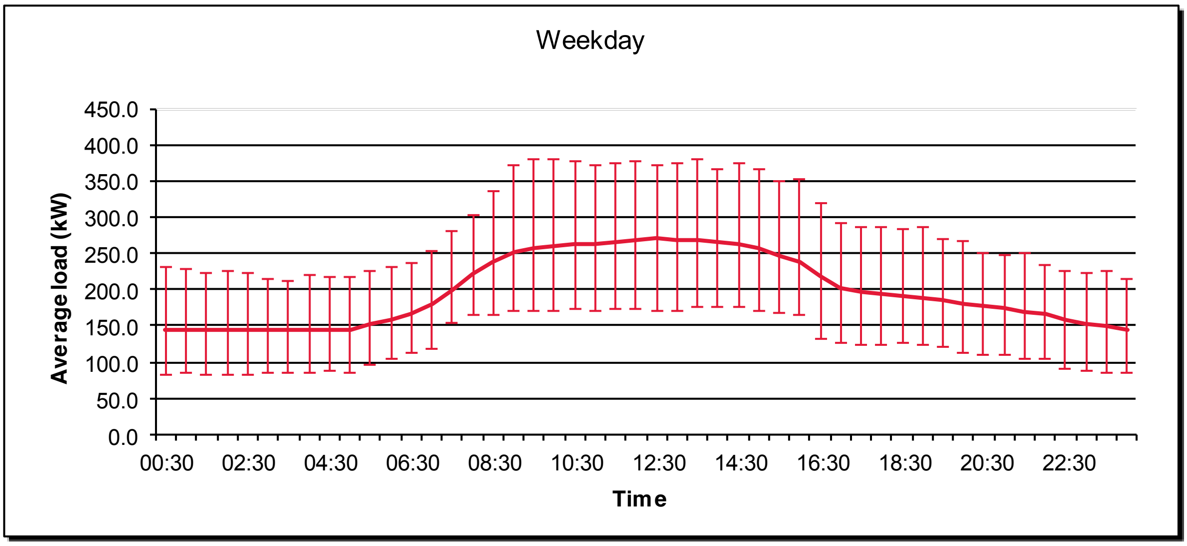


Figure 6.13: Average annual electrical power demand for Petchey Academy over weekday (kW); illustrating high electrical base loads

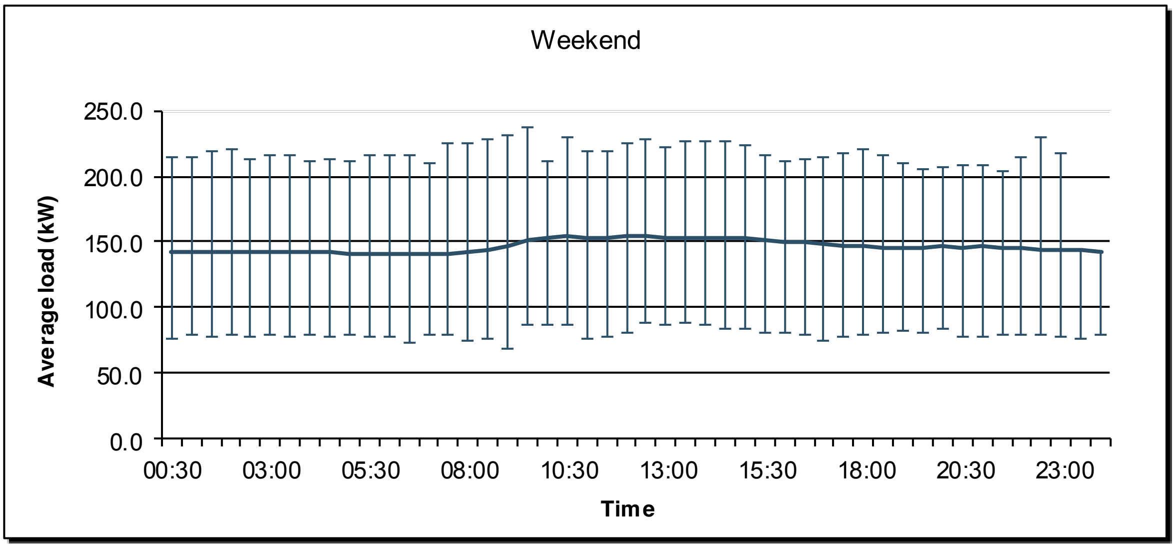


Figure 6.14: Average annual electrical power demand for Petchey Academy over weekend (kW); showing similarly high electrical base loads

The following night time usages were accounted for in TM22 analysis based on site survey:

- HVAC Control: 0.9 kW
- Server and hub rooms: 8.6 kW (maximum power rating of 28.7 kW with a load factor of 30%)
- ICT equipment in out of hours use or plugged in to charge: 1.5 kW
- External lights: 2.5 kW
- Internal lights ON overnight (stair cores): 1.6 kW
- CCTV: 2.6 W

- Access control: 1.2 kW
- Telecom: 0.4 kW
- Kitchen fridges and freezers: 3.0 kW
- Allowance for other normal (e.g. security systems): 2.6 kW

This leaves around 115 kW overnight load which is considerably higher than the server and hub rooms cooling demand. It appears that overnight use of central chillers and a number of air handling units are the main root cause for this high baseline power.

Night time ventilation was part of the design strategy to cool down the building overnight in summer. According to the RIBA Stage D report, outside the occupied hours, common return air temperature will be monitored, and the AHUs will operate until the common return air temperature is 15 °C.

The BMS interface confirms that purge ventilation or night time cooling have been set up for the following AHUs:

- AHU03 Staff social: Night purge only (5.5 kW supply, 4kW extract)
- AHU07 ICT, Health, Staff: Night cooling only (4 kW supply, 3 kW extract)
- AHU10 Common: Night purge only (7.5 kW supply, 5.5 kW extract)
- AHU11 Classrooms: Night cooling only (2.5 kW supply, 1.5 kW extract)
- AHU12 Reception: Night Purge (4 kW supply, 3 kW extract)
- AHU14: Night purge (2.2 kW supply, 1.5 kW extract)

The electricity bills do not show a step change in night usage between summer months and the rest of year and it appears that these AHUs operate all year round.

Given that the server and data hub rooms are served by centralised chillers used to condition the whole building, part of the overnight energy use could also be attributed to excessive operation of chillers left ON to serve the server and data hub rooms. Again, as there is no major difference between baseline electricity consumption in summer and winter, this excess in cooling energy consumption overnight could be classified as non-regulated out of hours use indicating comfort cooling is provided to some spaces and cooling valves are letting by.

The pitfalls of serving local 24/7 load with centralised system was one of the findings of the PROBE studies. Petchey Academy's high baseline power is reminiscent of this phenomenon.

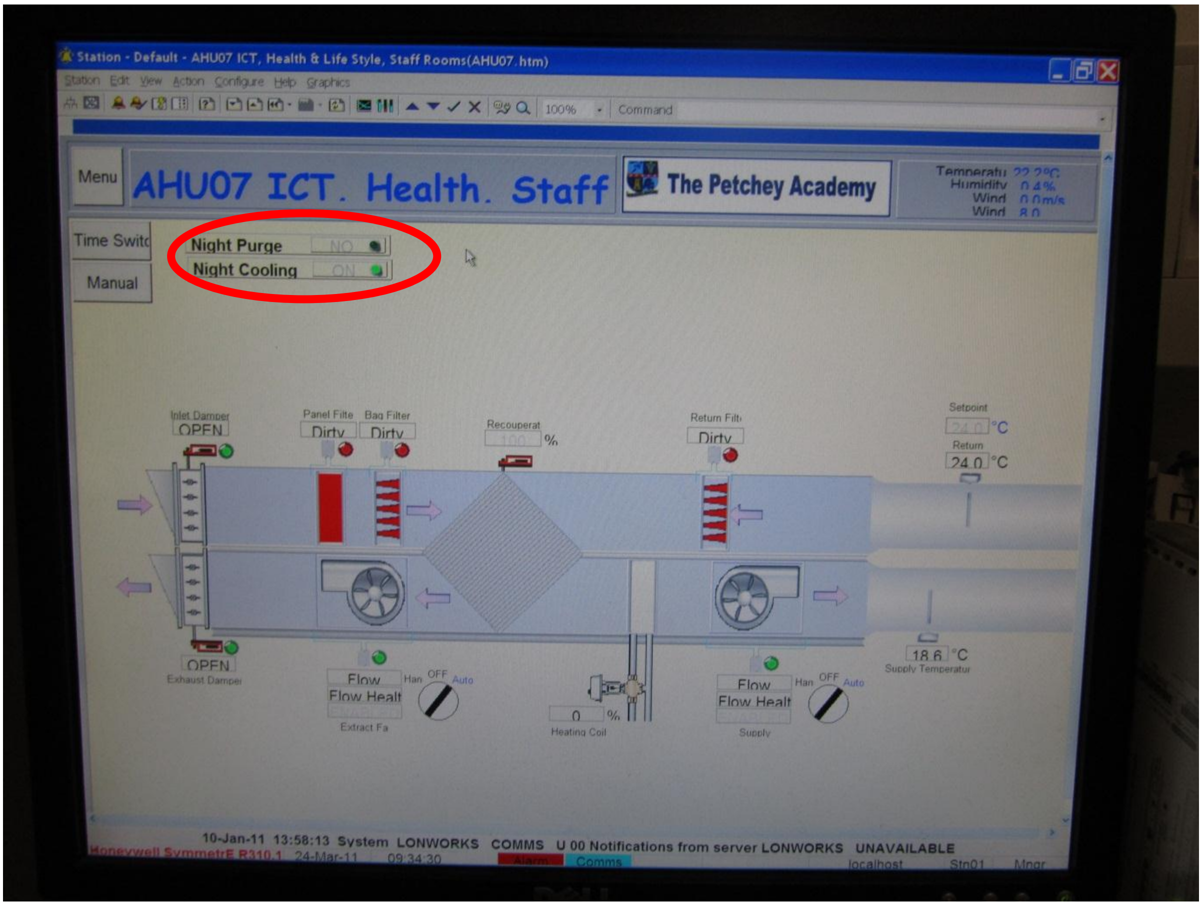


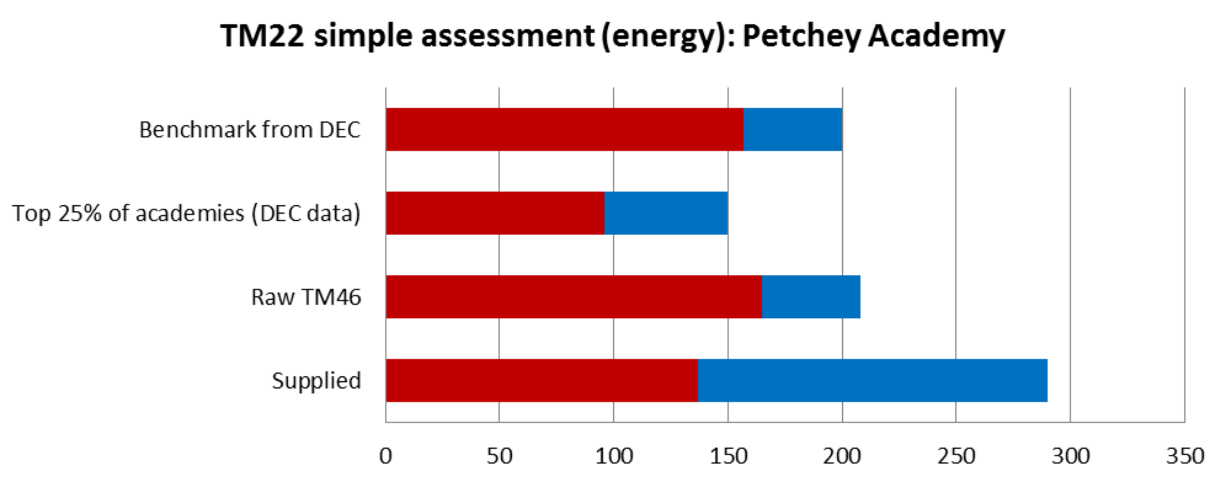
Figure 6.15: AHU 7 has been set up for Night Cooling

Consequently, the overnight absorbed power of the AHUs with purge ventilation or night cooling, one of the chillers (65.5 kW input), the chilled water pumps, and an allowance for out of hours operation of hot water pumps, if temperature falls below the setback temperature, have been taken into account in TM22 assessment. The unusually high baseline load for Petchey Academy (almost 50% of the peak load compared to 30% for most modern school buildings) and the wide variation band shows the erratic and unstable status of the existing control regime.

Figure 6.15 also shows dirty filters for AHU 7. The problems associated with building services control are compounded by poor maintenance regime and result in poor energy performance.

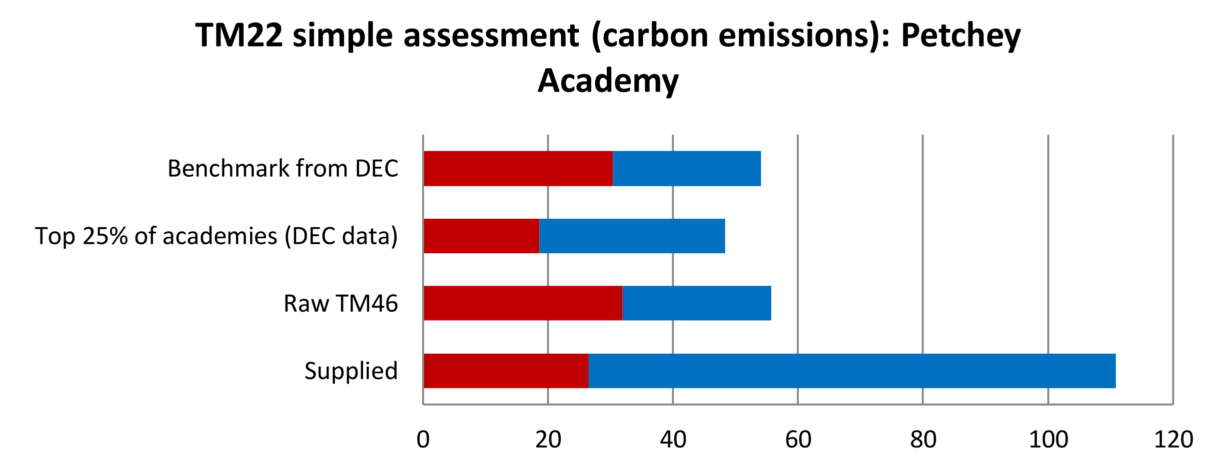
Figure 6.16 provides the results of the TM22 simple assessment carried out for Petchey academy based on metered gas and electricity data. Figure 6.17 includes the carbon emission breakdowns for the academy and benchmarks. Overall, Petchey academy is performing worse than all buildings. The latest lodged DEC for the academy is also G rated.

The academy was constructed before the inception of EPCs and, therefore, does not hold an EPC. The building is also 2002 Building Regulations compliant and there is no BRUKL report available for it either. The only source of design data for end-use energy estimation that the research team have come across is a CO_2 BB87 spreadsheet. However, this data is not very useful for benchmarking purpose not least because the cooling load is not included in the calculations.



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kWh/m²/annum)	136.6	164.7	96	157
Electricity (kWh/m²/annum)	153.5	43.3	54	43

Figure 6.16: TM22 simple assessment for Petchey Academy: energy supplied



	Supplied	Raw TM46	Top 25% of academies (DEC data)	Benchmark from DEC
Fuel/thermal (kg CO_2/m²/annum)	26.5	31.9	18.6	30.4
Electricity (kg CO_2/m²/annum)	84.4	23.8	29.7	23.7

Figure 6.17: TM22 simple assessment for Petchey Academy: carbon emissions

Petchey academy’s performance lies between good practice and typical Econ 19 type 3 air-conditioned office building. Given the extent of ICT equipment in the building and the fact that the building is mechanically ventilated and partially air-conditioned, Econ 19 type 3 good practice office may be a good benchmark for this academy. Table 6.4 provides energy break down results from detailed TM22 analysis along with good practice data for Econ19 type 3 office.

The end-uses were reconciled with the mains electricity within 1% in the TM22 analysis.

System	Petchey: Fuel/Thermal demand ($kWh/m^2/year$)	Econ 19 Type 3 Good Practice Fuel/Thermal ($kWh/m^2/year$)	Petchey: Electricity ($kWh/m^2/year$)	Econ 19 Type 3 Good Practice Electricity ($kWh/m^2/year$)
Space Heating	115.0	64.8	5.0	0
Hot water	12.4	5	0.0	0
Refrigeration	0.0	0	19.7	12.6
Fans	0.0	0	44.4	19.8
Pumps	0.0	0	16.4	7.2
Lighting (Internal)	0.0	0	30.1	24.3
Lighting (External)	0.0	0	2.9	n/a
Small Power	0.0	0	6.7	20.7
ICT Equipment	0.0	0	14.8	12.1
Catering - Central	5.8	0	6.5	4.5
Lab equipment	1.2	0	0.0	0
Total	**134.5**	**69.8**	**147.7**	**101.2**

Table 6.4: TM22 energy assessment for Petchey Academy: detailed analysis[4]

The academy preforms significantly worse than Econ 19 Type 3 Good Practice building in the following end-uses:

- **Space heating:** excessive mechanical ventilation & cooling overnight is a likely cause for higher than benchmark heating consumption. The high proportion of glazing and lightweight external envelope are other likely causes.
- **Hot water:** this could be attributed to sport hall activities and changing rooms. Office buildings cannot provide a good benchmark for schools' hot water consumption. Petchey academy's domestic hot water consumption is in line with most other school buildings surveyed by Aedas.
- **Refrigeration:** excess in cooling consumption is partly due to excessive cooling overnight, partly due to the size of the server rooms and data hub rooms that have cooling demand higher than typical 1990 office buildings (Econ 19 data source). Maximum power rating of the server room and data hubrooms in Petchey is around 30 kW.
- **Fans:** Night time ventilation and poor maintenance are the main root causes for this poor performance.
- **Pumps:** excessive cooling and heating consumption also contribute to high energy consumption of heating and cooling pumps.

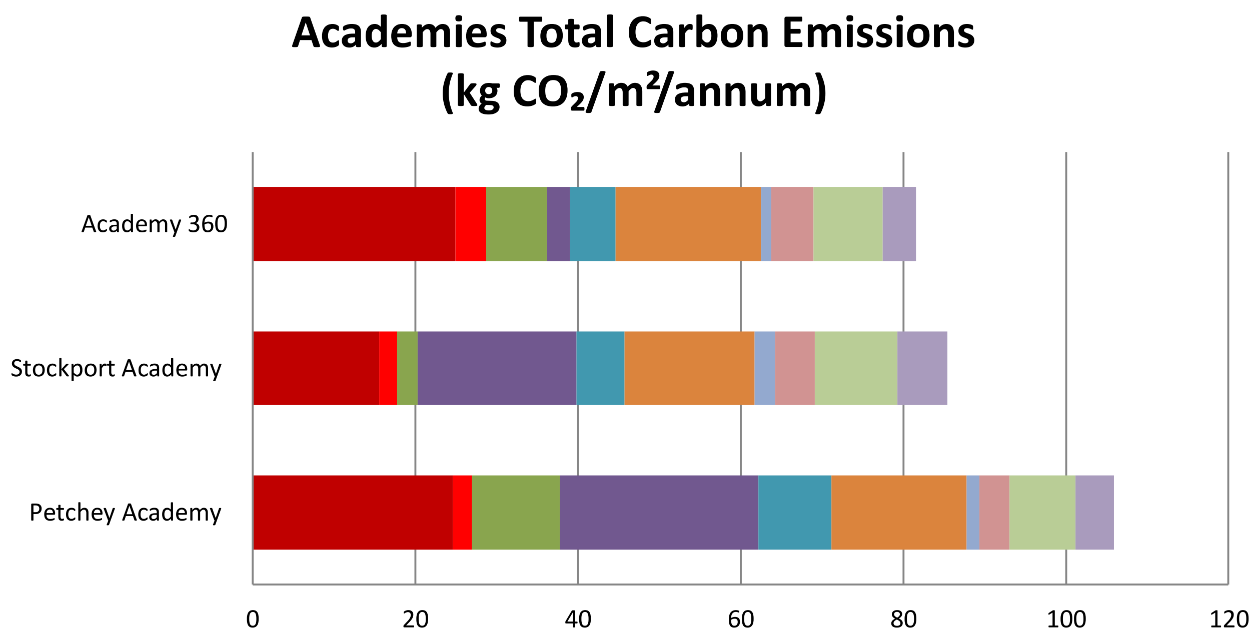
[4] Econ19 benchmarks have been extracted from *Energy Consumption Guide 19, Energy use in offices*.

6.4 Conclusions and key findings for this section

Figure 6.18 compares the total carbon emissions of the three academies investigated in this study. The following conclusions could be drawn:

- Heating consumption in all academies studied is considerably higher than design estimations (in case of Petchey the heating consumption is higher than Top 25% academies and Econ 19 Type 3 good practice office that may be used as benchmarks). Out of hours heating use as a result of out of hours activities and BMS interlock problems, heating systems conflicting cooling systems, poor interface control between lead low or zero carbon systems and supplementary heating were identified. Heating temperature set point in academies is also often higher than what is assumed in energy calculations (20-21 °C compared to the 18°C assumed in National Calculation Methodology for classrooms).
- Out of hours and excessive use of the mechanical ventilation and centralised cooling system seems to be a major issue in Petchey. A de-centralised cooling system for server and data hub rooms would have worked more efficiently and central chillers could have been shut off outside normal occupancy schedule. The heating system is also working excessively to compensate for the excessive mechanical cooling. This is consistent with the BUS feedback received from building occupants who complain about high variance in indoor temperatures in the building. The widespread use of portable heating and AC units throughout the building shows that the central systems and the control regime are not capable of providing acceptable levels of thermal comfort.
- Poor implementation of the mechanical ventilation strategy in Stockport Academy has led to huge increase in energy use for fans. Demand-controlled ventilation along with optimised schedules could save a lot of energy.
- Poor commissioning of lighting automated control and zoning along with out of hours use have led to relatively high energy consumption in all academies. Measures adopted in Pennywell Academy and saving achieved reinforce the necessity of getting these details right during commissioning and in early stages of post-occupancy.
- Default equipment load is used in Building Regulations compliance and EPC calculations to estimate the heating/cooling loads and is subsequently taken out from the total energy performance reported for the building. These case studies reveal that actual equipment load accounts for 20-30% of total electricity consumption for academies. Better understanding of the type of equipment used, the efficiencies, and control features available to minimise equipment load are necessary to narrow the design vs. as-built energy performance gap. Power down management and central shut down control for ICT equipment are very effective. More focus on energy performance requirements in procuring equipment for schools could further reduce energy consumption.

One of the key findings of this study was that most HVAC systems in all three buildings were in full operation during out of hours use, half term break, and holiday breaks, the exception being Pennywell AHUs that seem to have seasonal schedules set up by the building FM. This led to huge waste of energy in Stockport Academy where night schools run regularly on Tuesdays and Thursdays during term time and also in Petchey Academy where some extracurricular activities take place. Zonal heating and ventilation control could help optimise energy performance when few occupants use the buildings (e.g. night school and extracurricular activities), or in half term breaks when only a fraction of building (often the office space) is being used. This control strategy is often missed in actual operation. Better and more user-friendly control interface along with training in handover and early stages of post-occupancy would be required to enable a more energy efficient facilities management.



	Petchey Academy	Stockport Academy	Academy 360
Space Heating	24.6	15.6	24.9
Hot water	2.4	2.2	3.8
Refrigeration	10.8	2.5	7.5
Fans	24.4	19.5	2.8
Pumps	9	5.9	5.6
Lighting (Internal)	16.6	16	17.9
Lighting (External)	1.6	2.5	1.3
Small Power	3.7	4.9	5.2
ICT Equipment	8.1	10.2	8.5
Catering - Central	4.7	6.1	4.1

Figure 6.18: Academies' operational carbon emissions[5]

[5] Carbon emissions conversion factors used are 0.19 kg CO_2/kWh for gas and 0.55 kg CO_2/kWh for electricity respectively.

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 Stockport Academy

This case study was procured under a traditional contract, with Buro Happold as the M&E consultant from the outset. As part of this Building Performance Evaluation, Buro Happold was commissioned to perform a design vs. as-built study in order to establish the factors that led to the observed issues. The full report is enclosed with this submission and each technical issue is summarised below.

7.1.1 Heating system & Ground Source Heat Pump (GSHP)

Symptom

GSHP not making intended contribution to the heating demand

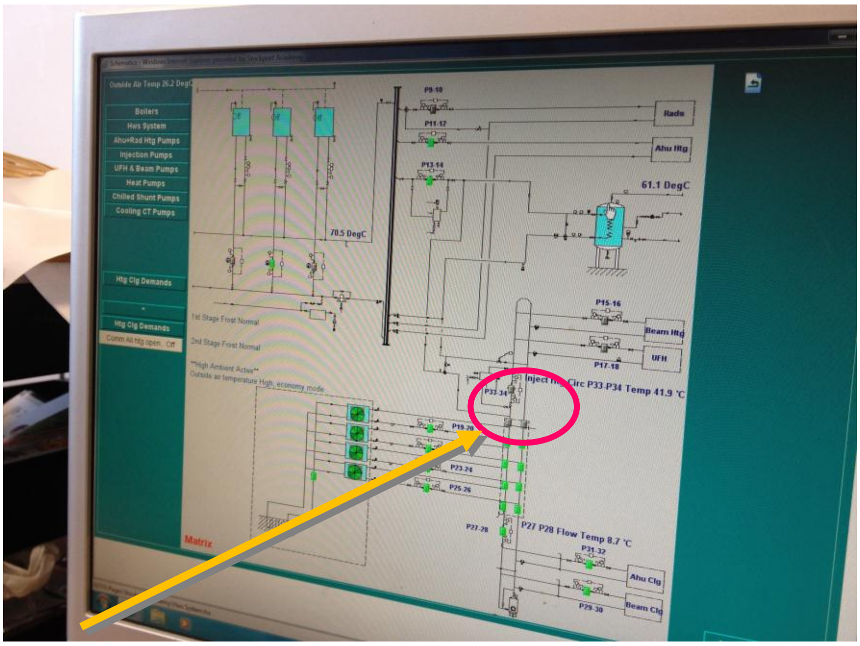


Figure 7.1: BMS snapshot: The ground source heat pumps and circulation pumps are all in working order. However, while all ground source heat pumps are working, indicating there is both heating and cooling demand for the units,

the control valves linking the sliding header arrangement to the low temperature hot water loop are closed and, therefore, gas-fired boilers take the lead for heating.

Over the course of the evaluation, meter readings, reconciliation and BMS interrogation exercises concluded that the contribution of the ground source heat pumps to heating was less than half what was assumed in design stages.

Cause

Upon interrogation of the documentation from design to commissioning, it was discovered that the design intent for the system had been misinterpreted from stage-to-stage;

- Stage D report proposes GSHP led heating and cooling with peak heating being topped up by gas-fired boilers.
- Tender package was subsequently issued to specialist sub-contractors for provision of system.
- Although tender requirements included the interfacing with all trade packages and controls, the GSHP tender was issued before all other systems and so this information was not provided.
- Neither issued, nor return tender documents explicitly discuss GSHP as the lead system
- O&M manuals state, *"Central gas-fired modular boilers are provided to meet the heating demands of the building. The remainder of the heating requirements is provided from the ground source heating and cooling system."*

Action

A site meeting was held with all maintenance parties present: Matrix, NG Bailey, Energy G – now undertaking cyclical maintenance of the GSHP, - along with Stockport Business Manager, Stockport Building Manager, on site FM and Aedas representatives. It was observed that the companies had had no previous communication with each other and each were maintaining their kit in good working order but that the interaction between all systems was not being managed. EnerG and Matrix made a commitment at the meeting to work collaboratively in order to achieve the design intent of GSHP-led heating. Since the meeting, EnerG has confirmed that the system installation is capable of performing as specified at design stage and will meet Matrix on-site in due course to rectify the problem.

Recommendations: Several measures should be employed in order to avoid this problem in the future;

- Specialist systems should be co-ordinated with M&E proposals as early as possible and more detailed information provided regarding interfacing and control strategy,
- A person should be identified as having responsibility for co-ordinating system interactions or a specialist BMS / controls consultant appointed,

- Maintenance support should be identified at tender stage whilst considering the potential for loss of information if a different company is chosen for installation and maintenance. Occupants should also be educated and informed,
- Specification of controls should be considered as an integral part of Stage D proposals and, ideally, a specialist consulted, particularly if the project includes low or zero carbon technologies.

7.1.2 Ventilation

Symptom

Excessive fan power use: all AHUs operating at 100% full fresh air at all times, inverters set to 99-100% on all. No ramping up or down of units. No evidence of CO_2 sensors on the BMS or in the classrooms and, therefore, potentially no capability for the automatic enabling of the inverters without CO_2 sensor retrofit. Furthermore, mechanical ventilation creates excessive noise in classrooms.

As discussed in earlier sections, Stockport Academy is sited under the Manchester Airport flight path. In order to escape potential noise disruption, the building was designed as a sealed envelope, making the efficient ventilation of the volume a priority. The ventilation strategy was modelled in IES as part of the compliance requirements.

It was also observed that all 10 AHUs were delivering full fresh air to the building during the night schools run on Tuesdays and Thursdays. This was due to the existence of just one scheduling profile for all main AHUs.

Cause

All design documents – Building Services Stage D, Mechanical Performance Tender Specification, Building Regulations Compliance Advice – uphold the design intent for variable speed drives and in some cases reiterates this as an important design feature for achieving compliance.

While the O&M manual states that variable speed drives have been used and all AHUs are provided with inverters on supply and extract fans, there is no evidence that the inverters were enabled at commissioning. When consulted at the site meeting, a Matrix representative confirmed this and explained that the variable speed drives were used only to balance the system at commissioning. He also reiterated that there were no CO_2 sensors in the ductwork that would enable the system to respond on an event-driven basis.

Action

Stockport Business Manager, the facilities manager and Aedas have arranged to meet in order to compile a schedule of occupant density and operating hours for the school for the next year in order to put together a programme for the ramping down of individual AHUs in line with this. Matrix have agreed to create extra screens on the BMS interface to support the changes. They will also perform a more extensive search for the CO_2 sensors to confirm their absence / presence. In the event that the manual programming of the AHUs does not have the desired, minimising effect on the energy consumption, Matrix will provide a quote for installation of CO_2 sensors.

Cause

Following the recent let-out of sport pitch and other spaces for out of hours use, the school is now open every day until 9PM with the danger that mechanical ventilation will rocket.

Recommendation

Take more advantage of zoning and set schedules to reflect actual needs.

Action

Meeting scheduled with the contractors and Matrix to review actions and agree on solutions.

Recommendations for future projects

- Use informed values for specific fan powers (SFP) in design stage & as-built Building Regulations Part L; in this case, it was revealed that the Building Regulations limiting SFP values were used in both design and as-built compliance calculations. Likely to have been used as the worst-case scenario and not as a reflection of insightful modelling,
- Develop a dynamic modelling methodology that enables more accurate reflection of variable speed drive operation,
- Evidence to be provided at commissioning stage which details both the design intent and the measures implemented to achieve this during commissioning,
- Ensure the mechanical ventilation system has adequate level of attenuation and meets BB93 acoustic requirements.

7.1.3 Lighting

Symptom

Excessive load, common area lights on during operating hours

During early investigations meter reconciliations and occupant interviews, lighting was identified as an unexpectedly high end-use.

Cause
There are a variety of lighting strategies and control systems across the buildings. Office local control switches and classroom PIR with daylight dimming and local override were observed to be working in accordance with design intent, although there was no consistency of settings between classrooms and some were noted to be over-sensitive to movement. This led to classroom lights switching on when someone walked past in the corridor. The circulation area lighting, not only has been calculated at between 13 and 15W/m^2 installed capacity, but has been set up on one circuit with PIR sensing. As the corridors are continuously occupied somewhere in the building, these lights are always on. There is also only one main override switch serving the entire area.
Lighting densities and control specifications are reported by Buro Happold to be aligned with all necessary parameters at design including: BB87 & 90, NCM values and Building Regulations Compliance. When questioned, the facilities team were not in possession of a controller to change the PIR settings, nor had they been advised about how to source and use this equipment. A remote control unit was eventually requested and received but it was sent with the wrong communications protocol and instructions; no-one on site followed this up.

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 is issued with the kit upon handover.

7.1.4 Small power load:

Symptom
Excessive small power consumption

Cause
15 servers operating 24/7

Action
Virtualisation of ICT resulting in a reduction of servers from 15 to 4 as of end of summer 2012. Virtualisation is different than cloud computing: it means having fewer, more efficient servers than conventional servers i.e. managing more and more software with less hardware. This has significantly reduced the server room power and cooling requirements; therefore, one air conditioning unit is enough now for the server room (two installed) and hub rooms only need extract fans.

7.2 Pennywell 360 Academy

7.2.1 Lighting

Symptom
High energy use, external lighting running overnight and without dimming

Cause
Inadequate profiling of external lighting.

As described in *the energy use by source section*, at the beginning of the evaluation, all external lights were set on one schedule; this included both security lighting and general external lighting. These circuits were running overnight, causing a high energy load.

Action
New, separate schedules were set up by Astral maintenance and set points created to ensure adequate lighting provision should the lux levels fall below 300 during scheduled hours.

Symptom
High lighting energy use, lights continually on

Cause
Poor commissioning of lighting systems, lack of user-friendly manuals, lack of training

Observations concluded that the daylight dimming was not functioning at all. There were many light fittings that the facilities manager could not switch off as she couldn't find the light switches. Some of these fittings were adjacent to large sun-pipes that were providing adequate day-lighting already. There were some cases where she was unsure as to whether the fittings were manual or had malfunctioning PIRs.

Where PIRs were in place, there was no consistency as to their set-up in terms of time delay and sensitivity and many lights were much too sensitive, resulting in some being on constantly throughout the day.

Figure 7.2: Light fittings on next to sunpipes

Action

Once this had been flagged up, a remote controller was sent to the school and the BPE team worked with the FM to zone and tailor the PIR settings as necessary.

The FM has also put up extensive labelling on all lighting controls which has added to a change in behaviour amongst occupants.

Recommendations for future projects

- Provide a detailed BMS screen hierarchy and profile list in specification,
- Commission or appoint a person to oversee all controls implementation and coordination
- 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 is issued with the kit upon handover.

Of the 5 case-studies undertaken by Aedas – 3 academies in this project and 2 schools in a separate bid - this is the third in which a switch-off-fortnight campaign was instigated and the third to return negligible results in terms of a decrease in energy consumption over the campaign period.

The conclusion drawn from this was that student engagement does not seem to cause any immediate, significant effect. This is likely to be due to the fact that students tend not to have much influence or control over their environment and that it may be more effective to educate the adults. However, it remains important to educate the new generation and it was expected that the campaigns would cause a slower development of environmental awareness in the students. The decrease in lighting consumption observed in this case study can be attributed to many factors and this lag in student behavioural change is likely to be one of them.

7.2.2 Metering

Symptom:
Incomplete picture of energy consumption

Cause:
No sub-meter installed for the solar hot water panels, making it impossible to assess their contribution to the daily hot water use.

Action:
This was not rectified during the evaluation.

Symptom:
Meters and Submeters not visible on BMS interface

Cause:
At the beginning of the evaluation, many meters were not communicating with the BMS.

Action:
Astral maintenance has been very proactive in rectifying issues and tweaking the BMS interface where necessary.

Cause:
Hot water meters have never communicated with the BMS. Figures had to be read from the hot water meter located in the ceiling void of the Attendance Manager’s office. The meter was situated facing upwards above a pipe.

Recommendations:

- Ensure that placement of meters facilitates manual reading in order to future-proof the kit,

- Metering strategy to clearly state where interactions with BMS are to occur and will ensure that this will provide a whole picture of the building,
- 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.

7.2.3 BMS

Symptom

Gives poor overview / control of the building

Cause

Missing screen and functionalities logged by the monitoring team at the beginning of the evaluation

Action

Astral responded well to the FMs requests and were very diligent when it came to amending the interface according to the school's needs.

Cause

- Interlocking occurring across the heating system controls
- While Pennywell could be described as one of the better examples of a BMS system in our sample of buildings - with functionalities such as the ability to view the trend for all energy end uses at a daily profile granularity – it is still affected by problems of interlocking systems and controls
- Many meters do not communicate with the BMS

Action

Astral have been proactive in remedying as many of these interactions as possible

Recommendations

- BMS hierarchy and specification to be detailed during design and revisited at commissioning with occupants on board,
- BMS to be set-up in conjunction with systems installations and personnel to collaborate to achieve an effective building,
- All meters to communicate with the BMS and to be displayed in an intelligible way so as to communicate the building's energy use to a person outside the industry,
- Controls maintenance contract to include the sporadic update of the interface according the users' needs,

- Where controls maintenance contractors are different from the systems maintenance contractors, explicitly include the need for communication and collaboration between companies in order to deliver the efficient running of the building.

7.3 Petchey Academy

Technical issues have been captured in the project Energy Efficiency Measures Matrix which formed the basis of the 'design vs as-built' investigation for all buildings. Petchey Academy was particularly problematic in that the building engineers involved with the design have long left the project. The MEP specification comparison against the information contained in the O&M manuals was conducted by an engineer who participated in the building commissioning and has since moved on from Buro Happold, the design engineers.

The TSB evaluator of this BPE project raised concerns early on over the benefits of conducting such a study on a building that has been operating at sub-optimal level for such a long time. However, the feedback from the study prompted an additional energy survey carried out by OR Consulting alongside a cost/benefit analysis of remedial actions. The school's business manager recently applied for funding to cover the costs of carrying out the related works.

7.3.1 Metering

Symptom
As noted in the EEM Matrix, chilled water is being supplied by the same system to both the IT server and hub rooms and the rest of the building. The monitoring team perceives this as the root cause for the building's excessive energy consumption and comfort issues identified by interviews and the Building Use Survey. Normal industry practice is to separate IT equipment cooling from the main chiller circuits as these have very different cooling schedule requirements.

Cause
As a result of the system configuration, the building heating systems have to compensate for excessive cooling. Pumps are also operating excessively due to the 24/7 requirement for chilled water supply. The detailed end use implications were discussed under the TM22 analysis but extremely high cooling loads, and out of hours use of pumps and fans form the bulk of the electrical base loads observed being above 140KW for the building.

Action
The cost of remedial action has been estimated by OR Consulting at £40K. The potential annual savings based on cooling demands for similar buildings (ECON19 Good Practice Office) are estimated at more than 50% of cooling loads, a reduction from 19.7 kWh/m^2/yr to 9.8 kWh/m^2/yr respectively. It is also recommended to install sub-meters for chillers so that the actual cooling load could be measured and savings accurately quantified.

Symptom

In this building, as in the others studied, fan inverters in AHUs do not appear to have been enabled or adequately configured. Both design and O&M documentation assume these to be enabled and lack of these have resulted in greatly increased fan power consumption.

Symptom

Some AHUs schedules are not possible to alter through the current BMS interface – they end up operating at times when not required and not supplying fresh air when needed. Complaints around air quality are largely attributed to this point.

Symptom

Lighting control is a critical source of excessive electrical consumption. Daylight sensors, PIRs and easy to use dimmer switches are critical for optimal operation. This building was built prior to Part L 2006 which may be the reason for the absence of daylight sensors. Shortly after opening, the FM installed pull-cords in the classrooms to allow teachers to override the automated lighting controls. PIRs are operational but time offs are excessive and these are ineffective in well-lit circulation areas. As a result, common area lights are constantly on during school opening hours, which was taken into account in the TM22 analysis.

Symptom

ICT equipment is centrally controlled and an auto shut-off script is run at 16:10, 18:00 or 21:00 depending on daily requirements and any tutorials, extra-curricular activity, etc. Server room loads and power ratings are consistent with other buildings and close to the ECON19 good practice value for offices. Although IT density is close to an office building, schools are seasonal buildings so consumption is expected to be lower than good practice office building.

Cause

In terms of the Building Management System – the fundamental control issues have been discussed under the respective systems, heating, cooling, ventilation, lighting and detailed further in the matrix. Petchey Academy displays all the endemic BMS issues encountered on the other education project: inadequate configuration, absence of seasonal commissioning and lack of usable manuals and training.

Petchey Academy's building envelope was the only lightweight building fabric out of all the education buildings Aedas studied. The monitoring team was keen to see whether this lightweight and highly glazed envelope could provide adequate protection from solar gain. In fact the team found that on hot summer days the inside surface of the south façade was regularly very warm to the touch. This does not necessarily rule out lightweight construction but points to the benefits of heavy thermal mass in regulating indoor temperatures especially in seasonal buildings with transient occupancy such as schools.

7.4 Conclusions and key findings for this section

The team has found it extremely helpful to structure the findings in a matrix format. The headings have been broken down to end uses and lists key control and management factors.

The findings for the three academies as well as experience from other projects indicate that some of the issues encountered may be endemic, especially when it comes to control systems and building management. It also seems that building regulations have a positive impact on the performance of building fabric. When it comes to building systems, tougher building regulations seem to have driven buildings towards automated electronic control systems that allow buildings to be more responsive to occupant needs but that these systems are severely let down by the lack of emphasis on these in the contractual and procurement framework.

Buildings constructed with better U values and higher thermal mass appear to have less complaints about overheating – although the comparison is unfair given that the other two buildings studied in this project are in the North of the country. When comparing Petchey Academy with the London based Loxford School, from another Aedas BPE project, the comparison is more striking. Loxford School is naturally ventilation and of high thermal mass. Complaints about air quality and thermal discomfort are significantly less than in the case of Petchey Academy. Without seeing Petchey Academy's cooling system issues addressed it is difficult to arrive at final conclusions. However, Aedas is committed to following up the Academy's funding application process and, if successful, aims to collect further thermal comfort data to verify the impact of further remedial action.

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 Recommendations for Education Clients

The most important conclusion from 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 build a much better grasp of building physics and awareness of the risks involved with the integration of different system types.

Poor system configurations not only result in excessive energy costs but also can affect the effectiveness of the day-to-day running of the school, staff productivity and well-being and absenteeism. Going after energy use means that other problems get exposed. The cost of mistakes can cost the equivalent of several teachers' salaries per year, as in the case of Petchey Academy.

When undertaking a new building or refurbishment it is critical for end users to understand the complexity and maintenance requirements of the systems that maintenance staff will be in charge of. Most education end users will not have the skills in house to manage complex systems and need expert advice on how to procure such services, scopes of work and how to get external contractors to effectively support the day-to-day concerns of school FMs. Putting in place a performance contract for managing these systems is the first logical step to take. However, there is currently NO pro-forma for the procurement of facilities management services for building controls and management and Aedas has been lobbying CIBSE as well as BSRIA to make such a document available to their respective members. If energy performance is tied to the FM scope it is much more likely for contractors to take an interest in the design measures related to energy performance and comfort.

In our experience schools need help immediately after handover to recognise if systems are not adequately configured or installed equipment is not in line with what was specified. Many of these issues only emerge if there is a dedicated person with knowledge of the building pursuing energy consumption data. 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 uncalibrated 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.

Metering strategies need more scrutiny – metering of key end uses is frequently missing from the schematics as in the case of Petchey Academy where many lighting and small power section boards are not submetered.

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 very easy to benchmark building performance and start diagnosing problems. The lack of a realistic energy performance baseline hampers this – in the absence of a building specific measured energy use prediction, better and more granular benchmarks would help schools understand what savings can be achieved.

Installing submeters is a costly but 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 none of the buildings studied had read their sub-meters or carried out any benchmarking exercise before the start of the study. Therefore, the academies were unaware of how their energy bills compared to those of similar buildings and whether their building energy use was acceptable.

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 develops. That 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.

Aedas 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

In terms of design issues – the most pervasive question for school buildings is around ventilation strategy. In actual fact, even naturally ventilated schools, included in our parallel BPE studies, have large parts of the building mechanically ventilated and cooled, mainly core spaces and ICT enhanced classrooms. It is essential that the impact of this is not under-estimated during design stages and the end users have a good understanding of the maintenance and operating issues associated with these. Low heat-gain ICT solutions are becoming more common and should be investigated before a mechanical route is chosen.

The arguments for mechanical ventilation can be compelling, especially in the age of climate change and the increased overheating risks it brings. However, the monitoring team felt that the financial, maintenance and comfort risks associated with mechanically ventilated schools are not adequately exposed and that in the case of school buildings there is a strong argument to opt for minimal mechanisation unless the financial commitment has been made towards a more sophisticated maintenance and management programme. In other words, mechanically ventilated school buildings are a potential 'time bomb' for the sector. The same could be said for low and zero carbon systems such as ground source heat pumps, solar water heaters and biomass boilers. When simple systems such as lighting and meters cannot be properly installed, commissioned and maintained how can schools occupants be expected to look after plantrooms the size of a small sports hall filled with mechanical equipment worth millions of pounds?

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 ours operation should be emphasised during early design stages and incorporated in the buildings spatial organisation and services strategy, as well as the teaching programme.

In terms of spatial planning, storage is a persistent comment. Successful schools in particular have a tendency to grow rapidly but current funding structures mean that schools do not have spare capacity built in by default. In the case of Petchey staff and pupil numbers have grown by 50% and storage is at very short supply, hampering teaching. It is worthwhile to include in a school's brief an adequate buffer for the expansion of teaching and storage.

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.

Based on the feedback received architecture can contribute or diminish users' forgiveness towards comfort issues arising from poorly configured building services.. 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 services, controls and 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.

9.1 Wider lessons

Out of the three large Academies studied as part of this project (in total Aedas is monitoring seven) none of them came within proximity of the TM46 benchmark average in terms of energy performance, with a DEC rating of F/G.

The causes were in all cases related to the integration, commissioning and management of MEP systems within the building. They were also largely systemic; interviews with contractors, engineers and industry bodies highlighted a severe lack of understanding of the scale of the risks associated with embedding complex building services in buildings where staff are not equipped to supervise these.

While staff were more 'forgiving' in the more 'attractive' buildings, in many cases the issues uncovered reflected on staff productivity and health. Once staff costs and teaching are affected, the indirect costs of these problems become much higher than the energy costs, which themselves amount to tens of thousands of pounds per year per academy.

Such costs would be further compounded by the high capital cost of equipment that does not get utilised to its full potential. These typically include ground source heat pumps, biomass boilers, fan inverters, lighting controls, meters, sensors and building managements systems.

Bearing in mind that mechanical ventilation and cooling systems in schools tend to be installed due to concerns over noise and overheating, this small sample of academies indicate that it would be more effective to focus on low-energy and minimum gain ICT systems and tackle noise and overheating via passive systems. A good example is server room virtualisation that happened in Stockport Academy towards the end of the monitoring period.. As the examples of Stockport and Petchey Academies demonstrate, noise and overheating can be an issue regardless of the extensive mechanical ventilation installed.

To target investment more effectively and achieve low operational energy use alongside good occupant satisfaction, a paradigm shift is required from industry and policy makers. The recommendation for energy efficiency measures need to be rooted in evidence which needs to include the actual whole-life impacts and costs of such measures, including the cost to occupiers. To gather and substantiate such data, the notion of 'feedback', in other words a link between capital and operational expenditure, needs to permeate the construction industry.

9.1.1 Mechanical vs. passive systems

A recent UCL analysis of DEC data shows that the top 25% of Academies, a recent building type that has emerged in the past decade, meet only the median consumption figures for all education buildings and that the excess consumption arises predominantly from electrical energy use.

We know that ICT accounts for some of this excess in energy use but certainly this is far from all. In all the academies, the ICT loads are between 12-20 kWh/m^2/yr – 12 being reasonable for a good practice office building but high for a school. Mechanical ventilation and cooling systems are responsible for around 20-40kWh/m^2/yr for Academy 360 and Stockport Academies respectively again perhaps reasonable for a good practice office but certainly high for EPC B rated schools that are only used seasonally. However, supplying fresh tempered air and mechanical cooling at Petchey Academy is using significantly higher energy, around 65 kWh/m^2/yr, demonstrating the extent to which mechanical ventilation and cooling systems can go wrong.

It is possible that buildings constructed under Building Bulletin standards may have had a stronger motive to opt for mechanical services to meet noise and overheating targets. Once this decision is made engineers need to demonstrate under Part L that these highly serviced buildings systems are running at optimal levels – which means that complex building management systems are inevitably installed and relied on. Yet at no point in the design and procurement process are the risks associated with these systems quantified and highlighted. Not even the Soft Landings process guarantees that it is possible to extract end use energy data from the systems installed automatically, that energy end uses are reconciled with predictions and that performance contracts are in place for the management and maintenance of the building systems.

It is of great concern that energy efficiency measures are often determined on the basis of compliance calculations. As demonstrated, these imply a high degree of uncertainty that is currently not addressed at any stage of the design, construction and operation process. Soft Landings is a step in the right direction but the requirement for measured energy use targets and related 'data drops' need to be incorporated for the scheme to deliver effective change.

9.1.2 Cooling

The evidence collated from these academies suggests that cooling demand from server and data hub rooms is under-estimated in EPC calculations.
ASHRAE Thermal Guidelines for Data Processing Environments recommends a temperature range of 65 to 80 °F for server rooms (18.3-26.7 °C). The actual setpoints observed tend to be close to the lower end of this range between 19-21 °C – the energy implications are huge. Temperature setpoints sometimes are as low as 17 °C; this was witnessed at Darwen Academy, a building where Aedas carried out a shorter BPE outside the TSB BPE programme.
It is also under-estimated how many areas are comfort cooled – these tend to include ICT, catering, science labs and music classrooms that can easily account for 10-20% of the total area. This raises the question whether we should be providing such extensive cooling at high operating costs or design more resilient buildings at slightly higher capital cost and lower operating costs. The figures are rarely there at design stages to make such informed decisions and engineers tend to perceive passive design as a risk during design stages as it requires more elaborate analysis than a standard dynamic thermal model. As the Stockport virtualisation solution demonstrates, cooling requirements can be slashed by a third by innovative ICT solutions.

As discussed under mechanical ventilation and passive systems, cooling brings its own benefits and costs – the question is whether routine analysis incorporates the right level of risks in early performance evaluations.

9.1.3 Are Building Management Systems Jinxed?

Without providing the expertise to supervise and operate them these expensive systems are often poorly configured and do not provide the benefits they offer or worse, impede the efficient operation of a building. Out of all seven projects studied by Aedas under the TSB BPE programme and a further five outside of it, no completed building had a fully operational BMS. Some buildings just experience nuisance as a result of malfunctioning or poor programming but in many cases the BMS can only support a comfortable environment by excessive energy use and cost. In severe cases comfort is badly affected. It is not surprising to find such problems. BMS are complex and their programming should take place over several months as part of seasonal commissioning and alongside feedback from monitoring comfort levels. Yet seasonal commissioning was not in the scope of the subcontractors responsible for this on any of the buildings studied, the time available for commissioning was reduced due to pressures over handover and very little training was offered to end users who didn't have the qualifications to control a computerised relational model meaningfully.

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As we have seen on the Academies, schedules and zoning are typically poorly programmed without an interface for end users to make alterations. Underlying parametric relationships are not accessible to anyone except the original provider and no documentation has been seen describing the key relationships between set points, services and time schedules. For example, in the case of Petchey Academy the school needs to re-engage Acorn to program in the appropriate buttons to be able to change schedules for AHUs. To overcome this problem, interoperability via industry standard software language should be made mandatory so that independent software engineers can access the underlying system specifications and alter the controls. Should BMS providers go out of business, a generation of buildings would have to be retro-fitted with new systems.

The evidence from Stockport shows that where mechanical ventilation is the only means of supplying fresh air CO_2 sensors are essential to avoid health effects, should the ventilation system fail. In practice occupants know how to control windows but not how to control AHUs or a BMS. When mechanical ventilation systems are designed it is assumed that the purpose of AHUs is mainly to provide fresh air only, not to heat the building when there is no occupant in. However, in practice fans are commonly programmed to run when the heating comes on even though there is no CO_2 increase in the spaces serviced. A combination of demand control and proper optimised schedules is required to reduce the fans energy use. Any shortcoming related to these requirements can only be highlighted by collecting and analysing energy end use consumption data, hence the argument for better monitoring, management and reporting.

AHUs are designed to provide tempered fresh air to schools but, in practice, they are being used for pre-heating and heating the building. They start up well before normal occupancy starts (around 7 am) and run well after core occupancy hours in schools (usually until 5-6 pm).

AHUs are often in full operation during out of hours operation whereas effective use of zoning could have substantially reduced the demand for mechanical ventilation. In one building all the AHUs came on when only one zone was occupied during out of hours operation.

Aedas has asked UCL to look at the data from Display Energy Certificates and more detailed energy use data from the BSF programme to establish the impact of the widespread use of BMS in the education sector. More data on school buildings with BMSs is likely to be needed to verify the exact scale of the risk and establish whether BMS solutions should be implemented in schools at all. Interaction with other education projects from the TSB programme should be encouraged to ascertain this.

The monitoring team is looking to follow-up whether the zoning and scheduling problems experienced in these three buildings studied are typical in recentl buildings or if these are outlier cases. Data gathered in the CarbonBuzz platform may be able to demonstrate this in the long run.

9.1.4 Heating controls

The case studies in this project demonstrate how building regulations since 2006 have reduced heating demands. However, the question is whether this has been achieved at the cost of higher electrical loads.

In an effort to reduce heating loads via 'smart systems', the experience from the projects studied is that too many systems are specified to provide heating and despite the elaborate control systems (or in some cases because of them) these systems do not complement each other well and in some cases fight one another.

Biomass systems are used less effectively or not at all due to maintenance issues or cost and issues with pellets or delivery sizes. They are also perceived as a H&S risk, as in Pennywell Academy where concerns were raised over wood pellets generating excessive carbon monoxide. As a result, backup systems often take the lead and low carbon systems are abandoned as the backups are generally sized to take 100% of heating load. For the ground source heat pump, the contribution of systems is significantly lower than predicted, again due to control issues relating to set points or flow temperature settings. Because monitoring is not endemic, heating profiles tend to be set very generously, offering plenty of scope to optimise.

The recent drive towards lower carbon buildings demands more sophisticated controls but these need more proactive FM and commissioning. We have the evidence that the actual performance falls short of expectations where these are not followed – see GSHP, demand-controlled ventilation and biomass boiler.

9.1.5 Lightweight fabric vs heavyweight fabric

A major question of this study was whether a lightweight building fabric such as the one specified for Petchey Academy can withstand summertime overheating.[6] The conclusion discussed in the main part of the report, based on BUS feedback and measured temperatures, was that heavy-weight buildings are more resilient to overheating and are more comfortable to users than lightweight ones.

[6] Note that only part of the building is air-conditioned.

9.1.6 Openings in the building fabric

Any opening in the building fabric needs to be entered to the energy efficiency measures risk log and its specification scrutinised in great detail. The operation of windows, the air-tightness of fittings and doors being open while the heating system is on are the most common problems witnessed.

Windows are useful in fully mechanically ventilated buildings too. If mechanical systems fail windows are the only sources of fresh air. In Petchey each classroom has operable windows, where they provide a means to top-up fresh air when the AHU supply is not adequate to reduce overheating or CO2 levels. Stockport is sealed and there are no complaints over noise however occupants were unable to open the windows when the AHU serving a stack of classrooms failed.

In some cases entrance lobbies have been value engineered and as a result occupants complain that the entrance area is too cold.

Escape doors, when used in both directions can be problematic and just left open during the winter compromising the building's air tightness. School doors experience a great deal of wear and tear and in most design and build contracts service agreements with providers are 'value engineered'. As a result high performance doors, that need re-hanging after the first year of operation to ensure correct fit, are routinely not serviced and leaking.

9.1.7 Lighting controls

Lighting controls were poorly commissioned in all the buildings and users were left without the right controllers, zoning diagrams and threshold settings despite high end system specification in the newer buildings. Similarly to the BMS, when the capital investment is made it is not clear who is responsible for making sure that the controls perform correctly. It is advisable that lights are submetered and lighting loads benchmarked as part of a performance contract to ensure correct operation.

Lighting consumption is higher than the EPC estimates in all cases and this is largely due to the poor zoning and sensor actuation of the common area lighting.

In classrooms occupants seem to prefer elaborate controls for zoning and dimming which is rarely fully functional if specified or simply not specified. A better understanding of occupants needs would help improve the product design of switches and controls.

9.1.8 The use of TM22 in Building Performance Evaluations

While the research team found the bottom-up approach to energy analysis adopted by TM22 very useful in developing an understanding of the electricity consumption of buildings, the following methodological issue may hinder the ability of this method/tool to carry out a whole-building energy performance analysis:

- All versions of TM22 developed so far, including the new version, are for electrical end-use analysis. The tools developed based on this method allow users to record non-electric end-uses if they are available from sub-meters or estimated by other means. The tool itself, however, does not offer any insight into fossil fuel end-use analysis.
- As for Heating, Ventilation, and Air Conditioning (HVAC) equipment, the method is mainly reliant on supply side information i.e. the installed capacities. These systems are often oversized and it would be very difficult to estimate the absorbed power of the equipment without an evaluation of building's demand taking into account building's thermal characteristics, occupancy patterns and climatic conditions. The method does not take into account these aspects of energy performance assessment.
- Usage and management factors are also often related to building's demand. It is not clear from CIBSE TM22 (2006) how these could be established with reasonable accuracy without systematic evaluation of building's demand.

9.1.9 The need for whole-life costing

One of the most important lessons from this project has been the need to be able to discuss building performance in terms of the costs of getting it wrong.. It appears that as an industry, construction is lamentably poor at ensuring that equipment is specified with occupancy patterns and end users in mind, that these are properly installed, configured, then monitored and maintained. If these factors are not in place then it is altogether less costly and more productive to deliver buildings that are entirely passively designed, with excellent fabric performance, high thermal mass and simple heating systems.

The question is whether getting building performance right is a matter of 'enforcement' or the right financial incentive. The lack of measured energy use targets and the absence of a performance contract pro forma for managing building services in the education sector is seen as a major barrier. And if buildings do need to go down a more complex service route then good metering and a properly completed log book is the first thing to check for at handover.

9.1.10 Better incentives – targeting measured energy consumption

Aedas R&D has been engaged in a parallel research project with the Technology Strategy Board called CarbonBuzz under the Design and Decision Tools competition. The outcome of this project is an online platform that offers feedback to built environment professionals about the robustness of their predictions and allows them to track and benchmark project energy data from design to operation anonymously. CarbonBuzz involved extensive stakeholder engagement with other BPE participants as well as government bodies, landlords, developers, local authorities and facilities managers. The platform has been online since 2008 and demonstrates significant differences between expectations and outcomes. A solution CarbonBuzz offers is a framework that helps users track measured energy use and contributing factors from design to operation.

Pilot projects are demonstrating that targeting measured energy use and logging energy efficiency measures and their performance assumptions online is a more effective way of achieving low energy buildings than relying on building regulations or the energy sections of BREEAM or similar sustainability ratings. In fact, without this process, it is very costly, time consuming, and in some cases impossible, to gather energy consumption data to carry out routine benchmarking and diagnostics. Without such data, project teams and contractors lack the focus and motive required to ensure that energy efficiency measures are correctly designed, installed, calibrated and used by occupants. There is some evidence pointing to buildings designed with a low measured energy use target are more resilient as building systems are better integrated and geared up for operational uncertainties which the current regulatory framework excludes.

Using the Academies and CarbonBuzz data as a basis, there is a 1.5-2 fold difference between the as-built EPC and measured energy data. This difference is even greater when comparing to design stage compliance calculations. Eliminating this ‘performance gap’ must be a major industry and policy focus for the next five years.

9.1.11 Energy management and reporting from design to operation

Mandating energy data drops and the preparation of an energy efficiency measures risk register throughout the project is highly recommended.

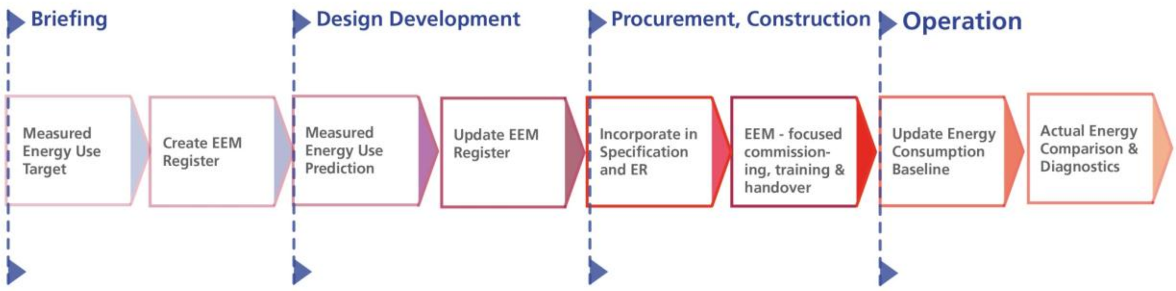

Figure 9.1: Energy 'data drops' at key stages in the Plan of Works

This would ensure that building services are more resilient to 'the human factor', that commissioning is performed with energy efficiency in mind and that on completion an end use energy consumption baseline is available against which operational results can be compared and diagnostics performed.

A requirement for data-drops would guarantee that metering is correctly installed and calibrated, that results are analysed early on, that BMS profiles are double checked in first year. In this way defects relating to control systems and metering are inevitably addressed during the defects liability period, which means substantial cost savings for clients and end users.

Good metering also allows payback times for any remedial measures to be rapidly calculated. For example, the lack of functioning meters on the chillers in Petchey Academy meant that establishing the true extent of the chillers' operation was extremely time consuming. The error margins on estimates can vary greatly, which has an important ramification to the deployment of the Green Deal for non-domestic projects. Most buildings applying for Green Deal finance will not have detailed monitoring in place. Yet without submetering the estimates of potential improvements will inevitably be highly inaccurate.

The gathering of energy end use data in an online freely accessible anonymised database would ensure that more evidence about the real maintenance and replacement costs of electrical and mechanical systems will be available in the public domain. Such data will allow more statistically robust benchmarking and will incentivise innovation in delivering buildings that demonstrate actual improvements in energy consumption.

The question inevitably arises about who on the client's side would monitor these data drops? Client side expertise has been highlighted as a major challenge to achieving improved building performance. Communicating such data in a transparent and user-friendly manner is important so that persons without engineering training can easily benchmark and compare results to similar buildings and understand the cost implications of shortfalls.

Building Log Books have a section where FM are supposed to log an energy target and subsequent achieved annual energy use. However not a single one of the Log books in these projects had these fields filled in. An online tool, such as the CIBSE|RIBA CarbonBuzz tool, that allows a more visual presentation and easy sharing of this data may be a better alternative in the long run.

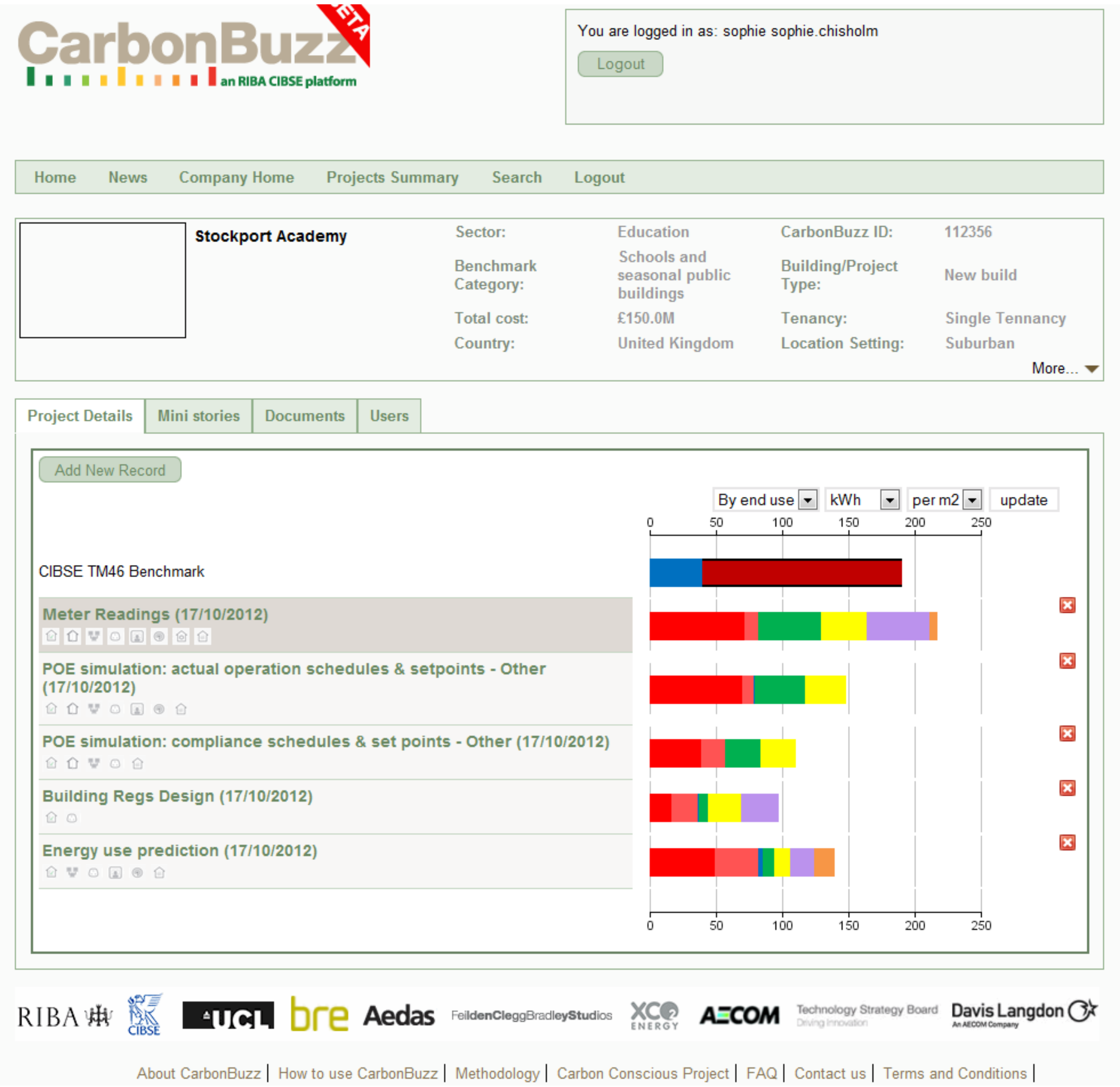

Figure 9.2: Snapshot of energy consumption data uploaded to CarbonBuzz from design to operation

9.1.12 Changes to Procurement

Performance contracts for construction and facilities management are an obvious recommendation. However, there is no pro-forma available for either and this has been raised with

BSRIA already and will be raised at the RIBA Sustainable Futures Group, CIBSE Benchmarking and Energy Performance and School Design Groups.

There are strong reasons as to why these do not exist and for consultants and contractors being wary of engaging in performance contracts. To start with, it is not in the commercial interest of either group to promote this as neither has anything obvious to gain by what is perceived as taking on extra work and increased liability. When it comes to energy performance, clients and end users have a major influence on energy use outcomes in areas that consultants and contractors cannot control.

However, recent pilot projects such as Keynsham Town Hall, designed by Aedas with Max Fordham, which has a DEC performance target, demonstrate some obvious benefits. Targeting a DEC rating instigates better information flow from design to contractor teams, more advantageous appointments for MEP engineers, more rigorous review of system specifications and ring-fencing of energy efficiency measures from cost engineering. Soft Landings is taken for granted as is the focus on training, aftercare and data reporting. Seasonal commissioning is not ‘value engineered’ as with all the projects studied and a service agreement is included in the main contract. Keynsham Town Hall is not yet complete; however, if the results are demonstrably better and achieved at a similar cost then this project will provide a template for a new way of procuring low energy developments. It is therefore essential that much effort is focused on monitoring the progress of this project.

It is great progress that the government’s new design brief for schools is asking for a prediction of measured energy use. Ensuring that the outcomes are published, read and used will be an even greater outcome.

With regard to facilities management, if performance contracts for FM would become mainstream then capital investment in submetering and building management systems may pay off and schools would have the incentive to get their FM involved earlier in the design and commissioning stages. For now, the expenditure and expertise required to extract energy data from building tends to exceed the scope of most facilities managers. With schools being largely unaware that performance contracts exist business managers continue to pay the high bills and cover the extra cost of FM without seeing performance gains.

Industry credentials for energy management may improve the situation. Since lobbying via the RIBA Sustainable Futures and CIBSE Benchmarking groups, both institutions have embedded the requirement for energy data as part of award submissions. If BSRIA and BIFM follow, the industry will be on its way to recognise Carbon Conscious Consultants.

9.1.13 Architecture – is it the answer?

This study has been led by an architectural practice with input from services engineers, contractors and researchers from University College London. The conclusions of the study are rooted in over a decade of architectural practice and several years' worth of feedback from post-occupancy evaluations. It is always a challenge to translate the lessons learned from such evaluations to practice and the recommendations so far have been made largely towards policy makers, funders, end users, contractors and engineers.

Yet architects have a key role to play. The problem witnessed in all the projects studied was the lack of 'integration' and appreciation of the 'human factor' in systems design. Although in practice architects probably revisit buildings just as rarely as engineers they are in a position to communicate lessons learned and channel the need for change between engineers, contractors and clients.

The drive for energy efficiency has no doubt started a revolution in the design of building services and controls – opening up a bonanza of design opportunities that architects are best placed to make the most of. If we accept that buildings are more than just an assembly of building products, but an expression of identity then funders and architects have a great deal to take away from the BPE programme too.

Most certainly a greater awareness of where and how energy is used in a building and what are acceptable levels of consumption and key contributing factors should form an elemental part of secondary and higher education and should certainly be part of the core architectural curriculum.

Finally, all building industry professionals should learn from product design, where it is unthinkable for designers and manufacturers not to gather feedback about a product's performance in use.

With better feedback, architects will gain a better understanding of the implications of control systems and equipment on spatial configuration, occupant well-being as well as cost and maintenance. With a better grasp of the data they can be empowered to lead the design and integration of mechanical and electrical systems to low energy buildings that outperform expectations.

9.2 Conclusions and key findings for this section

9.2.1 Summary of recommendations

- Mandate the prediction and disclosure of measured energy end use data and assumptions behind these at critical project stages via 'data-drops' as part of the Soft Landings Rollout.
- Gather this data in an anonymised freely accessible database that is regularly analysed by an independent group of experts who feed back to industry and government on the progress in closing the performance gap.
- Invest in the analysis of the gathered data to identify the true extent of the risks involved in the mechanical servicing of education buildings. Incentivise innovation in this area.
- Encourage the gathering of data on the productivity of occupants and analyse relationship with energy consumption.
- Feedback – embed the verification of performance in the investment cycle for new buildings and refurbishments.
- Ensure that measured energy end use readings are required to conclude all non-domestic construction contracts three months after completion and again at the end of the defects liability period. Link the records section of the Log Book to an online database logging year-on-year improvements.
- Create a performance contract pro-forma for the management and maintenance of building services; include energy performance targets and ways of measuring and benchmarking these.
- Separate 'Commissioning' in the RIBA and CIC scope of works to give it the correct weighting in the construction process. Highlight the roles and responsibilities of clients, contractors, design team and end users.
- Mandate the verification of Energy Efficiency Measures installation and commissioning by an independent M&E Clerk of Works for all non-domestic construction projects above 500 m2.
- Embed building performance evaluations in all non-domestic construction projects above 500 m2.

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, CO_2 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