Cressex Community School

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

Innovate UK project number	45018
Project author	XCO2 Energy Ltd (via BAM Construct UK)
Report date	2014
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	Location	Form of contract	Opened
School (secondary)	High Wycombe	N/A	2011

Floor area*	Storeys	EPC / DEC (2010)	BREEAM rating
11,624 m^2	3	31 (B) / 200 (G)	Very good

*Floor area quoted as 11,687 m^2 in EPC. DEC rating for 8255 m^2 of floor area. It is unknown why floor area was low. Possibly the quoted area was the only occupied space at the time of the lodged DEC. No DEC was lodged during the research period.

Purpose of evaluation

Cressex Community School is a secondary school in High Wycombe, Buckinghamshire. It was designed for highenvironmental performance and low energy use. Upon completion it achieved a BREEAM "Very Good" rating and a 'B' rated Energy Performance Certificate. This study examines how this achievement relates to the building's in-use performance and the possible reasons for any differences.

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

Electricity 69.2 kWh/m^2 per annum, thermal (gas) 52.7kWh/m^2 per annum. Energy data covered a one year period of monthly electricity and gas consumption. Electricity AMR metered data was available for afull year (June 2011 to May 2012). The biomass boiler was not separately metered. No annual energy breakdown was attempted. No heat meters were provided and so it was not possible to separately monitor space heating and hot water. Some electricity meters did not appear to be assigned to end-uses. For example, power for fans, pumps and cooling all seem to be on the same sub-meters which have an assigned end-use of "mechanical services". There was no mention of the ground-source heat pump being independently monitored.

Occupant survey	Survey sample	Response rate
BUS, paper-based	53 of 55 (population 75)	96%

Overall the occupants reported feeling moderately comfortable at the school. The summary results showed that occupants perceived the building's temperature and indoor air quality to unsatisfactory in summer and winter. The occupants are generally satisfied with the natural light levels, but a perception that glare is too high led to some pupils experiencing difficulty seeing the whiteboards. As a consequence the blinds are used regularly. These issues led to the school changing theoriginal semi-translucent internal blinds with more opaque blinds capable of blocking out more natural light.

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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.

Contents

About us:
XCO2 Energy are a low-carbon consultancy working in the built environment. We are a multi-disciplinary company consisting of both architects and engineers, with specialists including CIBSE low carbon consultants, Code for Sustainable Homes, EcoHomes and BREEAM assessors and LEED accredited professionals.

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.

Cressex Community School is a secondary school in High Wycombe, Buckinghamshire which was occupied in 2010. It was designed for high environmental performance and low energy use. Upon completion it achieved a BREEAM "Very Good" rating and a B rated Energy Performance Certificate (EPC). This study examines how this achievement relates to the building's in use performance and the possible reasons for any differences.

This final report summarises the findings of the BPE study which has included reviews of:

- Design and construction data
- Metering Strategy
- Commissioning and sign off
- Handover
- Controls
- Room usage

The experience of occupants and those involved in the design and construction has been evaluated, and this has been related to monitoring of internal conditions at the school. The energy performance has been evaluated in as much depth as the available data allowed.

The school's occupants find the school aesthetically appealing, and are proud to show it to visitors. The space provided is good, and a significant improvement on the previous school building. Classrooms and circulation areas are light and airy. The building fabric also performs well, with a relatively low air permeability and few significant thermal bridges.

The main challenges at the school have related to three key issues. Firstly the Biomass boiler has had difficulties due to problems with the fuel store. Secondly the occupants have experienced some perceived discomfort in their thermal environment in terms of temperature and humidity. The extent to which this is a result of performance issues or of a perception of lack of control is explored in later sections. Thirdly, the absence of a suitably qualified Facilities Manager from handover has led to reduced building performance and energy wastage. Improvements are now being made, but energy use is still higher than expected.

Other findings are also explored in later sections and are discussed in detail in accompanying subject specific reports on the following topics:

- Metering Strategy Review
- Review of Design and Construction Data
- Semi Structured Interviews
- Walkthrough Report
- BUS Survey Results
- Infra-red Thermography Report
- Review of Commissioning and Sign Off
- Annual Energy Use Assessment
- Controls Review
- Internal Conditions Monitoring
- Review of Handover
- Review of Room Uses
- Review of Technical Performance

2. Details of the Building, its Design, and its Delivery

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

2.1 Building Design

Cressex Community School, occupied in September 2010 after a two year build phase, is a secondary school located in Holmer's Lane, High Wycombe, Buckinghamshire (see map below). It is located on the outskirts of the town and is 0.33km north of the M40 motorway.

The school has capacity for approximately 1,100 pupils but is currently under-occupied with approximately 500 pupils in attendance, although this is growing year on year. The 11,624 m^2 three storey, concrete frame school consists of four blocks all linked by the main atrium space (see Figure 2.2).

The purpose of this building was to replace the existing secondary school at the site. This consisted of multiple individual buildings in a poor state of repair, which all had their own separate services consisting of gas heating and rudimentary natural

Figure 2.1: Site Location Plan

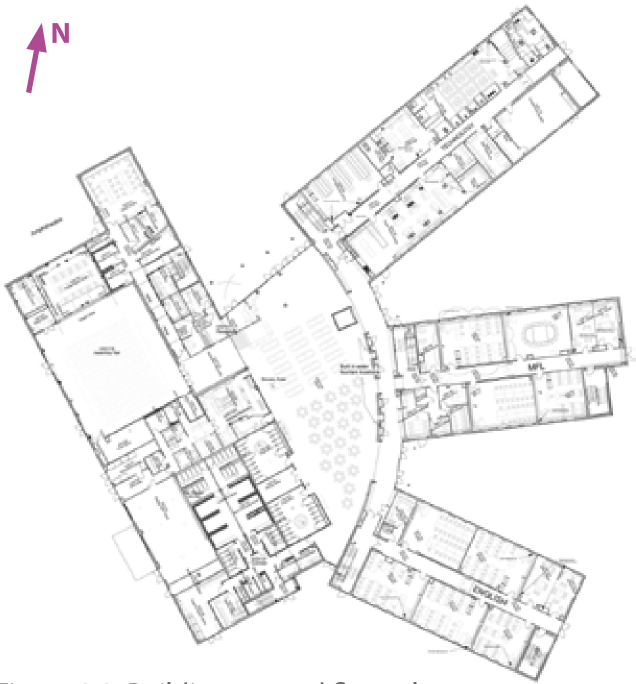


Figure 2.2: Building ground floor plan
ventilation.

The main teaching areas have been designed with east-west teaching wings (A, B and C) creating north-south orientated classrooms with the intention to reduce difficult to control east-west solar gain and glare entering the classrooms. The north facing classrooms should benefit from the quality of the north daylight without suffering from excessive solar gain. The south facing classrooms should benefit from passive solar gain during the winter with the intention of blocking excess solar gain in the summer through the use of solar control glass. The narrow classroom blocks coupled with the wing arrangement provide classrooms with large glazed areas, which increases the amount of available daylight and theoretically reduces dependence on electric lighting.

The courtyard has been covered with a thermoplastic ETFE roof which provides diffuse daylight to the spaces below.

The materials used in construction had U-values which were improved beyond building regulations. As noted in other reports though, in places these U-values were slightly higher than specified in the original concept design.

The increase in design U-values from the conceptual stage are likely to have increased the space heating loads of the completed building. Although the U-values achieved meet the Building Regulations they would not be low enough to be considered as best practice within the industry.

Heating, cooling and ventilation of the building are provided by a combination of a woodchip biomass boiler, a top-up gas boiler, GSHP and roof-mounted AHUs.

Lighting in the building includes the use of presence sensors and daylight sensors to allow strategic dimming of luminaires that are adjacent to windows.

2.2 Design Changes

During the design process a number of changes to the design took place. Details of the changes can be found on page 33 and 34 of the *Review of Design and Construction Data - Cressex Community School*. The most significant change was the change from natural ventilation to an entirely mechanically ventilated scheme without openable windows. This was in part due to noise considerations and a necessity to meet BB101, but is thought to have led to occupants feeling poor levels of comfort in some parts of the school. In particular, the lack of local control of their environment is thought to be a significant factor. This is compounded by the fact that in hindsight, noise was not seen to be a significant issue by occupants prior to construction (see section 7.3 for further details and explanation).

Other notable changes include the decision to include the atrium within the conditioned building envelope to make it a more usable space (leading to increases in the surface area, average U-value and thus space heating requirements), and the dropping of passive and low energy measures including earth pipes, wind turbines and solar thermal panels. It is suspected that these measures would have added unnecessary complexity to the scheme for little benefit.

2.3 Procurement and Timeline

In 2006 Buckinghamshire County Council (BCC) applied for, and received funding from the One School Pathfinder Programme (OSP) run by the Department for Education and Skills, as a late part of the Building Schools for the Future programme. Cressex Community School was selected by BCC for the OSP for its location in an area of high deprivation and the existing school buildings being in a poor condition. The initial funding received was £30.5 million in early 2007.

This funding was dependent on the school meeting a number of conditions and standards including:

- BREEAM Very Good rating as a minimum
- Building Bulletin 77 – Designing for pupils with Special Educational Needs
- Building Bulletin 87 – Guidelines for the environment design of schools
- Building Bulletin 101 – Ventilation of Schools
- Show cost effectiveness in accordance with Building Bulleting 98
- Use Design Quality Indicator for Schools (DQIs) to influence the design
- Apply for specialist status. Cressex applied for Business and Enterprise status
- Involve the school community in the planning of the project
- 60% reduction in CO_2 emissions over 2002 building regulations

The procurement for the design and build contract was via the South East Centre of Excellence (SECE) framework, a joint procurement programme for 8 OSP schools in the region. The model scheme (which effectively took the design to RIBA stage C) was developed by Hampshire County Council with support by their Architect's Department and the M&E consultants White Young Green. The school, BCC and local community were involved in this design process with representatives attending two DQI workshops. A revised cost calculation of the proposal took place and funding was reduced to £25.2 million.

Of the three contractors short-listed for the project, BAM Construct UK Ltd was selected for the design and construction of the school. During the design process a number of changes were made to the HVAC design, including the specification of a GSHP system to assist with achieving the 60% CO_2 reduction target. Planning permission was granted in March 2008. The detailed M&E of parts of the development were designed and constructed by Briggs and Forrester (B&F) with BAM acting as lead contractor.

Construction began in early 2009, with handover and commissioning of the new building beginning in May 2010, completion of the new building in July 2010. The old school was demolished by February 2011. There was a full year defects liability period for the completed building with additional support provided via a maintenance contract with B&F, and on site support from BAM during a later landscaping phase of the project.

The design and construction phases adopted the BAM standard commissioning and handover package at the time.

As of April 2013, the school had been fully occupied for over 2.5 years.

More details on the subjects discussed in this section can be found in the *Review of Design and Construction Data* report.

3. Review of Building Services and Energy Systems.

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

3.1 Building Controls

The building systems are controlled by a central Building Management System (BMS). The BMS is designed to use temperature and CO_2 sensors to take readings from different spaces to control the heating and ventilation according to the figures set by the school. The school design incorporates zoning to allow each teaching block to be operated separately.

3.2 Heating Systems

The space heating is distributed through three systems operating in different parts of the building.

- The teaching and support rooms have solely air based heating systems, with mechanical supply and extract ventilation, where the heated air is fed through the terminal units and supply vents.
- The changing rooms have underfloor heating.
- The circulation and administration areas have ceiling mounted radiant heating panels connected to the gas/biomass heating system.
- The atrium has two sources of heating integrated into the ventilation system: waste heat, in the form of air, from the teaching wings can be discharged into the atrium, or supplementary heat from a biomass/gas fed heating coil can be discharged into the space.

In Winter the HVAC system is designed to maintain temperatures in the school as follows:

Internal Conditions - Winter Temperatures

Space	Temperature (Dry Resultant)
Classrooms	21°C ± 2°C
Circulation Areas	18°C ± 2°C
WC's	15°C ± 2°C
Kitchen	16°C ± 2°C
Dining Rooms	20°C ± 2°C
Covered Courtyard	15°C minimum

In summer, the HVAC system is designed to maintain the following temperatures through GSHP pre-cooling where necessary:

Internal Conditions - Summer Temperatures

Space	Temperature (Dry Resultant)
Teaching Accommodation	21°C to 28°C - Not exceeding 28°C for more than 120 occupied hours - Not exceeding 32°C at any time during occupied hours
Comms Room	23°C ± 2°C
Kitchen	26°C ± 2°C

Two GSHP units located at roof level generate heating and cooling via a ground loop within multiple boreholes beneath the sports field. The low-grade heating or cooling that is generated, conditions the supply air to the building via heating and cooling loops contained within the large roof mounted air handling units (AHU).

The pre-heated or cooled air enters a terminal unit prior to entering an occupied space. Within each terminal unit there is an additional heating coil which is served by a heating network connected to boilers located within the main ground floor plant room. The terminal units allow for independent control of temperature within each room.

The main plant room contains a woodchip biomass boiler and gas backup up boiler. The boilers supply heat for space heating (within room terminal units and areas where underfloor heating or radiant panels have been installed) and to meet the building's hot water demand. A thermal store has been installed to account for the daily fluctuations of heat demand and to allow each boiler to meet the entire heat load through night charging.

It is felt that inclusion of the GSHP added additional complexity to the biomass heating system and a more complex controls setup in the BMS. The change to biomass and gas rather than only biomass seems to have been a fortunate move given that during the first year of occupancy the biomass plant was rarely operational.

3.3 Ventilation and Cooling

The roof mounted AHU's operate a mechanical supply and extract system supplying either pre-warmed or cooled fresh air to all the teaching and support rooms, in the winter and summer respectively. During the shoulder seasons there are times when the conditioned air from the GSHP is sufficient to meet the space heating demand. In which case the biomass/gas heat network is not used.

The atrium space uses a mixed-mode ventilation system to cover the summer and winter operations. When the atrium overheats, high and low level natural ventilation openings provide ventilation through stack ventilation. Window actuators open windows and louvres on each side of the building to allow fresh air to enter and warm air to escape. When the atrium temperature falls to below the preset level the natural ventilation openings close. Destratification fans circulate air in the atrium space when the atrium is in closed mechanical ventilation mode.

Areas of the building where there are high internal heat-gains, such as the I.T. rooms, have air-conditioning via roof-mounted DX-type chillers.

The kitchen spaces have direct extract and supply of external fresh air with a boost for increased extract ventilation.

The ventilation was designed to provide a minimum rate of 3 l/s/person, an average of 5 l/s/person, and capable of providing 8 l/s/person. Apart from the atrium, it is provided through an entirely mechanical system after an external noise survey suggested that external noise from the M40 and other nearby roads would cause disruptive noise levels in classrooms with natural ventilation.

Humidity is not directly controlled by the BMS, and an assumption that levels would naturally be maintained within the comfortable range of 40-70% RH was made.

3.4 Lighting

The preferred source of lighting for the school is daylight and when daylight levels are low electric lighting is provided.

The artificial lighting is controlled by daylight sensors, occupancy sensors and manual override. This level of control is provided in all spaces where daylight is the main source of lighting. Roller blinds are provided in classrooms to allow the occupants to control glare. Dual switching is provided in classrooms to control the white board and classroom lights. Perimeter fittings parallel to the windows are controlled by daylight sensors.

Lighting to the atrium is by means of suspended high bay luminaires with floodlights fitted at intervals along the spans of the ETFE roof. The lighting in this area is via manual controls with daylight dimming.

3.5 Metering

In total 82 meters are present on the Cressex BMS user interfaces including 4 gas meters, 7 water meters, 12 heat meters and 59 electricity meters. The number of meters present is different to both the building log book and schematic drawings. The number reported ranges from 67 to 84.

Lighting and small power are metered by floor within each block and for specific areas within the main block D, such as the assembly hall etc. External power and general plant power for different areas are metered on mixed end use meters, which means that separating total energy into individual uses is difficult. There was also found to be no direct metering of heat supplied from the biomass boiler, making it difficult to assess its performance accurately.

More details and discussion on the subjects covered in this section can be found in the *Review of Design and Construction Data,* the *Controls Review* and the *Metering Strategy Review.*

4. Key Findings from Occupant Survey

Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the early stage BPE process and in particular with cross reference to the commissioning, handover process, training and operating manuals, aftercare, BUS survey, interviews and discussions. This section should draw on the BPE team's initial studies into possible causes and effects, which may require further study. Graphs, images and test results could be included in this section where it supports a developing view of how well or otherwise the design intent has been delivered during the pre and post completion phases.

4.1 Building User Study

A BUS study was carried out at Cressex School on 15th May 2012 to gauge the occupants views on comfort levels and the design of the building. The questionnaire included questions on building design, comfort, noise, lighting, health, productivity, controls, response to problems, travel to work and work requirements.

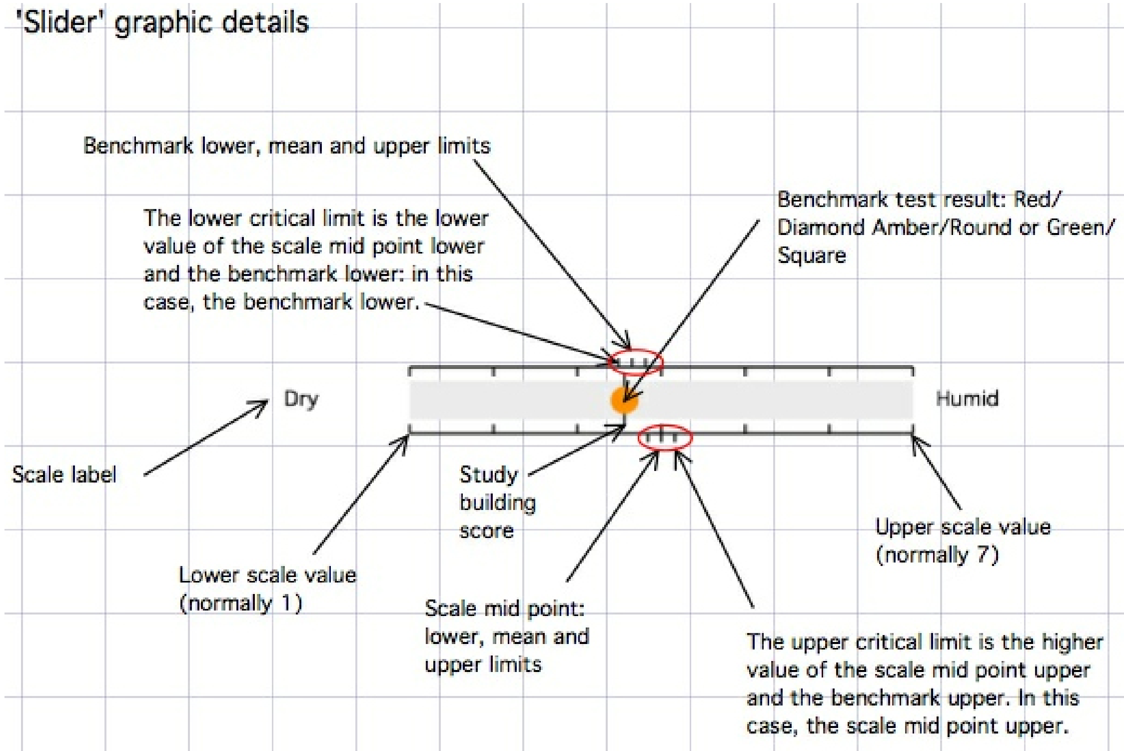
Out of a total of 75 full and part-time staff at Cressex School, 55 were given a questionnaire and 53 responded. The response rate for the staff was therefore 96%. The response rate from the questionnaire was statistically valid and can therefore be used to highlight the thoughts of the majority of the staff.

The positive findings of the questionnaire included:

- good lighting
- low noise levels
- good overall comfort
- pleasing design

The questionnaire brought up issues including perceived:

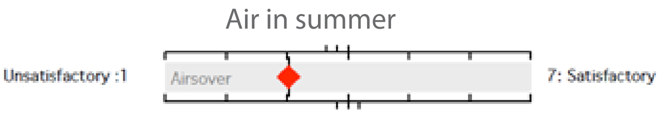
- poor air quality,
- uncomfortable temperatures,
- concerns over healthiness whilst in the building,
- difficulties with glare on white boards,
- lack of control over heating, cooling and ventilation
- minor issues with internal noise control

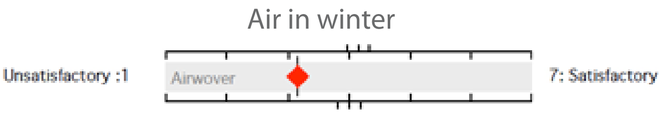


4.1.1 Air Quality

The questions relating to air quality covered seasonal air movement, humidity, freshness and odour. The overall results showed that occupants found the air quality more unsatisfactory than satisfactory in both summer and winter, as shown in the graphs against the ARUP schools benchmark dataset.

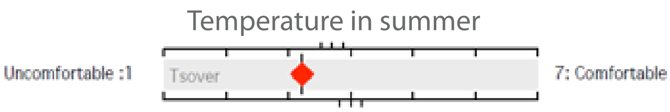
The majority of occupants who responded stated that the air is often too dry. In addition to this some occupants also noted they felt there was a lack of fresh air and attributed this to having no openable windows.

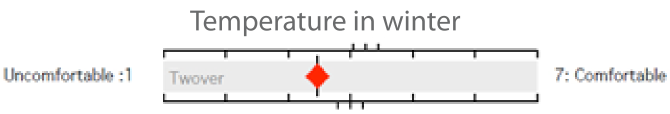




4.1.2 Temperature

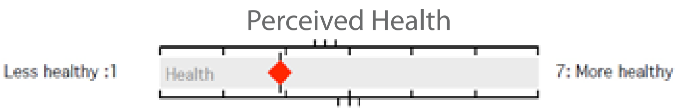
Overall the occupants perceived the building temperature to be more uncomfortable than comfortable in both summer and winter months.





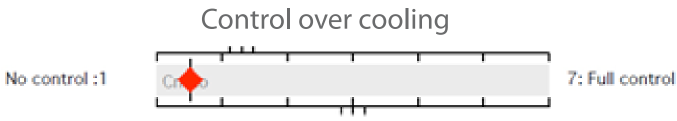
4.1.3 Health

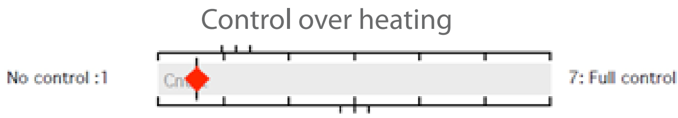
The occupants generally felt the same or less healthy when in the building. In the comments received from occupants there were some suggestions that they had more headaches, caught illnesses/colds more often, felt tired and had dry eyes and throats leading to them feeling dehydrated.

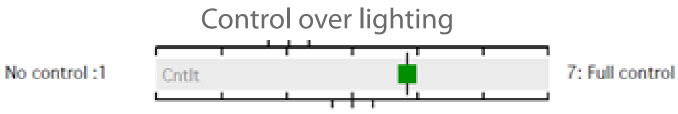


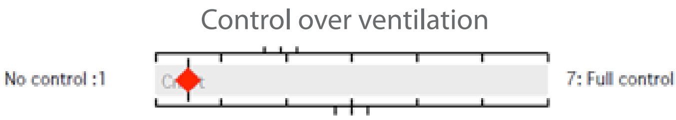
4.1.4 Controls

The occupants had a mixed response to their availability of controls. They found that their control over noise was adequate and control over the internal lights was more than adequate. However, the occupants felt they had no control over heating, cooling and ventilation. This response was expected since the building has few local controls for altering these conditions and instead this is carried out centrally via the BMS.







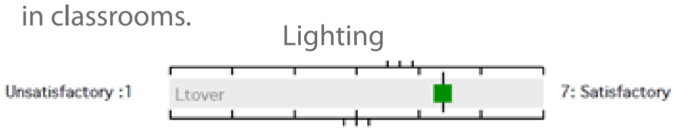


4.1.5 Lighting

The occupants appear to be mostly satisfied with lighting levels overall. The occupants are generally satisfied with the natural light levels and have found the glare from artificial lights to be acceptable, however, the users found the glare from the natural light through windows to be too high in some areas of the building.

The feeling that glare is too high has led to some pupils experiencing difficulty seeing the white board and as a consequence the blinds are used regularly.

These issues have led to the school changing the original semi-translucent internal blinds with more opaque blinds capable of blocking out natural light. Since the replacement of the blinds teaching staff have been generally more satisfied with the lighting in classrooms.

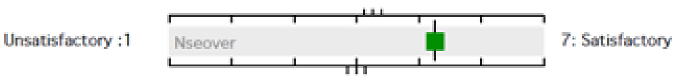


4.1.6 Noise

Overall noise levels in the building were deemed to be satisfactory by the occupants with few unwanted interruptions and little noise from inside the building. The only noise issues noted were associated with the atrium and library.

Most people noted that the sound insulation in classrooms was good and that noise generally comes from the movement of pupils outside the teaching times.

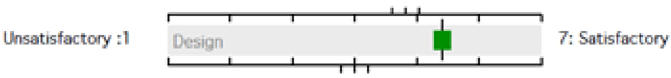
Noise



4.1.7 Design and Image to Visitors

The questions regarding the design of the building, its image to visitors and facilities management (including cleaning, furniture, meeting rooms and storage space) were the most highly rated answers in the survey, with occupants particularly liking the atrium and the main meeting room for visual impact. However, lack of storage space was identified as an issue.

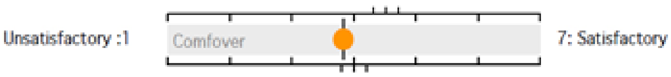
Design



4.1.8 Comfort

Overall the occupants reported feeling moderately comfortable at the school. One might expect a fully mechanically ventilated building with such tight controls over internal conditions to provide a higher level of comfort than has been achieved.

Comfort



4.2 Analysis

Thermal imaging of the building fabric showed that in general there are few thermal bridges or areas of excessive or unexpected infiltration. Therefore, where some occupants feel too hot and others feel too cold it may be that the ventilation and/or heating system together with their controls are causing this issue. Alternatively, it may be a simple issue of individual preferences with respect to comfort. What one person sees as comfortable may be seen as uncomfortable by others.

The mechanical ventilation is designed to be capable of providing the necessary ventilation rates for occupants to feel comfortable. Perceived ventilation issues may indicate that either the systems are not working as expected or are not being controlled and managed effectively. Investigation into internal conditions, detailed in the *'Internal Conditions Monitoring'* report showed that CO_2 and temperature levels were within industry guideline acceptable limits for the majority of the time, however, internal conditions monitoring (in 6 classrooms, the library and an office) was only carried out for a short period of time (between 2 and 11 days) in each location.

Further commissioning of the building systems and improved management of controls on the BMS may solve the temperature variation issues.

Comments from the BUS suggest the feeling of unhealthiness whilst in the building are linked to internal climate and the issues surrounding the supply of fresh air and the regulation of temperature. It is suspected that these symptoms are caused by a combination of problems with the ventilation system and a negative response to the lack of control.

Overall, the occupants' dissatisfaction with the building relates to the air quality, temperature and system controls which feed into the general feeling that they are less healthy whilst in the building. All of these items appear to revolve around the heating and mechanical ventilation system, the lack of openable windows, and the capability of this arrangement to provide comfortable temperatures and fresh air.

It should be noted that the occupants are generally pleased with the look and design of the building. If the issues surrounding the levels of comfort and control in the building can be improved then the overall levels of satisfaction could be increased. This will no doubt ensure that the building is enjoyed more in the future.

4.3 Issues Raised by Semi-Structured Interviews

Interviews were carried out with representatives from organisations involved in the Cressex Community School project. In total eleven semi structured interviews were carried out with different members of the construction team including:

- Design - BAM M&E and B&F M&E
- Construction - BAM Construction and B&F M&E
- Client - Buckinghamshire County Council (BCC)
- User - Cressex Community School employees

Issues mentioned in these interviews which have not been discussed in relation to the BUS results are detailed below:

- The low occupancy of the building is a contributor to the high energy use experienced at the school. Ventilating and heating classrooms that are not being used is a waste of energy that would be avoided through occupying a more compact space. A more robust control strategy that allowed ventilation to be turned off on a room by room basis could have helped the school to make energy savings even with a less space-efficient occupancy. However this would have been at a significant additional expense. The school should act to ensure that BMS-integrated thermostats in rooms that are not being used are set back to a suitably low temperature to ensure they are not heated unnecessarily. The school may also want to reconsider how it currently uses the building and attempt to isolate block C.
- When the school is unoccupied, the main plant should be in fabric frost protection mode. Heating and ventilation plant should ensure rooms do not drop below a 10ºC setpoint. Ventilation should switch to re-circulation only where required to maintain the temperature threshold. This setup has not been in operation during the half term holidays.
- A log book was produced for the development which describes the building systems and intended operation. The log book is difficult to find on site as a physical document and is not being actively updated by anyone at the school. Since there has been no technical building manager at the Cressex site a 'non construction professional' type user guide, detailing the basic principles of the HVAC system and providing operational guidance for the BMS may have been beneficial.
- It was suggested that some problems had arisen, especially during handover, as a result of the school's adoption of Cooperative Trust school status in 2010, distancing it from the local authority (LA). The client was still the LA, but the future building users had less input after the change.

4.4 Conclusions and Key Findings for this Section

Issues relating to heat and ventilation are having an impact on occupant comfort levels. A significant contributor to the discomfort is thought to be the lack of control felt by the occupants, and this has been made worse by the school being unable (until recently) to use the BMS's full potential due to a lack of expertise.

When carrying out interviews and surveys, there can be a tendency to focus on negative aspects and therefore it should be stressed that the completed school is enjoyed by many. Ensuring that positive aspects are repeated in future designs is as important as addressing those aspects that could have been improved.

More details on the subjects discussed in this section can be found in the *BUS survey Results*, The *Semi-Structured Interviews* and the *Walkthrough Report*.

5. Details of Aftercare, Operation, Maintenance & Management

Technology Strategy Board guidance on section requirements:	This section should provide a summary of the initial aftercare process, post completion building operation, and initial maintenance and management – particularly in relation to energy efficiency, reliability, metering strategy, building operations, the approach to maintenance i.e. proactive or reactive, and building management issues. How were users trained to use equipment and do they demonstrate the right competences? Was the maintenance team employed, trained and up to speed at handover? Was a proper system put in place to log problems, and did this help resolve teething issues?

5.1 Initial Aftercare Process

The handover procedure did not conform closely with the process suggested in Soft Landings. However, it was never intended to do so.

The handover process was frustrated by the lack of experienced and interested people with available time. The client was Buckinghamshire County Council (BCC) but the new building was to be run by the School themselves. Demonstrations were offered/given to BCC M&E advisors but these were primarily to prove the systems worked as they had no involvement/interest in later running the school. The school were advised and talked about employing an experienced facilities manager with the knowledge to use the BMS but this did not happen until April 2012, approximately 19 months after handover was complete.

The school did not have sufficient remaining funds to employ someone whilst retaining the existing long-serving caretakers whom they felt a duty to retain. The existing caretakers had limited technical knowledge and were not equipped to use a computer based BMS, so responsibility for dealing with the BMS system was left with the Assistant Head teacher and the Business Manager. Support was provided by the school's IT coordinator and a caretaker with IT experience. However these two employees had no formal training on the BMS. It was challenging for the two staff members to find enough time to carry out this function whilst continuing with all their other responsibilities which usually took priority.

5.1.1 Physical demonstrations

As the new building neared completion all members of staff and pupils were given tours of the new building and especially their department to gain familiarisation and appreciation of the space and storage available in the new building.

A timetable of demonstrations was set up prior to the school summer break. Often the school staff did not have sufficient time available and the demonstrations were cut short.

The BAM Site Manager was in close liaison with the school and organised training to be repeated as necessary to the staff who actually needed to know how to operate various pieces of equipment.

This was frustrated by the lack of personnel with available time. A day was allocated for the Assistant Head and Bursar to be trained on the BMS but on the arranged day the Bursar was too busy and the Assistant Head could only spare the morning. The BMS had been provided on a stand-alone computer but the school IT coordinator transferred it onto the main school server which then prevented it being accessed remotely. This action resulted in the construction team and maintenance contractor not being able to check or alter BMS settings without attending site.

5.1.2 Documentation

The written documentation for commissioning and handover has been evaluated in detail in the Review of Sign-off and Commissioning Plans report.

5.1.3 Ongoing support

For the first two full terms after the new school opened there was a BAM Site Manager permanently on site overseeing Phase 2 of the contract (demolishing the old school and constructing the car park and landscaping). He was also in daily contact with the school and dealt with any problems or issues as they arose. The school provided him with remote access to the BMS and he would interrogate the BMS and assist them to manage the building.

The approach to maintenance by the school began, and has remained very much a reactive process. Corrections are attempted when things go wrong. The staff initially tasked with running the BMS did not have the time or understanding to respond to maintenance alarms when they first arose, instead leaving them until the lack of maintenance caused a noticeable breakdown. This has possibly led to a less satisfactory user experience.

There does not appear to have been a formal system to log problems and maintenance within the building, with the staff responsible for the BMS responding to verbal requests and complaints without keeping records. This led to problems building up in the BMS, as changes were made with no record kept as to the reason, and the original settings not being reinstated after the changed settings were no longer required. It is possible that significant amounts of electricity and gas were wasted in this way before the appointment of the facilities manager enabled a rationalisation process.

5.1.4 Biomass

One system that has experienced significant maintenance issues since handover is the biomass boiler. This has been non-operational for significant amounts of time since handover due to moisture ingress into the woodchip storage pit. This is discussed further in section 7.2.

5.2 Conclusions and Key Findings for this Section

In future projects we would recommend that handover follows a standardised approach such as Soft Landings or similar schemes in order to ensure suitable documentation and provision is made for the handover process from the outset.

While commissioning on this project did occur, the process was poorly documented, and this should be remedied in future projects. The lack of an FM at handover stage meant that an O&M review was not completed by the school. It also meant that training could not be provided to an appropriate person.

The incidental on-site attendance was no doubt beneficial and helped the school to operate the building during early occupancy.

The school should have used the defects liability period to better effect as, with the right attention, many irregularities could have been picked up that were in actuality only noticed after this period ended.

Better records should be kept by the school of both the building performance through regular reporting, and of all changes made to the BMS and other settings. Without this, predictions of future performance cannot be meaningfully compared with actual results. Information should be disseminated to other occupants in the form of newsletters or a website so that the users feel more connected to the building.

It would be advisable for school building projects with a BMS system to budget for a qualified and suitably experienced Facilities Manager from the outset. School buildings are increasing in complexity as meeting increasingly stringent environmental targets in public buildings have led to highly technical solutions. Modern building services are capable of producing very efficiently run buildings, but without proper management this potential can never be met.

More details on the subjects discussed in this section can be found in the *Review of General Handover and Review of Sign-off and Commissioning.*

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 first 6 months of metering results and other test results. Where possible, provide a simple breakdown of all major energy uses/producers such as renewables and the predicted CO_2 emissions. A commentary should be included on the approach to air leakage tests (details recorded elsewhere) and how the findings may be affecting overall results. This section should provide a review of any initial discoveries in initial performance in-use (e.g. after fine-tuning). If early stage interventions or adjustments were made post handover, these should be explained here and any savings (or increases) highlighted. The results should be compared with other buildings from within the programme and from the wider benchmark database of CarbonBuzz.

6.1 Where is energy being consumed?

A preliminary study estimated the breakdown of energy use within the building to be as shown in Figure 6.1 below. This was based on one month's metered data before the appointment of the Facilities Manager.

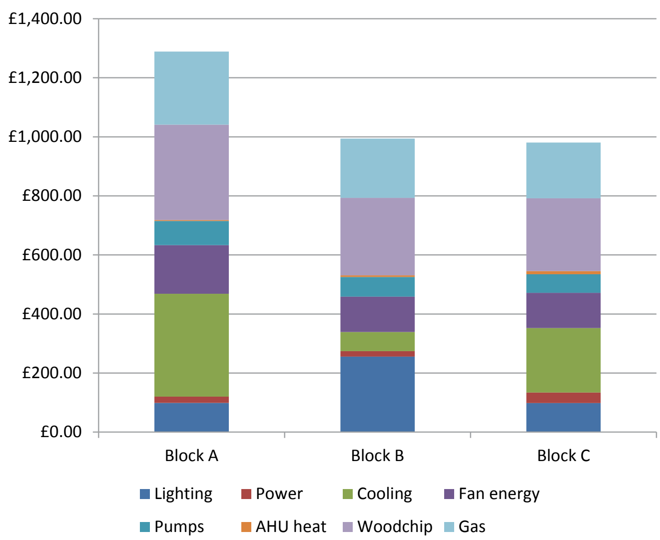


Figure 6.1: Running Cost per Month

The TM22 analysis was completed early on in the study and updated with 2012 data when it became available. The results of this analysis can be seen in figure 6.2. The bottom bar shows the most recent result for the school. The result is broadly comparable to the Carbon Buzz benchmark with slightly lower electricity usage and higher heating requirements. The Carbon Buzz benchmark comprises the median actual consumption data for 77 educational buildings which have been submitted to the website. By their nature the buildings entered are generally recent builds, and may reflect more accurately typical usage in a modern school building. There is a marked

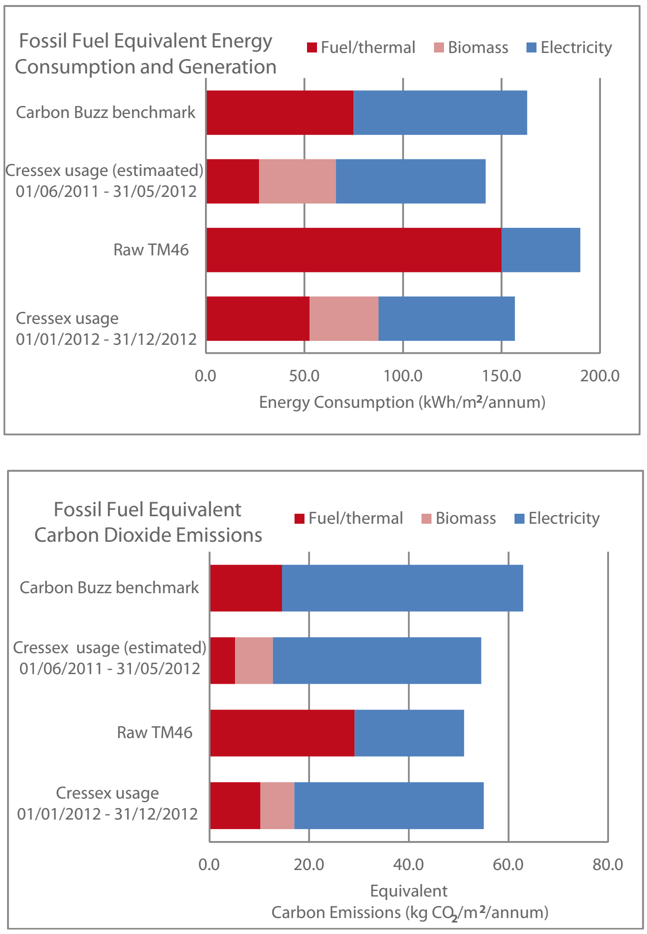


Figure 6.2: Energy and CO_2 benchmarking against Carbon Buzz and TM46 data based on a TM22 simple assessment.

difference from the TM46 benchmark for all schools and seasonal public buildings, which reflects the change in demand patterns in more recent schools like Cressex. The TM46 benchmark is a median value of all schools from the DFES database circa 2003.

6.2 Actual CO_2 emissions

The estimated CO_2 emissions at the school for the year 2012 were approximately 55 $kgCO_2/m^2$. This has remained relatively stable for the previous year and a half, but hides a significant drop in electricity consumption and a rise in gas use due to the maintenance problems with the biomass boiler.

6.3 Air leakage testing

Air leakage testing was carried out at the school on the 17th June 2010, close to practical completion, and a result of 4.97 m^3/m^2h was achieved. The project team were unable to determine which area of the school this airtightness relates to.

The school was designed to be mechanically ventilated with no openable windows, so this low leakage value should be helping ventilation to work more efficiently.

6.4 Savings

The early operation of the school was not as the designers intended, as the school did not have a dedicated facilities manager, and the staff running the building had limited understanding of how the BMS worked. As a result, since the appointment of the facilities manager in April 2012, significant electricity savings of approximately 80,000 kWh (estimated to be worth around £8,000) have been made over the initial usage (based on a comparison between 2011 and 2012 usage), in large part simply by running the building more closely to the intended operation. There have, however, been setbacks thrown up by the problems with the biomass system, which has led to the gas boiler being used more often than expected.

The graph below shows some typical autumn energy use before (red) and after (blue) the appointment of the facilities manager. Overnight minimums and half term usage have improved dramatically. Sunday usage has grown, but this is a result of the recent use of the school on Sundays by a local church.

More details on the subjects discussed in this section can be found in the *Annual Energy Use Assessment and the Detailed Energy Review.*

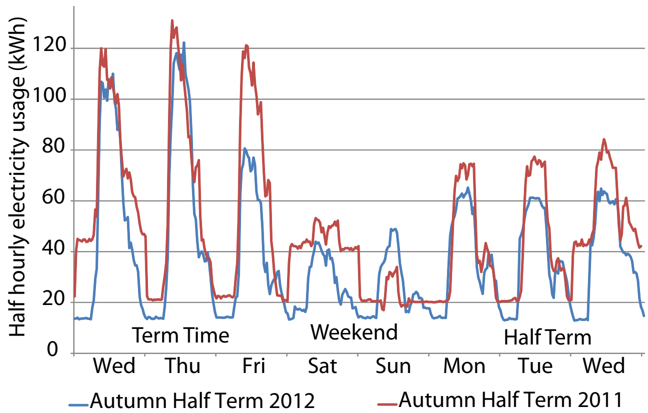


Figure 6.3: Actual Autumn electricity usage pre and post the appointment of the FM

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 technical issues have been discovered which could be leading to comfort or energy problems? Are the users using the automated or manual controls effectively or are they still becoming familiar with their operation? Did the commissioning process actually setup the systems correctly and, if not, what is this leading to? Are there design related technical issues, which are already becoming apparent and need to be highlighted for a future Phase 2 BPE study?

7.1 Thermal Imaging

Given the size of the building and scope of the survey, very few clear thermal bridges or insulation defects were captured during the thermal imaging survey. From a construction perspective, the survey suggests that the building follows the detailed design drawings with no obvious deviations.

From a design perspective, the detailing around common thermal bridges (structural columns and wall to slab junctions) could be improved. However, in comparison to some other new buildings viewed by the surveyor, the detailing in general is of a good standard.

The design team should also consider improving the detailing around non structural beams such as the aluminium channel discussed in the thermography report. For future projects the specification team may also want to consider thermally broken frame systems for windows and doors.

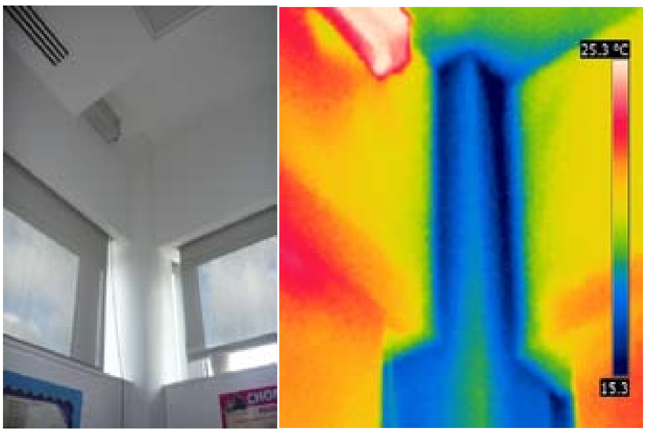


Figure 7.1: One of the few thermal bridges identified

Infrared thermography of the building services and systems brought up the following findings:

- Equipment is being left on in the school during the holiday period. This was also seen during the site walk-around.
- The ventilation or heating system was not working properly in all classrooms, which could lead to occupant dissatisfaction. The school's maintenance or caretaker team should carry out a full survey to measure the temperature of air supply grilles and to check for air movement. A maintenance engineer should then be brought in to address those spaces that are not being correctly conditioned.
- The underfloor heating system for the changing room area suffers from a lack of local control. Perhaps radiant panels in the corridors, which are specified in all other circulation spaces, would have been a more appropriate solution to heat these areas rather than over-sizing the underfloor heating network. The school should also avoid propping open doors to the atrium and sports hall stairwell as this is likely to increase the energy used by the underfloor heating system.

7.2 Biomass

Since the school's occupation in September 2010, the biomass boiler has been non-operational for several protracted periods. This has been the result of moisture issues in the fuel store leading to fuel becoming unusable.

The manufacturers and suppliers of the biomass boilers provided plans for the fuel store and example details of the drainage holes and their positions. It is not clear whether BAM Construction received these drawings prior to construction. The drawings mark example hole locations and specify that three 50mm diameter holes should be positioned within the base of the slab in accordance with the gradient. The drainage initially provided on-site consisted of one smaller drainage hole draining horizontally from a corner.

After the moisture issues manifested early on in the occupation of the school, a number of measures have been taken in an attempt to correct the problem:

1. Debris covers were installed over the drainage channels around the edge of the store to prevent woodchip and other debris from causing blockages.
2. The drainage outlet from the stores drainage channel was widened to increase the possible flow from the store and reduce the likelihood of it becoming clogged.
3. Rubber mats were installed around the edges of the store to stop water ingress from overground flow.
4. An additional drainage channel was installed uphill from the store to catch surface water before it reaches the store.
5. Shortly afterwards the holes in the supports of the drainage channels were widened to improve the flow.

Figure 7.2: Channel hole widening in February 2012 showing the new drainage channel from measure 4 (top) and the debris covers from measure 1.

It remains to be seen whether the corrections have solved the moisture issue. The location of the fuel store, below a busy access route necessitated a complex design which is thought to have been more prone to leakage and moisture issues than simpler storage systems which might have been suitable in other locations.

Figure 7.3: Moisture issues in the fuel store

7.3 Ventilation

The ventilation strategy at the school - fully mechanical - was chosen after an acoustic survey suggested that noise from the nearby motorway would be disruptive, and led to the decision not to have openable windows on the site. Although the results of the acoustic survey showed that ambient external noise levels were in excess of the Building Bulletin recommended levels, in hindsight the BPE project team believe that external noise was not a big issue for staff on the site.

The interviews with staff indicate that there was not an issue in the previous school with noise from the nearby motorway, however, there is now a perception among occupants that air quality is poor and there are no local controls, which is perhaps more likely to occur with mechanical ventilation systems. The lack of openable windows is believed to have exacerbated this perception as occupants feel powerless.

Schools are particularly sensitive to ventilation issues as they are subject to frequent and wide changes in occupancy as classrooms are occupied in one lesson and empty for the next. If a classroom suddenly fills up, temperatures can increase markedly, and the ventilation system may struggle to keep up. In the majority of schools, pupils are regularly moving between classrooms and have to adjust to differences in conditions that, if gradual, might not be problematic, but when sudden, may cause discomfort.

This issue could have been prevented by surveying the staff working in the old school on site, to determine whether they were affected by external noise and whether they felt mitigation was required. Following such engagement, the project team could have challenged the building bulletin guidance, and this may have changed the decision to mechanically ventilate the building.

7.4 Lighting

In some classrooms maintenance engineers were being called out to react to the row of lights closest to the window being off. However, in reality this was a design decision to reduce lighting energy consumption when daylight levels were sufficient.

Since discussions with the school regarding the light switching arrangements, the mechanical and electrical contractor has carried out the following work to adjust the daylight-linking set-points:

- South facing Windows in Zone 2 start to dim at 200 lux, fully dim at 400 lux.
- North facing Windows In Zone 2 start to dim at 170 lux, fully dim at 210 lux.

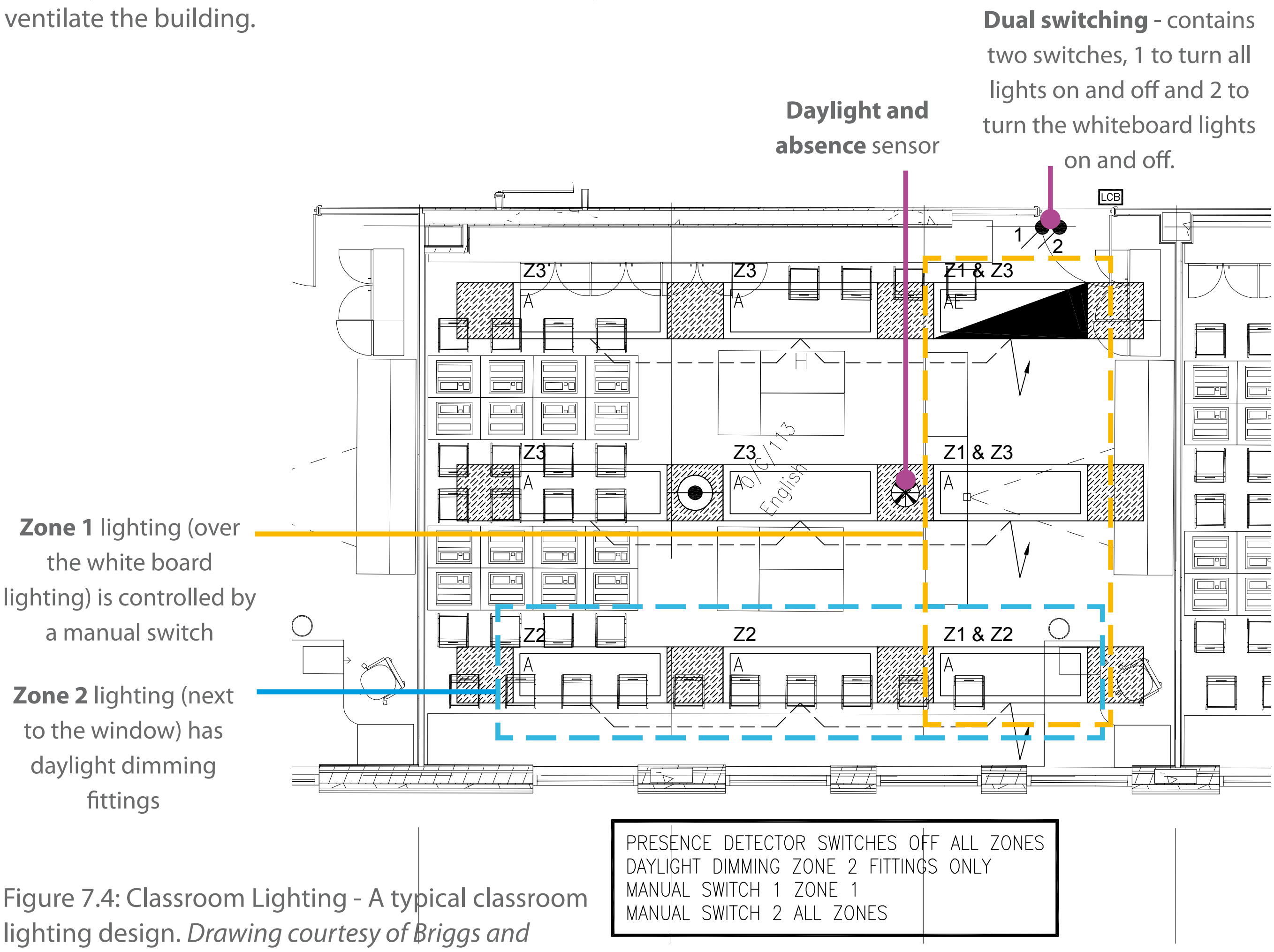


Figure 7.4: Classroom Lighting - A typical classroom lighting design. *Drawing courtesy of Briggs and Forrester*

Figure 7.5: Classroom lighting controls. 'Whiteboard' switch could be misunderstood

The engineers also disabled the 'OFF' function so the lights will only dim down to 20% maximum to prevent call-outs from the client who may believe the lights have failed.

They also assessed the possibility of installing a master override switch to enable the occupants to switch off the lighting in the circulation areas where the sensors can be overly sensitive to the movement of occupants.

The labelling of the light switches could be considered ambiguous. For example some might think that the whiteboard switch in figure 7.5 controlled power to the whiteboard itself rather than the associated lighting zone.

The lighting controls seem to need adjustment and the control of the lights does not seem to have been made clear to all occupants. The absence detectors in corridors also appear to be over sensitive to the presence of occupants leading to lights being left on. This may increase energy use where daylight sensors were not installed in the atrium corridors which receive adequate amounts of light for most of the day.

7.5 Metering

The metering strategy at Cressex could have been more clearly defined and there are a number of inconsistencies in labelling and in the information provided in the log book when compared to construction drawings. There were also a number of meters which did not appear to be functioning correctly.

There is some confusion between the construction documents produced for the metering strategy. The log book, schematic drawings and BMS description of operations are all meant to represent the metering that has been installed on the site. However, each document shows a different number of meters.

7.6 Building Operation

As has been discussed in Section 5, until April 2012 the school BMS was being operated by non-specialists. The understanding of the operation of the building was limited, and as a result the settings were initially left untouched, and later badly adjusted in an ad-hoc manner until the Facilities manager role was filled.

This may have resulted in energy wastage, discomfort among occupants, and poor maintenance of plant before his appointment.

Since the appointment of the FM, electricity use has improved noticeably, while the problems with the biomass mean that heating use has changed little overall, and got markedly higher in recent months. The FM is more familiar with the BMS than the previous operators, but even he feels that he does not fully utilise or understand the potential of the system, and his use of it is relatively simplistic. There is still significant potential for improvement in the building operation. With time and training, the building's FM should be able to improve the performance further and the school might approach its potential.

7.7 Conclusions and Key Findings for this Section

Overall, the building fabric at Cressex was good. The only problems shown by the thermal imaging were relatively minor.

The biomass system at Cressex has been problematic, and this is mostly felt to be due to the location of the fuel store under an access road necessitating a highly complex design which was more vulnerable to problems. We would recommend that in future projects with a biomass system, careful attention is paid to the location and complexity of the fuel store so that a simple and more robust storage system can be used.

The fully mechanical ventilation system at Cressex, with no openable windows, led to a lack of local control and potential for dissatisfaction. It may be that the system is operating as designed, but the lack of control may cause the slightest discomfort to be magnified in the minds of the occupants because of a feeling of powerlessness. We would recommend that the psychological advantages of local control are borne in mind when deciding how to ventilate future school projects. Alternatively the level of understanding of remote controls and reasons for them need to be better explained to staff.

It is important to ensure that meters are reconciled after the system has been installed to ensure that they provide an accurate reflection of energy usage on site. Large systems such as the biomass boiler should be metered separately. Labelling of meters should be consistent throughout the drawings, logbook, BMS and on site to facilitate understanding and fault correcting. The client should make use of the sub-metering from an early stage to aid an understanding of the new building's behaviour and highlight areas for improvement.

Operation of the BMS and the school in general is improving, but could be improved further. This will require further training and a desire on the part of the FM to optimise the building. The school should address the unnecessary out of hours operation of equipment as a priority in order to reduce their electricity use when the building is unoccupied.

More details on the subjects discussed in this section can be found in the *IR Thermography Report*, the *Review of Design and Construction Data*, the *Controls Review* and the *Metering Strategy Review*.

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 pre and post handover processes; a summary of lessons learned: things to do, things to avoid, and things requiring further attention/study; and a summary of the of benefits from a Soft Landings procedure, where applicable. Try to use layman's terms where possible so that the messages are understood correctly and so are more likely to be acted upon.

8.1 Lessons for Buckinghamshire County Council

Potential lessons for the County Council for future projects could include:

- Think carefully about how a building will be operated in reality during the design process as it might affect the level of complexity you wish to specify within the building. If the building is to be operated by non-specialists, or if there is to be heavy extra-curricular usage these issues need to be considered when choosing the most appropriate design.
- If occupancy is not expected to reach capacity for some time, the transition period should be carefully considered in the design process. Designing more flexibility into the building services so that areas can be switched off when not needed will help reduce energy wastage when the building is not used as expected.
- Make better use of defects periods. These exist for the client's protection. Try to have the right people in place to identify problems at an early stage so that they can be remedied before they become expensive.
- Think about the commissioning process and how it can be used to best serve the tenants and client. Consider moving part of the commissioning contract (e.g. head commissioning engineer) outside of the main contractor's responsibilities.
- Make sure whoever is to manage the building is involved in the handover process and, ideally, involved in the design (this is difficult in practice). Consider bringing in FMs from other low carbon schools at the design stage to provide guidance on practicalities of running a school if an existing FM is not appointed by the design stage.
- Try to ensure that the roles, rights and responsibilities of the client and future occupant are clearly defined so that there is no confusion and all parties feel properly represented from concept stage onwards.

8.2 Lessons for Cressex Community School

- If a school is to have a BMS, it is vital for there to be a suitably qualified Facilities Manager appointed before commissioning and handover begin. The delay in the FM's appointment may have cost the school significantly.
- The facilities management team should take responsibility for thorough and accurate change logging in the logbook so that reasons for changes in behaviour can be identified.
- While occupancy is still below capacity, consider compacting teaching activities to free up a block which can be deactivated.
- Make better use of defects periods (as for BCC)

8.3 Lessons for Designers and Contractors

- Designers need to be conscious that combining multiple systems and renewables together leads to complex systems integration and a greater likelihood of control difficulties e.g. heating and cooling fighting each other.

- The fabric efficiency at the school is good, and should be repeated/improved upon wherever possible.
- The school scores highly in the Building User Survey in terms of aesthetics - people like the way it looks.
- Think carefully about the layout of the building as early as possible, with a view to avoiding conflicts that will lead to increases in complexity. For example fuel stores under roadways. This will increase the robustness of the proposed building and help to prevent future issues.
- Similarly, pay close attention to the metering strategy early on to ensure that the system is fit for purpose. Consider the type of information likely to be required and review the design at each stage to check it is still suitable.
- Avoid removing control from occupants unless absolutely necessary. Feeling unable to control local conditions increases the perceived severity of any lack of comfort and increases dissatisfaction.
- Consider using presence sensors to control space heating and ventilation as well as lighting as this has the potential to generate large savings. It is also beneficial to use sensors and controllers which use open protocol control, in preference to proprietary systems, as the settings and feedback systems can be adapted by any suitably qualified person, and does not require the manufacturer's or original installers involvement.
- Ensure that building user guides are simple and easy to understand so that they will be used.
- Try not to site biomass boiler flues in close proximity to ventilation intakes or alternatively increase the height of biomass flues. The school has experienced occasions when wood smoke can be smelt internally. This is due to flue gasses entering the mechanical ventilation system when the wind blows in a particular direction.
- Follow a structured best practice commissioning plan from an early stage. Pay close attention to maintaining good documentation, and where possible keep the future facilities manager informed and involved from the outset.

9. Wider Lessons

Technology Strategy Board 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.

A number of the lessons learned in this project are highly relevant to the wider industry. The pitfalls encountered are common to many projects, and should be considered where possible in order to avoid the same problems occurring.

9.1 Lessons for Clients

- Try to have a clear idea of how a building will be operated in reality during the design process and bear this in mind when developing the brief.
- Avoid unnecessary complexity in the design as this creates greater potential for things to go wrong, and for the building to be operated in an unsuitable manner.
- If there is a possibility that the building will not be fully occupied for some time, or will fluctuate significantly, consider how to make the building adaptable to this. For example by allowing services to be controlled on a floor by floor basis, or providing room controls to occupants.
- Plan your use of defects periods. These exist for the client's protection. Try to have the right people in place to identify problems at an early stage so that they can be remedied without cost to the client.
- Think about the commissioning process and how it can be used to best serve the tenants and client.

9.2 Lessons for Building Operators

- Decide as early as possible who will be managing the building after completion, and ensure that they are involved in the handover process. If possible being involved in the design process may allow obvious issues to be avoided.
- Plan for the defects period and create a programme of reviews early on to find as many preexisting problems at as early a stage as possible. This reduces the chance of expensive discoveries later on.
- Be rigorous about the use of the building logbook. Log all changes to the system and relate them back to changes in performance. Report regularly on energy performance, identify areas for improvement and act on them.
- Review and understand the building submetering system as early as possible to enable the best use to be made of this information. Make ensuring you have clear information a priority, as you cannot make meaningful improvements without a good understanding of where energy is being used.

9.3 Lessons for Design and Construction Teams

- Designers need to be conscious that combining multiple systems and renewables together leads to complex systems integration and a greater likelihood of control difficulties e.g. heating and cooling fighting each other. A simple design is often more effective.
- Ensure that there is a clear understanding of needs and expectations of the relevant parties and that these are managed carefully throughout the project.
- Think carefully about the layout of the building and plant as early as possible, with a view to avoiding conflicts that will lead to increases in complexity. Complexity creates vulnerability.
- Consider using industry guidance such as CIBSE TM39 to create a metering strategy that meets Part L recommendations. This should be done

at an early stage in a project to ensure that electrical distribution boards and BMS controls are coordinated accordingly.

- Avoid removing control over conditions from occupants unless absolutely necessary. Feeling unable to fix problems increases their perceived severity and increases dissatisfaction.
- Question industry design standards such as BB101 when considering on site experience of tenants in existing buildings.
- In buildings with wide fluctuations in occupancy, consider using presence sensors to control space heating, ventilation and lighting as this has the potential to generate large savings. Use open protocol control systems wherever possible as these systems are easier to adapt once construction is complete.
- Ensure that building user guides are simple and easy to understand so that they will be used.