St. Peter the Apostle High 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	450045
Project lead and author	BAM Construct UK Ltd
Report date	2014
InnovateUK Evaluator	Tom Kordel (Contact via www.bpe-specialists.org.uk)

Building sector	Location	Form of contract	Opened
Schools (secondary)	Clydebank	Design and build	2009

Floor area	Storeys	EPC / DEC	BREEAM rating
16,185 m^2	3	B / N/A	Very good

Purpose of evaluation

The report includes reviews of the metering strategy, design and construction data, in-use energy consumption, assessment of the building management system and controls, fabric performance and Occupant satisfaction.

Design energy assessment	In-use energy assessment	Electrical sub-meter breakdown
No	Yes (estimated only)	No

For 2013 gas consumption was 78.6 KWh/m^2 per annum and electricity consumption 79.5 KWh/m^2 per annum. Due to the poor quality of the installed BEMS the BPE project team were unable to carry out accurate splitting of energy end uses and optimisation of energy use on site. A detailed energy analysis was carried out using the CIBSE TM22 estimation method (energy audit and profile estimation). Its accuracy cannot be verified and therefore the output should be treated with caution. Similarly, the BPE study was unable to monitor the performance of the ground source heat pump system.

Occupant survey	Survey sample	Response rate
BUS, paper-based	92 of 120	77%

The positive findings of the survey of adult staff included adequate lighting levels, low noise levels and pleasing design. Negative issues raised by staff included perceived uncomfortable temperatures, perceived poor health while in the building, lack of control over heating, cooling and ventilation, lack of space due to overcrowding. Problems with the specification and commissioning of the installed BMS and metering system has led to a significant loss in functionality for the facilities management team. This lead to a limited ability for FM to optimise the building with respect to energy use.

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

This report represents a summary of the methodology and findings of a detailed Building Performance Evaluation (BPE) study carried out on St Peter the Apostle School in Clydebank, West Dunbartonshire. The study was carried out by BAM and XCO2 Energy between November 2011 and June 2014.

St Peter the Apostle School is a secondary school that was constructed in 2008/2009. It was built as part of a wider Scottish Schools Building Programme which included more than 275 PPP/PFI school projects between 2000 and 2010. The school was designed for high environmental performance and low energy use. Upon completion it achieved a BREEAM (2006 standard) "Very Good" rating and a B rated Energy Performance Certificate (EPC).

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

- Metering strategy - Appendix A
- Design and construction data - Appendix B
- In-use energy consumption - Appendix C & I
- Building management system and controls - Appendix E
- Fabric performance - Appendix H
- Occupant satisfaction - Appendix G

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 building to be aesthetically pleasing and consider it to have a positive image with respect to visitors to the school.

The main challenges at the school have related to a few key issues. Firstly, a lack of user controls for heating, higher rates of occupancy than expected and areas of deficient fabric performance have lead to poor thermal comfort for some occupants. Secondly problems with the specification and commissioning of the installed BMS and metering system has led to a significant loss in functionality for the Facilities Management (FM) team. In turn this leads to a limited ability for FM to optimise the building with respect to energy use. Finally the contract in place between the PPP and West Dunbartonshire Council (WDC) focuses on thermal comfort conditions and in the first two years of occupancy provided little incentive to reduce energy use.

Throughout the course of the study, there have been improvements made by the BAM FM and BAM Construction team, including remedial works to improve fabric performance, provide additional heating to improve comfort, improve management and operation of the building and to upgrade the building management system and controls.

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 - Appendix A
- Review of Design and Construction Data - Appendix B
- Review of historic energy data - Appendix C
- Semi Structured Interviews - Appendix D
- Review of Building Controls - Appendix E
- Walkthrough Report - Appendix F
- BUS Survey Results - Appendix G
- IR Thermal imaging and air tightness report - Appendix H
- TM22 assessment - Appendix I
- Quarterly recommendation reports - Appendix J

The school, FM team and consequently the BPE project have been beset by problems with the building energy metering and monitoring system (BEMS) which has impacted the activities that could be carried out as part of this phase 2 BPE study. The problems with the BEMS system reflect across all parts of the construction process and are detailed in section 5. A review of the installed metering took place and quotes for the installation of a new system were obtained. Unfortunately the extent of the metering issues was not known prior to starting the study and there was insufficient BPE project budget to cover the necessary upgrades.

BAM FM considered providing the additional funding to cover the upgraded metering package, however were reluctant to do so as this was not covered within their 'life cycle' fund and they have little direct incentive to reduce energy costs (as the client bears all costs for energy). Additionally, the school was at the time, still within a normalization period under the PFI contract, whereby a 3 year baseline is set for energy consumption and costs going forward. While in this period, there is limited incentive for BAM FM or the school to invest in energy efficiency measures. At the time of publication, BAM FM were in the process of implementing upgrades to the BMS and metering and it is hoped this will lead to improved monitoring in the future.

Due to the poor quality of the installed BEMS the BPE project team have not been able to carry out the following TSB BPE Phase 2 tasks:

- Accurate splitting of energy end uses and optimisation of energy use on site. A detailed TM22 has been carried out using the estimation method (energy audit and profile estimation). However, its accuracy cannot be verified and therefore the output should be treated with caution.
- Monitoring of performance of low or zero carbon technologies. Which in the case of this building relates to the ground source heat pump system.
- Monitoring of internal conditions i.e. temperature, humidity and CO_2

The failure to carry out the important tasks listed above demonstrate the importance of designing, installing, commissioning and operating a BEMS. Without accurate metering, which is understood, analysed and acted upon it is not possible to optimise a building with respect to operational energy, cost and CO_2.

BAM intend to take this learning forward to ensure that appropriate metering is installed, commissioned and performing as required where this is something they can influence. Integrating BPE from the start of a project will assist this.

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

2.1 Building Design

St Peter the Apostle School, built in 02/2008 - 09/2009, is a secondary school located on Kirkoswald Drive, Clydebank, Glasgow (see Figure 2.1 below). It has capacity for approximately 1500 pupils but is currently slightly over occupied with 1600 pupils and more than 170 members of staff. The 16,185m2 three storey school consists of four blocks all linked by the main corridor.

The newly completed school achieved a BREEAM 2006 "Very Good" rating and a B rated Energy Performance Certificate (EPC).

The main teaching areas are located in wings (D,E and F) joined to the main corridor. The narrow classroom blocks coupled with the wing arrangement are designed to allow for classrooms with large window areas, increasing daylight levels and a reduced need for artificial light.

The arrangement of the teaching wings on the western side of the building were designed to protect classrooms from the high noise levels of the neighbouring road to the north east.

The design team proposed using the larger elements of accommodation and teaching spaces, which require mechanical ventilation, for example, gymnasia or music classrooms, to act as an acoustic 'buffer', between the noise source (the road) and the noise sensitive general teaching spaces.

The overall form of the school and layout of spaces remained constant from design stage to construction stage. With the main teaching wings being shielded from the noise of the neighbouring road by the larger elements such as sports halls and assembly halls.

One element of the school which changed significantly through an amendment to the design philosophy was the toilets. At design stage the toilets were laid out in the traditional fashion with enclosed banks of toilets for males and females. After discussions with the school it was determined that the toilets were a particular problem spot for bullying due to their enclosed nature. The BAM design team set about designing toilets which avoided unsupervised spaces.

St Peter the Apostle High School

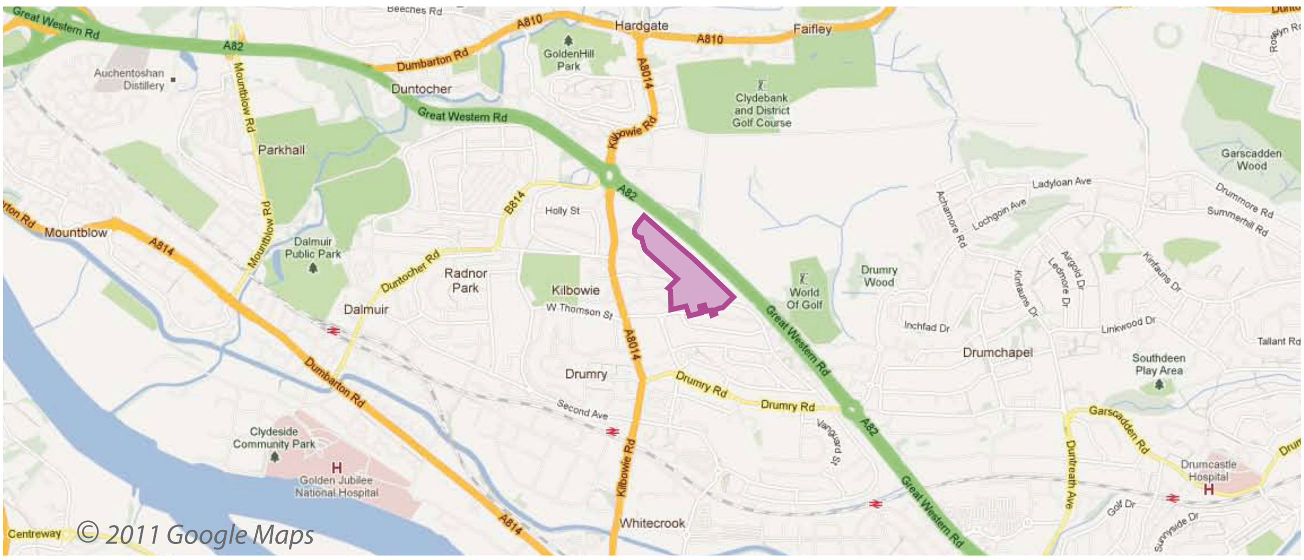


Figure 2.1: Site Location Plan

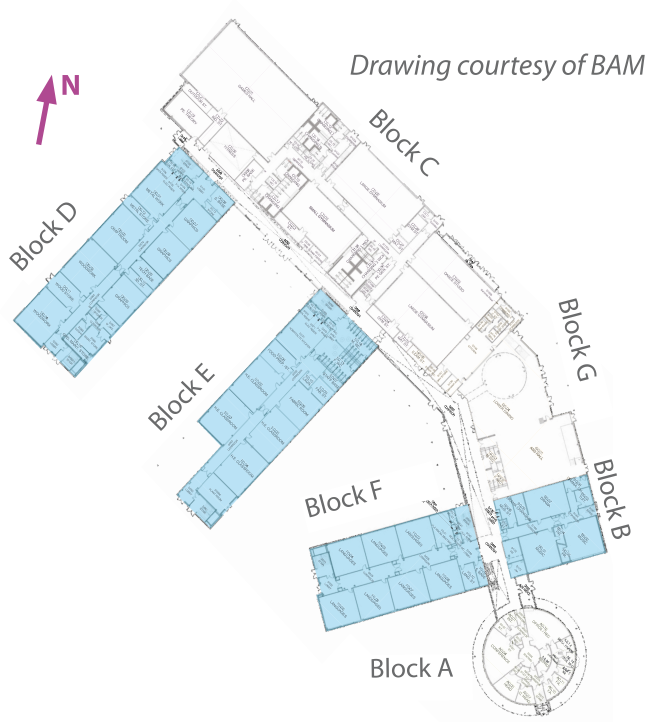


Figure 2.2: Ground Floor Plan

- Block A - The rotunda containing offices and pupil support
- Blocks B, D, E & F - Teaching wings
- Block C - Sports facilities and library
- Block G - Cafeteria, oratory and assembly hall

Figure 2.2: Building ground floor plan

A larger version of this image is provided on page 6 of Appendix B. Photos of the building and additional plans are also provided throughout Appendix B and F

The final design solution provided large banks of toilets open to the corridors. This design encourages the use of natural surveillance by teachers and other pupils to prevent the opportunity for bullying in the toilet areas.

Construction Type

The building is steel framed with external walls of brick or composite metal cladding over rigid insulation. The ground floor is a concrete slab, also on rigid insulation. The majority of the building includes a metal standing seam roofing system over suspended ceilings. At the 'rotunda', insulation is placed upon a layer of roof decking and covered with a waterproof membrane.

The majority of windows are aluminium-framed double glazing. Double glazed coloured spandrel panels provide aesthetic interest to the glazing system. External doors are aluminium-framed metal panel doors.

Construction U-values

The U-values listed below show that most of the fabric was designed to meet Scottish Building Regulations 2007. The external wall U-value of the original design was in-line with England and Wales Part L Building Regulations but was worse than the Scottish Building Regulations. This was rectified before the tender stage.

Element	U-values required by Scottish Building Regulations 2007 and used at tender stage [W/(m² K)]	U-values used for the building design [W/(m² K)]
External Wall	0.30	0.35
Floor	0.25	0.25
Roof	0.25	0.25
Windows	2.20	2.20

Figure 2.3: U-values at design and construction stage

Infiltration Rate

The maximum allowable air tightness was set by the design team at 0.25ACH this equates to an air permeability of approximately $5m^3/m^2$ at 50Pa.

2.2 Procurement and Timeline

The design, construction and client team were as follows:

- Client: West Dumbartonshire Council
- Design (architecture and M&E): BAM Design (formerly known as HBG design)
- Main contractor and mechanical contractor: BAM Construct
- Electrical sub contractor: FES Ltd
- Specialist GSHP: Geothermal International
- Facilities management: BAM FM

The design team were based in Hertfordshire at the start of the project. With the client team being based in West Dumbartonshire frequent trips were made by the design team during both the construction and design phases.

The school development began in 2006 when BAM (formally known as HBG) bid to win a Public Private Partnership (PPP) contract from West Dunbartonshire Council (WDC) to design, build and manage the facilities at St. Peter's school. Authorities Requirements (ARs) were set by WDC to ensure the design incorporated all their desired spaces and functions.

St Peter school was to replace St Columba's and St Andrews Secondary Schools and create a larger secondary school on the former site of St Columba's. BAM competed with other bidders to win the contract. BAM procured the school, within a PPP concession lasting 30 years, in 2007 after submitting their Best and Final Offer (BaFO) to WDC.

The PPP contract is held between WDC and BAM in which BAM provides and runs the school and assumes financial, technical and operational risk.

The type of PPP contract used for this project was a Private Finance Initiative (PFI) in which capital investment was made by BAM and a funder on the basis that they would provide the agreed services and that the cost was borne by WDC.

BAM designed the school from concept to construction, with planning granted in 2007 and site work commencing in 2008. St Columba's school was retained on site operating as normal whilst St Peter's was built on the previous sports fields. Once complete the pupils of St Columba's were moved to the new school and the old school was demolished. New sports fields were located on an adjoining piece of land and a new primary school called St. Eunan's was built on the demolished footprint of St. Columba's. Both St. Eunan's and St. Peter's were designed by BAM and are situated on the same site. As part of the PPP contract BAM designed, built and now maintain four schools; St. Peter's the Apostle High School, Clydebank High School, Vale of Leven Academy and St. Eunan's Primary school. These schools are all run from one FM centre located at St. Peter's school.

Handover and commissioning of St. Peter's school began in summer 2009 and the building was in use by August 2009.

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

3. Review of Building Services and Energy Systems

3.1 Heating Systems

3.1.1 Space Heating

The space heating strategy detailed at the design stage by the M&E designer included the following system setup:

Internal Conditions - Winter Temperatures

Space	Temperature (Dry Resultant)
Classrooms	20°C ± 2°C
Circulation areas	15°C ± 2°C
Common areas	18°C ± 2°C
Stores	15°C ± 2°C
Gym/Games Hall	15°C ± 2°C

Figure 3.1: winter design temperatures

The heating was designed to be supplied by a mixture of ground source heat pumps and gas boilers. Reversible GSHP's were selected due to their ability to provide both low grade heating and cooling. The boilers were sized to take into account the requirement for pre-heating due to the intermittent operation of the school in accordance with CIBSE recommendations.

The following heating circuits were specified to distribute heat:

- Constant temperature heating circuit, to serve heating coils in air handling units (AHU), fancoils and domestic hot water.
- Variable temperature heating circuit, to serve the radiators and radiant panels.
- Ground source heat pump heating circuit, to serve the underfloor heating.

In addition the heating was zoned to be controlled in line with the diverse occupancy patterns of the building.

The decision on the type of emitter was based on the following criteria:

- Room layouts and furniture arrangements
- Intermittent use of the space
- Response of the chosen system to pre-heating and internal gains
- Building thermal mass
- Maintenance costs
- Background noise ratings of the emitters

The initial design proposal was to use a mixture of underfloor heating, ceiling mounted radiant panels and fan coil units. Where necessary due to space restrictions radiators were also used.

In addition, underfloor heating was provided to the ground floor general teaching spaces, the gym, changing areas and the dining facilities.

The underfloor heating was zoned via manifolds, and each individual space was then fed from a manifold with an independent thermostat.

In teaching spaces which are not served by underfloor heating or fan coil units, heating was provided via ceiling mounted radiant panels fed from the variable temperature circuit.

It is not clear why teaching spaces on different floors were supplied by different heat distribution mechanisms (radiators, underfloor heating or radiant panels). It would generally be considered that radiators would be the most cost-effective heating option for classrooms, providing a faster response than underfloor heating and more even distribution than radiant panels.

3.1.2 Domestic Hot Water

The domestic hot water system was heated via centralised direct gas fired water heaters connected to a flow and return hot water network.

3.2 Ventilation and Cooling

The design intent was to achieve natural ventilation wherever practical in all classrooms and offices.

Supplementary mechanical ventilation was provided to areas where high functional heat gains were expected, areas where excessive water vapour may be produced, rooms which were acoustically sensitive, for internal rooms, or to maintain satisfactory air quality. Such rooms included: the sports halls, gym, librarhy and music rooms. Toilet and washroom areas were provided with mechanical extract. Supply and extract ventilation was provided to fitness, changing areas, dance studios, dining areas and assembly halls with kitchens using mechanical supply and extract balanced to provide a negative pressure within the space to prevent migration of odours into other areas of the building.

Generally the mechanical ventilation systems have presence detection and/or a BMS link incorporated in order to ensure that the systems are not operating when areas are unoccupied. For ventilation systems where supply and extract air was provided, the extract air stream was designed to be utilised for heat recovery, where practical.

3.2.1 Natural Ventilation

Windows that include an openable top pane and bottom pane are used for the majority of naturally ventilated spaces. This solution was designed to provide significant benefits in both summer and winter conditions. For summer periods both the top pane and the main lower pane were designed to be openable to provide single side fresh air ventilation. In winter, the upper pane is designed to be used to supply sufficient fresh air to maintain acceptable air quality.

The use of only the upper section was to ensure that the room occupants do not experience significant flow rate and draughts of untreated cold air whilst still providing fresh air for ventilating purposes. All windows are opened via standard handles. A pole is provided in each classroom to operate the high level window pane.

Figure 3.2 - Typical classroom window showing the openable top pane and bottom pane as well as the opening pole being used

In addition to providing the classrooms with openable windows, there were also air movement fans installed within the corridors which would promote air movement from the classroom to the corridors to ensure CO_2 levels were not compromised.

3.2.2 Acoustic Issues

One of the key issues arising from the location of the new school to the northern end of the site is the acoustic environment caused by traffic using the Great Western Road. From analysis of noise levels taken during the Invitation to Negotiate (ITN) period the design team believed it would not be possible to achieve the required acoustic conditions in teaching spaces with open windows.

BAM developed a design to shield noise to sensitive teaching spaces from the noise source, placing larger areas of accommodation which required mechanical ventilation (e.g. gymnasia and music rooms) on the road side. This provided a sound 'buffer' and allowed general teaching areas to be naturally ventilated.

3.2.3 Air conditioning and Comfort Cooling

Due to the high internal heat gain it was deemed that comfort cooling would be required in ICT classrooms, libraries, conference rooms, dance studios, and fitness suites. These areas were provided with chilled water comfort cooling capable of maintaining the rooms at an acceptable temperature throughout the summer months. This system utilises ceiling mounted cassette type fan coil units, or ceiling concealed ducted units where appropriate. The chilled water source for these units was from the ground source heat pump system. This was designed to maximise the energy efficiency of comfort cooling.

3.3 Lighting

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

3.3.1 Daylighting

The daylighting strategy for the school was targeted to optimise the amount of daylight entering the classrooms, offices and assembly areas. Ceiling heights of 2.9m in all general teaching classrooms were designed to permit significant quantities of daylight into the space.

For the daylight illuminance to be adequate for the task, the design team thought it necessary to achieve a level of not less than 300 lux, and for particularly demanding tasks not less than 500 lux. When the specified daylight levels were not achievable, the daylight is supplemented by electric lighting. Light exterior surfaces were chosen to increase reflected light into the building.

Adjustable blinds are provided to screen glare when necessary. Blinds were also specified to improve the thermal environment by reducing heat gains.

It would appear that external shading was not considered as part of the design strategy for reducing excessive solar gains. As is discussed in section 4.1, many of the occupants perceive the school to overheat during the summer.

3.3.2 External Lighting

External lighting is provided at each of the personnel/equipment doors to the building, all pavements and walkways around the buildings, all vehicle roadways bounding and approaching the building, sports pitches and also to support camera surveillance. The external lights are controlled via photocell and or time clock with manual override facilities.

3.3.3 Internal Artificial Lighting

General lighting is provided via high frequency linear fluorescents with T5 lamps and high efficiency compact fluorescent luminaires.

Lighting to all teaching areas and office type environments is suitable for the continuous use of computers throughout the school day.

A combination of manual switching, daylight and presence detectors is used to control the artificial lighting in classrooms. The main corridors, sports and assembly halls are manually lit. Offices have over ride switches to allow manual operation when necessary.

PIR sensors should have been considered in the teaching wing corridors so that energy for lighting is used only when occupants require it. The lighting in the main corridor and stairwells could have been split into smaller batches with daylight and PIR sensors installed. Sensors for lighting in the corridors would have reduced the amount of time the lights are on and also reduced the dependency on the FM team to operate them.

3.4 Building Controls

Other than the local controls described within each of the previous sections, the school also includes a Building Management System (BMS) configured to control, monitor and give alarm indications for the major mechanical and electrical services systems. The system also monitored energy use and therefore had Building Energy Management System (BEMS) capability.

The BMS was designed to provide the following functions:

- Three stage frost protection
- Optimum stop / start control for duty pumps
- Zone control to enable flexibility in use. This included isolating valves within each wing
- Monitoring of flow and return temperatures
- Manual override facilities to central plant
- Weather compensation of variable temperature circuits
- Plant status monitoring and alarm indication
- Plant and energy consumption record
- Plant extension facility

The BMS includes temperature sensors within communal corridors rather than in individual classrooms and therefore central control of individual rooms is not possible.

Thermostatic controls are located in each classroom to provide a level of 'comfort' control allowing occupants to adjust the temperature by +/- 2 deg C. The thermostatic control could then be set in each classroom by the facilities manager to fine tune the heating in the building. During the study there have been discussions as to whether the thermostatic controls are suitable to sense the temperature of a classroom where radiant panels are installed (although the majority of class rooms have radiators). Black-bulb thermostats are designed to measure radiant heat rather than air temperature and may have been more suited to those spaces with radiant panels than the thermostats used. This was not taken any further as part of the study but may be worth consideration in the future where radiant panels are specified.

The ventilation and heating seem to have been designed with sound low energy principles. However, the natural ventilation strategy is not linked to the heating controls. A heating shut off valve linked to a suitably placed CO_2 sensor would have been a valuable addition to reduce heat loss by stopping rooms from being over ventilated during the heating season.

3.5 Metering

According to the as constructed metering schematic drawings, 79 different meters are installed in the building which include 70 electricity meters, 6 water meters and 3 gas meters. However, when visiting the school, as part of the BPE walkthrough, an audit of meters was carried out by BAM FM and XCO2 following the discovery that the BMS did not appear to correlate with drawings. The audit showed that there were up to 8 less electrical meters on site than shown on the drawings.

Following the on-site audit, a number of issues were highlighted with regards to the usefulness of meters to the FM team and the sufficiency of the metering for TSB purposes. The issues found include:

- The labelling of the meters on site did not always represent their input
- The labelling of the meters on the BMS did not always match the physical labels or schematic labels
- There were meters missing from the BMS
- The meter readings on the BMS was not currently calibrated with the physical readings
- The kitchen meters were not monitoring lighting and power separately. Some of the kitchen power is included in the lighting meter due to the way the distribution boards were wired
- Some of the sub-meters were not reading any energy consumption
- There were no heat meters to measure the heat produced by the GSHP
- There were no heat meters installed in the building however space heating and hot water can be quantified to a certain extent from gas meters

In total 65 meters were present on the St Peter's BMS user interfaces including 3 gas meters, 2 water meters and 60 electricity meters. The amount of meters present on the BMS is different to both the BMS schematic drawings and the meters found on the site walk-through, as shown below:

	No of meters				
	Gas	Water	Heat	Electricity	Total
Schematic drawings	3	6	0	70	79
BMS	3	2	0	60	65
Observed on site	3	6	0	62	71

Figure 3.3: Inconsistencies in the number of meters on different documentation

Further discussion on the metering system is provided in section 5 of this report.

3.6 Findings from this section

In summary the findings from this section are as follows:

- Multiple types of heat emitters (radiators, radiant panels, underfloor heating, fan coil units) creates additional complexity from a controls, management and maintenance perspective. The varied response times of each heat distribution method could also have effect on thermal comfort for occupants who may struggle to understand the heating and controls in the different rooms.
- Linking natural ventilation to heating controls could help to reduce wasted energy due to over ventilation during the heating season.
- External shading should be considered as part of the design strategy for reducing solar gains in rooms where a overheating risk is present
- Black-bulb thermostats should be considered where radiant panels are used for heat distribution
- A clear and detailed BMS specification is vital to ensuring a close level of control is available in all rooms. The reduced number of thermostats at the school has resulted in reduced control over heating which can lead to heating being on when it isn't needed when the building is not at full occupancy.
- Clear and consistence specifications and drawings are also necessary for metering systems. Once installed, commissioning of metering and reconciliation of metered values is crucial to gaining reliable data for good energy management.

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

4. Key Findings from Occupant Survey

4.1 Building User Study

A BUS study was carried out at St Peter the Apostle High School on 12th October 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 201 full and part-time staff at St Peter the Apostle High School, 120 were given a questionnaire and 92 responded. The response rate for the staff was therefore 77%. 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:

- adequate lighting levels
- low noise levels
- pleasing design

The questionnaire brought up issues including perceived:

- uncomfortable temperatures,
- perceived poor health whilst in the building,
- lack of control over heating, cooling and ventilation
- lack of space due to overcrowding.

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 unsatisfactory in both summer and winter, as shown in the graphs below.

The majority of occupants who responded stated that the air is often too stuffy and still (in summer). Specific comments referred to feelings of discomfort and stuffiness.

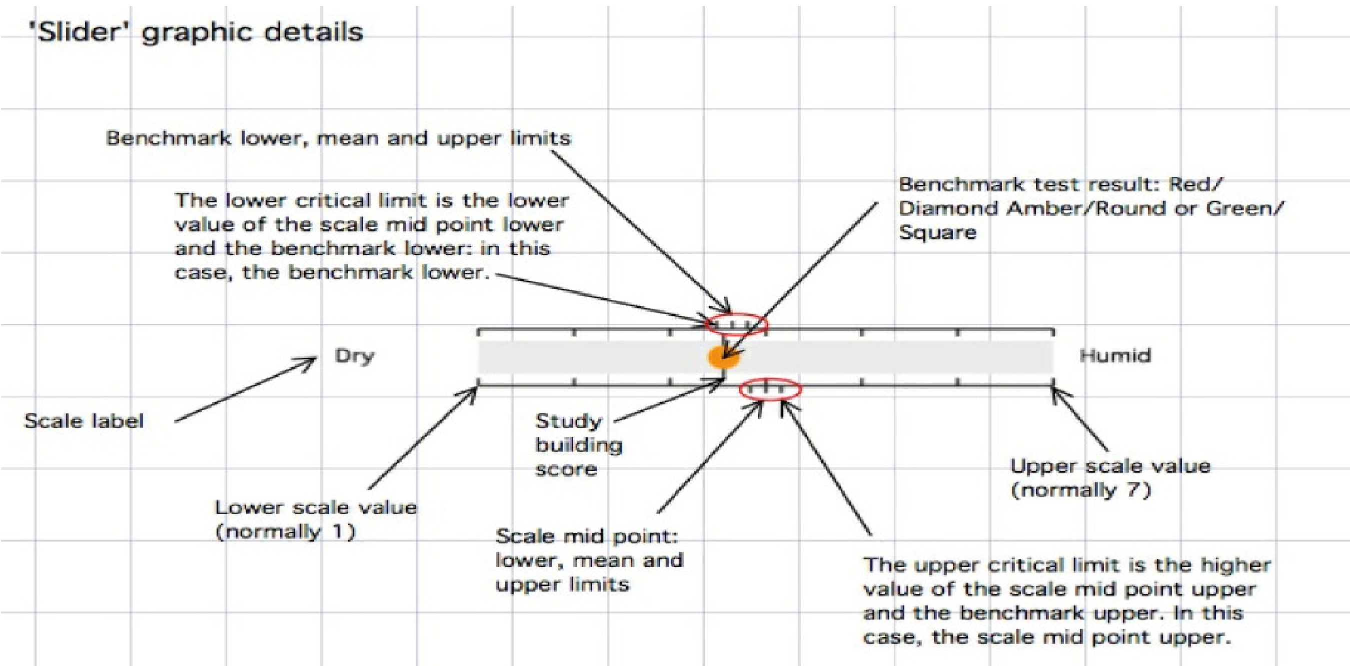


Figure 4.1: Description of how to interpret the slider graph used within the BUS methodology output

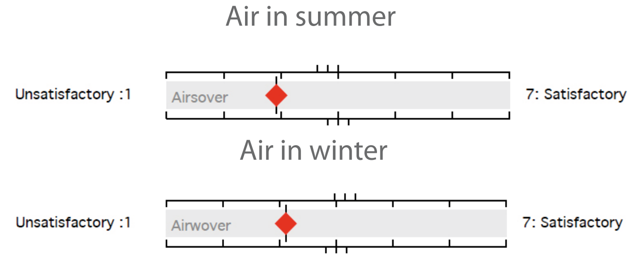


Figure 4.2: Slider graphs of air quality in summer and winter

4.1.2 Temperature

Overall the occupants perceived the building temperature to be more uncomfortable in summer than in winter. Most of the comments on temperature complained of it regularly being too hot. While a number of building users also complained of areas which were too cold in winter.

The school recently underwent an air permeability test, which showed that there were a number of areas in the school which suffered from significant infiltration. This is likely to have contributed to the low temperatures experienced.

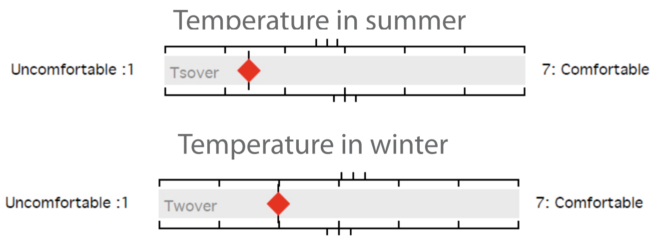


Figure 4.3: Slider graphs of temperature in summer and winter

4.1.3 Health

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

One representative occupant commented:
"Breathing - it can feel very stuffy and hard to ventilate. Dry eyes - My contact lenses are becoming uncomfortable."

Several comments complained of :
"Sore throat/ headaches"

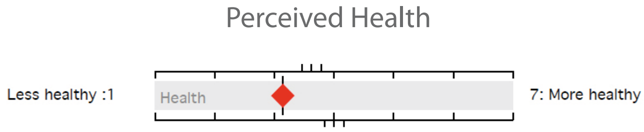


Figure 4.4: Slider graph of perceived health

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 and cooling, with slightly more control over ventilation.

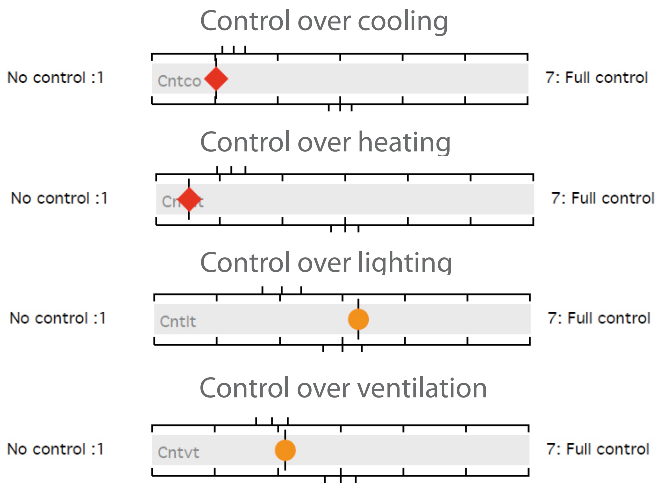


Figure 4.5: Slider graphs of occupant control over cooling, heating, lighting and ventilation

4.1.5 Lighting

Although the occupants appear to be satisfied with lighting levels overall, some of the more detailed questions reveal there are slight issues. The occupants are generally satisfied with the natural and artificial light levels, but have found the glare from daylight and artificial lights to be a small problem in some areas.

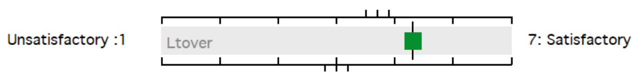


Figure 4.6: Slider graph of overall lighting

4.1.6 Noise

Overall noise levels in the building were deemed to be satisfactory by the occupants with little noise from inside or outside the building. The only significant noise issues noted were unwanted interruptions which were relatively frequent. The occupants noted that the neighbouring primary school was the source of significant noise at playtime and lunch, and that tannoy announcements were overly loud and frequent. Users of the library noted that it was possible to hear sports activities in the sports hall below.

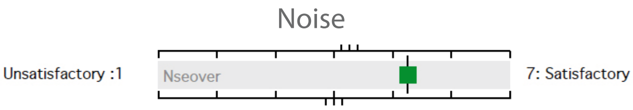


Figure 4.7: Slider graph of overall noise

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 highly rated in the survey.

Occupants feel that the building looks good to visitors.

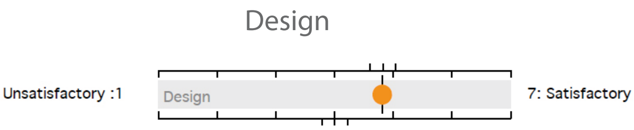


Figure 4.8: Slider graph of response to design

4.1.8 Comfort

On longer exposure, thermal comfort and other issues have affected occupants' satisfaction with the design. Many comments emphasized issues related to lack of space:

"Corridors too small, not enough classrooms, building too small."

"No way for pupils to line up outside my room."

"There are still not enough rooms! Pupils are forced to sit in cramped conditions, bases are small."

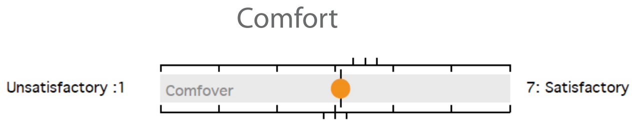


Figure 4.9: Slider graph of overall comfort

These comments are not unexpected, as the school is currently over-occupied.

4.2 Analysis

Overall, the occupants dissatisfaction with the building relates to temperature control. The limited temperature sensing in the school linked back to the BMS prevents occupants from controlling the heating in their own spaces. This also prevents the facilities management team from having control over individual classrooms or spaces. The heating is controlled wing by wing floor by floor with a single thermostat in the corridor and +/-2°C manual adjustment in classrooms.

The overcrowding due to higher than expected occupancy may also have an impact both on overheating and perceived lack of space.

As discussed in section 6.5 of this report the building suffers from higher than expected infiltration in certain areas. A potential way the building user satisfaction could be improved with respect to winter temperature and temperature control would be attempting to decrease the building air permeability by seeking out and sealing leakage points.

It is also possible that a lack of control is contributing to overheating, with teachers unclear on how to use openable windows or unaware that they should be using them. If teachers can be given instructions on how to operate the windows effectively, they may be able to increase comfort and feel much more in control.

It is likely that filling in an occupant survey tends to encourage a respondent to focus mostly on the negative aspects of the building. As such 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 will be increased. This will no doubt ensure that the building is enjoyed more in the future.

The results of the questionnaire generally showed that the occupants have united opinions, except for temperature, where answers depend on location within the school. Otherwise the majority of occupants chose similar answers for air quality, health and controls.

4.3 Issues Raised by Semi-Structured Interviews

Interviews were carried out with representatives from organisations involved in the St Peter the Apostle School project. In total six semi structured interviews were carried out with different members of the construction team including:

- Design - BAM M&E
- Construction - BAM Construction
- Facilities Management - BAM FM
- Client - West Dumbartonshire Council

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

- Due to the slow response time of the underfloor heating the FM team often run it constantly in the winter months and suggest that it is difficult to keep the building up to temperature if they turn it off. It is likely that this over cautious control strategy is influenced by the PPP contract which includes financial penalties when internal set temperatures are not met (for more details see appendix D). Even if the building takes a long time to heat up there should still be times at which the underfloor heating could be turned off without affecting the occupants or the target temperatures. For example the heating should not need to be run all night or all weekend. There are opportunities for the heating to be turned off for at least a couple of hours overnight and for a substantial amount of time over the weekend. The suggestion that the underfloor heating could receive lower temperature water overnight has the potential to provide a solution, however, the current controls set-up in the building does not allow for short term temperature changes in the underfloor heating.
- Mechanical ventilation, as opposed to windows, was fitted in the Music department to mitigate noise from the A82 road adjacent to the building. However, the school has had complaints about the air quality and temperature of the music rooms, with staff complaining of headaches and nausea. It was suggested that in hindsight the school would not have allowed mechanical ventilation to be installed into the music rooms due to the comfort complaints. Natural ventilation with acoustically lined openings may have been an alternative approach. Otherwise mechanical ventilation with greater temperature and air flow control may have improved comfort conditions.
- The main cause of summer overheating and winter underheating was a lack of understanding of the natural ventilation strategy; with in many cases overheating rooms being found to have windows closed. It is anticipated that as occupants become accustomed to the spaces, thermal comfort will improve.
- After reviewing the metering strategy it is clear that the meters were either not correctly calibrated with the BMS from day one or that the BMS has somehow got out of sync with the meters. Without a BMS that accurately reads the meters it is extremely difficult to monitor energy use in any detail. A commissioning report was carried out on the BMS and the results showed that there were a number of very basic things wrong with the system. One of the things that came up in the report was that the external mechanical ventilation sensor was positioned on an east facing wall instead of a north facing wall,

resulting in the sensor instructing the building to be cooled unnecessarily.

- The physical distance between the design and construction teams did not encourage close working or communication. This allowed for some of the design intents and ideas to be lost between the design and construction stages.
- The condensed commissioning phase meant that some of the mechanical systems were probably rushed. It is likely that systems weren't checked as closely as they perhaps should have been and possibly this has resulted in some of the issues in the building.
- Through energy analysis by BAM a number of key issues have been raised about the amount of energy being used during periods of low/no occupation. The FM team appear to be working to resolve these issues but the importance appears low and there seems to be a culture of denial by the team.

4.4 Findings from this section

In summary the findings from this section are as follows:

- The building users are experiencing perceived thermal comfort problems with respect to summer air quality, high summer temperatures, poor health, lack of control of heat and cooling
- Management issues relating to thermal control are likely to be having an impact on occupant comfort levels.
- Modifications to the sensors and control strategy of the heating systems in winter, as well as additional education to building users on the operation of the natural ventilation strategy to prevent summer overheating, should allow the building to function better in the future.

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

5. Details of Aftercare, Operation, Maintenance & Management

5.1 Facilities Management (FM)

Due to the on-site FM team the school is generally well maintained. Under their contract they are obliged to maintain the schools systems and ensure they are running as required by the school. The FM team have a pro active attitude to operating the school and where problems are logged by occupants the team respond quickly.

The FM team seem to maintain and run the building as effectively as possible. As an aside from this there are a number of issues surrounding the set-up of the BMS, controls, and systems together with the implementation of the PPP contract which seem to prevent the team from being able to run the building more efficiently.

The team are pro-active with respect to maintenance of key plant for example, ensuring that AHU filters are changed and boilers are maintained regularly in order to reduce the possibility of plant failures. The focus of the FM team is on ensuring the school is maintained open and it seems that operating the building in an energy efficient manner is given significantly less attention. Reducing energy use is severely impacted by two key factors: a lack of incentive created by the PPP contract and problems with the sub metering system.

5.2 PPP Contract and Energy Efficiency

The BAM facilities management (FM) team on site are required to meet all items in the PPP contract Services Specifications.

Where requirements are not met WDC are entitled to enforce financial penalties for failure to comply with the Services Specification. These take the form of Availability and Performance deductions. An example of a specification is that the FM team must keep the building at the internal temperatures set in the Services Requirements.

The PPP contract is set out so that BAM adopt the risk of not meeting the Services Specifications. Where they do not meet the Services Specifications they are penalised with deductions. For example if they do not meet the target internal temperature for a space, they will be faced with a deduction. If there is then a repeat failure under the same target but in a different part of the school for a different reason, the deduction will be multiplied, because they are seen to be making the school suffer. Mandating strict internal winter temperatures encourages the FM team to take a risk averse strategy towards heating the building. For example it may be seen as beneficial to run the heating through the night or begin it very early in the morning in order to ensure that the building is up to temperature in the morning. Such a strategy is likely to use more energy than may be strictly necessary.

The energy bills for gas, electricity and water are paid by WDC. BAM are in control of managing the building and therefore determine the amount of energy the school uses as far as possible to meet the Services Specifications. Although BAM have control over the regulated energy use, the energy use from the building services, they have little control over the unregulated energy use which include plug loads from computers and classroom equipment, kitchen equipment use and cleaning.

There is a total energy target for the school as part of the FM contract. The target was set on the base energy consumption of the building, after a normalisation period. The energy target then acts as a financial risk and reward for the FM team. For the first few years after the completion of St. Peter's school BAM FM were tasked with determining the normalisation period where the FM team stabilise the energy usage in the school. A year after the completion of St. Eunan's school the normalisation period started (November 2011). The normalisation period sets the base energy consumption target (Base normalised performance index, NPI) for BAM to meet for the next 7 years. The base NPI has an upper and lower NPI. If the FM team do not control the energy use in the building they will risk using more energy than the base NPI and face financial deductions. If the FM team reduce energy use to below the base NPI they will be financially rewarded. After 7 years of the first base NPI a new base NPI will be formed for the next ten years of the contract.

The normalisation of energy use and the setting of a base energy consumption was designed to ensure that BAM do not over consume energy in the future whilst meeting the Services Specification. However, it is unclear how such an arrangement would stimulate the FM team to optimise the performance of the building during the normalisation period since a high energy use during this period would allow for greater opportunities to make profitable savings in the following 7 years.

The fact that BAM FM do not have complete control over the unregulated energy use and are limited by the controls provided, could make them more hesitant to commit to a lower base NPI. This is because BAM are unable to guarantee the energy use of computers, school equipment, kitchen equipment and cleaning. A performance related Facilities Management contract with a normalisation period is not uncommon in the public sector. It is not clear how such a contract stimulates building optimisation or energy reduction during early occupancy.

Other options for more robust performance in-use targets that incentivise energy optimisation should be considered in the future, for example:

- A target based on a building achieving energy use below a robust industry benchmark
- The setting of energy targets for the energy that the FM team have greater control of i.e. regulated energy (heating, cooling, hot water, lighting, pumps and fans)
- A clearer operational target such as a specific Display Energy Certificate rating target

5.3 Metering

As discussed previously the FM team have had significant problems with the building energy metering and monitoring system (BEMS). The problems with the BEMS system reflect across all parts of the construction process, for example:

- A clear brief defining the operational principles of the BEMS was not provided
- Detailed design and construction information in relation to the BEMS was unclear. In particular, there was insufficient sub metering allowed for with respect to allowing the accurate splitting of energy end uses and heat metering of the GSHP
- Value engineering is likely to have occurred which resulted in poorer quality equipment being installed and 8 fewer electricity meters were present than was indicated on drawings. The installation had faults in relation to mislabelling and a lack of consistency in labelling on the BEMS, drawings and physical meters
- Mismatching energy figures between the BEMS and physical meters would suggest that the meters were not correctly calibrated during the commissioning process. However, the mismatching is also partly due to the fact that pulse sub metering was installed, which has a tendency to drift when the central BEMS computer is off due to maintenance or power outages.
- The FM team had little confidence in the sub metering system due to the mismatching and therefore tended not to use it.

For future projects the following should be integrated into the construction and design process:

- A metering strategy that is compliant with CIBSE TM39
- A robust Building Energy Management specification should be detailed at an early stage in order to reduce the potential for value engineering by sub contractors

- Sub meters with a direct connection to the BMS/BEMS should be specified where the full reading is transmitted to the server rather than just a pulse
- Metering labelling should be defined in design documents and then consistently delivered on site
- Calibration and zeroing of meters should take place at the same time
- Sub meters should be reconciled against main AMR utility meters shortly after initial occupancy of the building
- Clear records of installed sub metering should be provided to the FM/client team along with a user manual and recorded demonstration of the BEMS.

5.4 Findings from this section

In summary the findings from this section are as follows:

- The FM team are focused on ensuring thermal comfort is maintained within the building whilst also pro-actively addressing the maintenance of the central plant. Operating the building efficiently is less of a priority and therefore provides an opportunity for improvement.
- The ability to optimise the building from an energy performance perspective is hampered by the quality and usability of the sub metering installed. It is recommended that a full upgrade of the sub metering and associated BEMS is implemented.
- For future projects FM contracts should be assessed to ensure that sufficient incentive is provided to optimise a buildings energy performance from the outset.

More details on the subjects discussed in this section can be found in the *Appendices B Review of Design and Construction Data* and *A Metering Strategy Review.*

6. Energy Use by Source

As discussed in section 1 and 2 the school and FM team have been beset by problems with the building energy metering and monitoring system (BEMS) which has impacted the activities that could be carried out as part of this phase 2 BPE study. Due to the poor quality of the installed BEMS the BPE project team have not been able to carry out an accurate detailed TM22 assessment. A detailed TM22 has been carried out using the estimation method (energy audit and profile estimation). However, its accuracy cannot be verified and therefore the output should be treated with caution.

This section of the report therefore focuses on analysis that has been carried out on the Automatic Meter Reading (AMR) utility data that has been collected throughout the BPE study period. The AMR data is robust half hourly readings for total gas and total electricity supplied to the site.

6.1 Comparison Against Benchmarks

A comparison of energy use against benchmarks has been carried out on the most recent full year of measured data; year ending 2013. The annual consumption figures are 78.6 KWh/m^2 and 79.5 KWh/m^2 for gas and electricity respectively. These figures are compared to different benchmarks on the following page.

The St Peter data appears to be mostly in line with other schools registered on Carbon Buzz. The actual Carbon Buzz benchmark median has a similar electricity consumption to St Peter, suggesting that the electrical performance of St Peter School is close to that of other recently completed schools. The gas consumption is slightly lower than the Carbon Buzz fossil fuel actual data median, this could be due in part to the electric heat pump providing part of the heat load to the building.

On analysis, the energy consumption of St Peter School is very different from the TM46 and ECON73 benchmarks. Firstly, the TM46 and ECON73 fossil fuel benchmark are much higher than observed with the St Peter natural gas consumption. This is perhaps due to the better performing fabric of new build schools when compared to this older benchmark data.

A further difference from TM46 and ECON73 is the higher electricity consumption observed within St Peter School. It is possible that newer schools typically use much more electricity to operate equipment than previously established by the 1997 and possibly 2008 benchmarks due to the higher IT demands of a modern curriculum. It should also be noted that the school is overcrowded with respect to the design occupancy and therefore it is likely that the larger amount of pupils and associated staff would lead to higher electricty use for small power and IT.

Converting the data into CO_2 emissions makes the electricity use much more significant due to the higher carbon factor of electricity. TM46 and ECON73 benchmarks show much lower emissions from electricity than both Carbon Buzz and St Peter School. In contrast, the gas/fossil emissions are much lower in the Carbon Buzz and St Peter data.

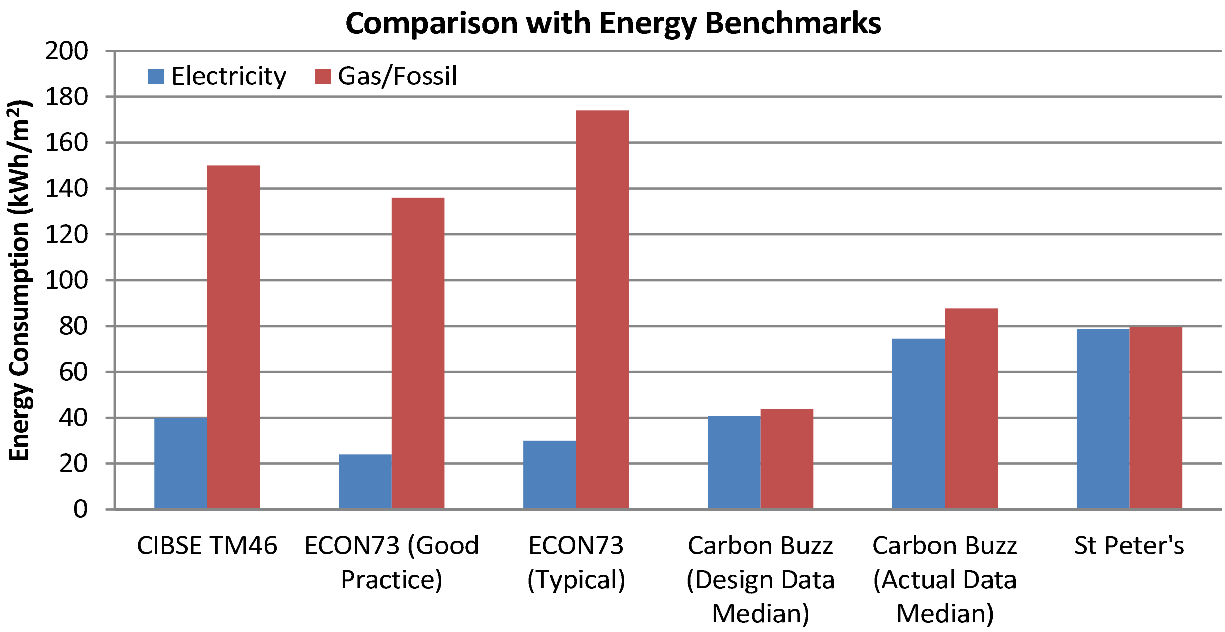


Figure 6.1: Energy benchmarking against Carbon Buzz, TM46 and ECON73 data based on a TM22 simple assessment.

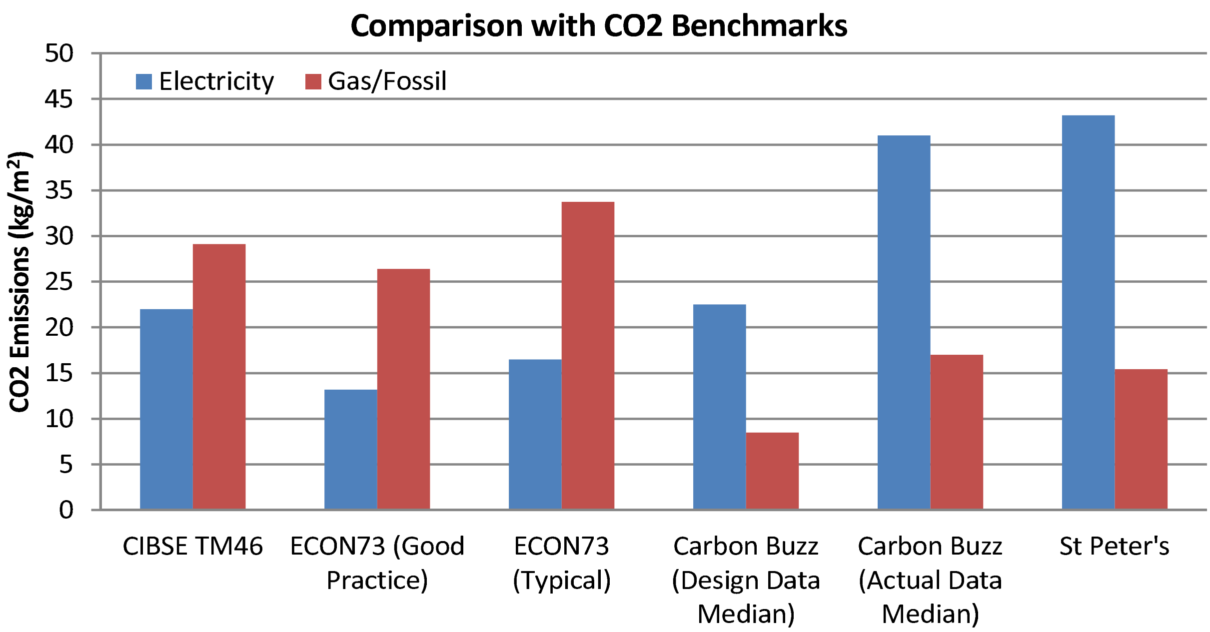


Figure 6.2: Energy and CO_2 benchmarking against Carbon Buzz, TM46 and ECON73 data based on a TM22 simple assessment.

6.2 TM22 Simple Energy Assessment

The TM22 tool begins with an initial assessment of energy performance based upon annual electricity and gas consumption.

The bar charts below provide an energy performance comparison between St Peter School and the following benchmarks:

Benchmark from DEC

The TM22 tool allows the user to enter the benchmarks provided on the DEC (Display Energy Performance Certificate). This would give an indication as to how the building is expected to perform. DEC's are mandatory in public buildings in England but this is currently not the case in Scotland. St Peter School therefore does not have a DEC and hence this row is left blank.

User Specified

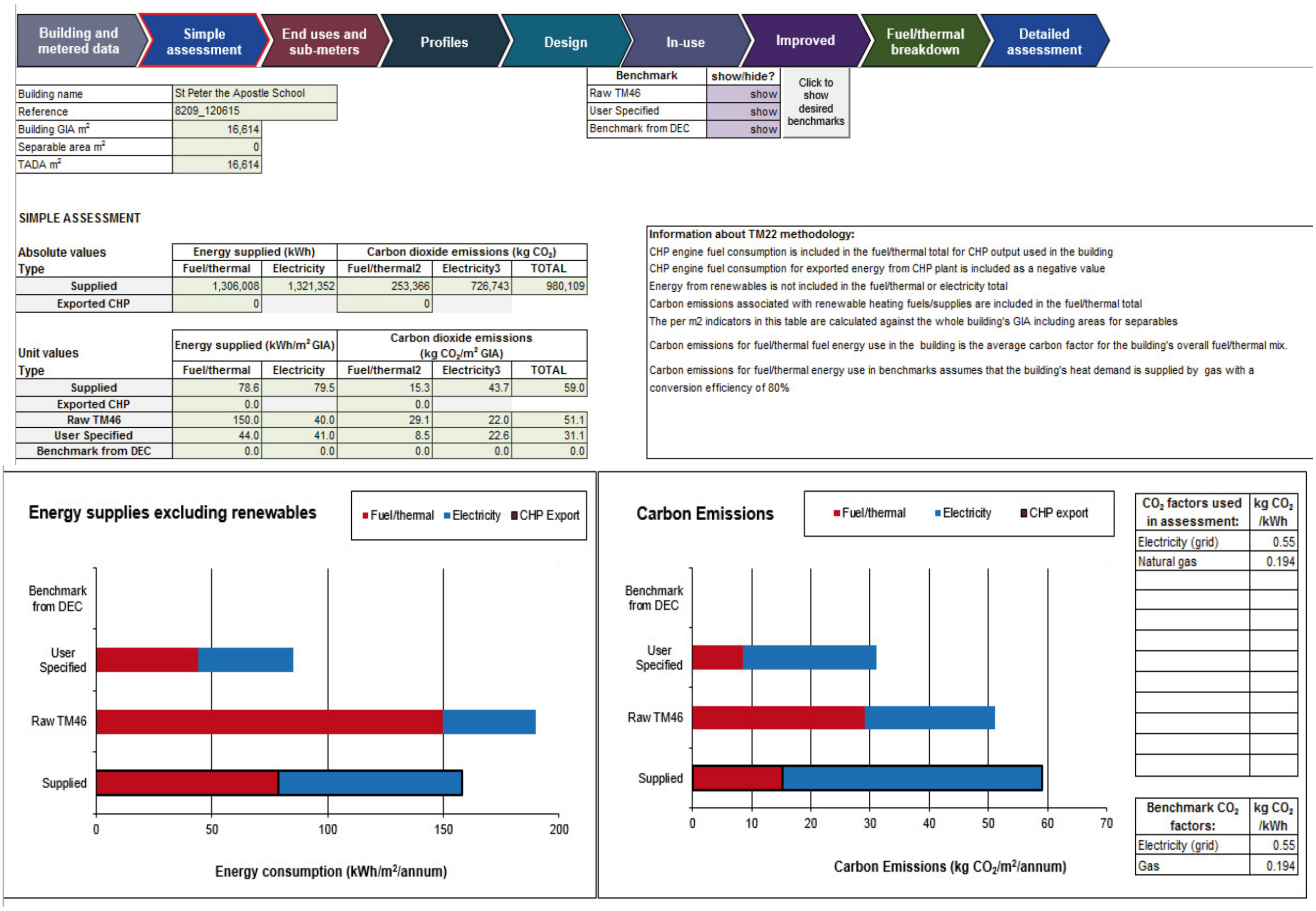
The TM22 tool allows the user to enter an energy benchmark of their own, to act as an energy performance target in the assessment. In this case, the Carbon Buzz actual data median benchmark for schools has been entered which is considered a good target performance as it is based on a number of recently built schools.

Raw TM46

This TM46 value is dependent on the building type. In this case, the building falls under *schools and seasonal public buildings* and is the same as the benchmark described on page 24.

Supplied

This data is the St Peter School metered data.



Building name	St Peter the Apostle School
Reference	8209_120615
Building GIA m²	16,614
Separable area m²	0
TADA m²	16,614

Benchmark	show/hide?
Raw TM46	show
User Specified	show
Benchmark from DEC	show

SIMPLE ASSESSMENT

Absolute values	Energy supplied (kWh)		Carbon dioxide emissions (kg CO_2)		
Type	Fuel/thermal	Electricity	Fuel/thermal2	Electricity3	TOTAL
Supplied	1,306,008	1,321,352	253,366	726,743	980,109
Exported CHP	0		0		

Unit values	Energy supplied (kWh/m² GIA)		Carbon dioxide emissions (kg CO_2/m² GIA)		
Type	Fuel/thermal	Electricity	Fuel/thermal2	Electricity3	TOTAL
Supplied	78.6	79.5	15.3	43.7	59.0
Exported CHP	0.0		0.0		
Raw TM46	150.0	40.0	29.1	22.0	51.1
User Specified	44.0	41.0	8.5	22.6	31.1
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0

CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Natural gas	0.194

Benchmark CO_2 factors:	kg CO_2 /kWh
Electricity (grid)	0.55
Gas	0.194

Figure 6.3: TM22 assessment for energy performance at St Peter school in year 2013

The energy data collected for St Peter School covers a four year period of monthly electricity and natural gas consumption figures. This allows us to draw significant conclusions on the operation of the building and highlight seasonal variations.

The table and graphs on the next page show the variation in total energy consumption across the 48 month period and also the separate electricity and natural gas consumption.

The total energy consumption (heating and electricity) across the 48 months as displayed in Fig. 6.4 shows significant variation between the summer and winter periods, from about 100MWh on average in the summer to 350MWh on average in the winter. A drop in heating energy is to be expected as the higher number of degree days in the winter requires more energy.

Regarding annual gas and electricity consumption, as shown in table 6.1, there is significant variation in energy demand year-on-year. Gas consumption was highest in 2010 and lowest in 2011 while Electricity consumption was highest in 2012 and lowest in 2010. This could be seen as surprising when looking at Figure 6.5 as gas consumption seems to be reducing over time, however this could be misleading as it is just the peaks that are decreasing. This is especially evident in the 2012-2013 heating season where the peak gas consumption is at its lowest but the baseline consumption (summer time consumption) is significantly higher.

The electricity consumption drops in usage for the summer holiday (July-August) and to some extent the Easter holiday (April). This is because schools are vacant or operate at a lower occupancy over holiday periods and therefore may show less energy consumption at these times. The reality proves that often parts of the school are still operational and/or the building services are left on during holidays.

6.3 Heating Degree Day analysis

Figure 6.6 shows gas usage and Degree Day (HDD) data at 15.5ºC for a weather station located 5km to the South West of the school in Inchinnan.

HDD data is a measure of the expected heating requirements of a building based on the external temperature and the temperature below which heating is expected to be required. The greater the difference between the actual temperature and the stated value (e.g. 15.5ºC), the more heating energy is expected to be used.

Considering when the school is unoccupied over the Christmas period, the correlation between gas usage and HDD is relatively strong. However, there does seem to be a lag between gas and HDD over the 2012-2013 heating season. It is unclear why this lag is occurring, one possible reason could be that gas data from this period was provided weekly as opposed to daily. It is also evident that gas consumption is higher than expected during the summers of 2012 and 2013; this is particularly surprising considering the school is unoccupied for a large portion of this time for summer holidays. High gas usage outside of the heating season is most likely to be due to high domestic hot water use.

Figure 6.7 further underlines the generally strong correlation between gas use and HDD. One possible reason why the correlation is not stronger is because part of the heating demand is met from electrically driven ground source heat pumps.

Table 6.1: Energy and carbon performance data year by year from 2010 to 2013

	Energy supplied (kWh/m2.a)		Carbon dioxide emissions (kg CO2/m2.a)		
	Gas	Electric	Gas	Electric	Total
2010	90.2	74.4	17.5	40.9	58.4
2011	66.3 (-26.5%)	76.9 (+3.4%)	12.9 (-26.5%)	42.3 (+8%)	55.2 (-5.6%)
2012	72.8 (+9.7%)	82.8 (+7.6%)	14.1 (+9.7%)	45.5 (+7.6%)	59.6 (+8.1%)
2013	78.6 (+8%)	79.5 (-3.9%)	15.3 (+8%)	43.7 (-3.9%)	59 (-1.1%)

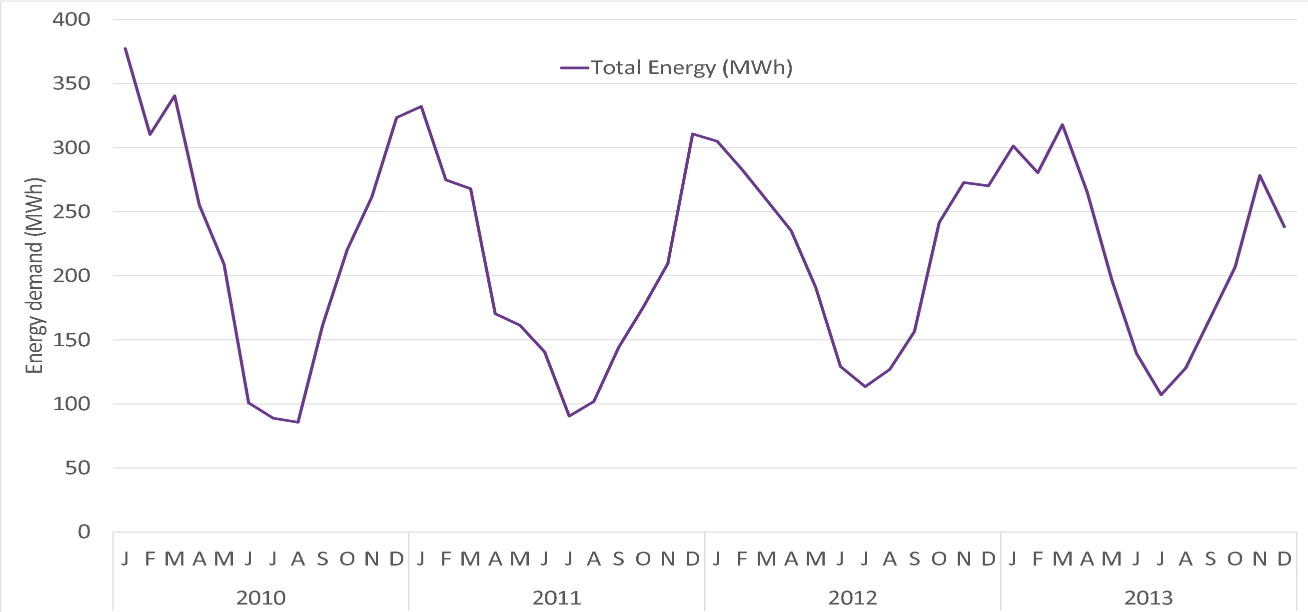


Figure 6.4: Total energy consumption over 4-year monitoring period

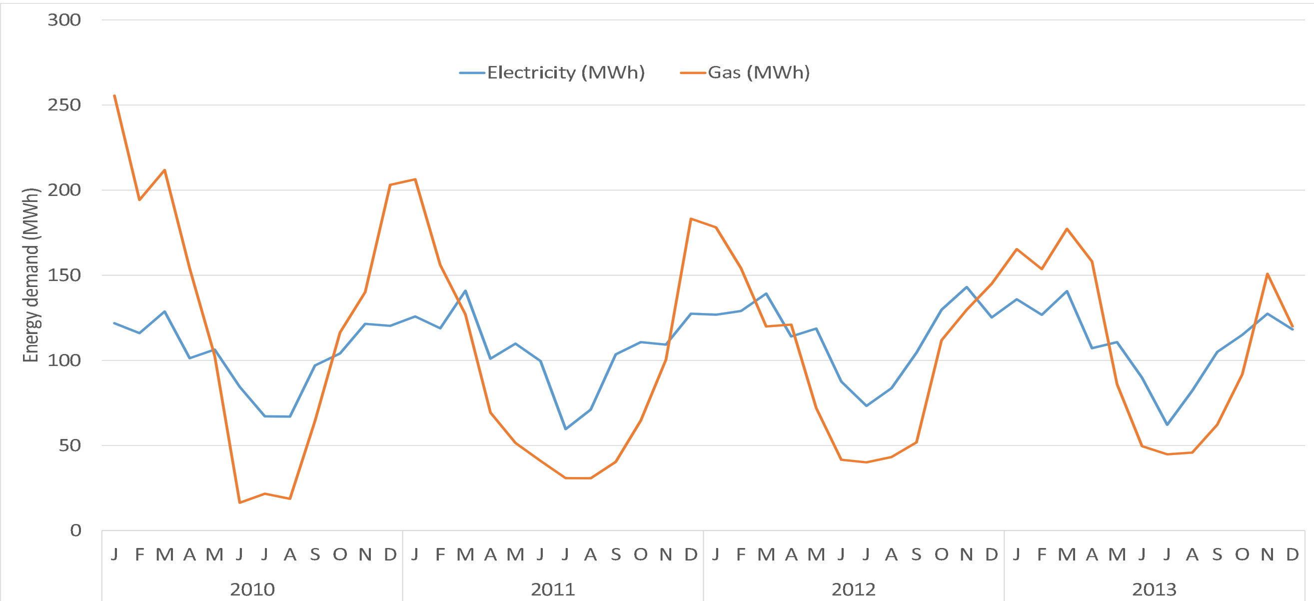


Figure 6.5: Electricity and gas consumption breakdown over 4-year monitoring period

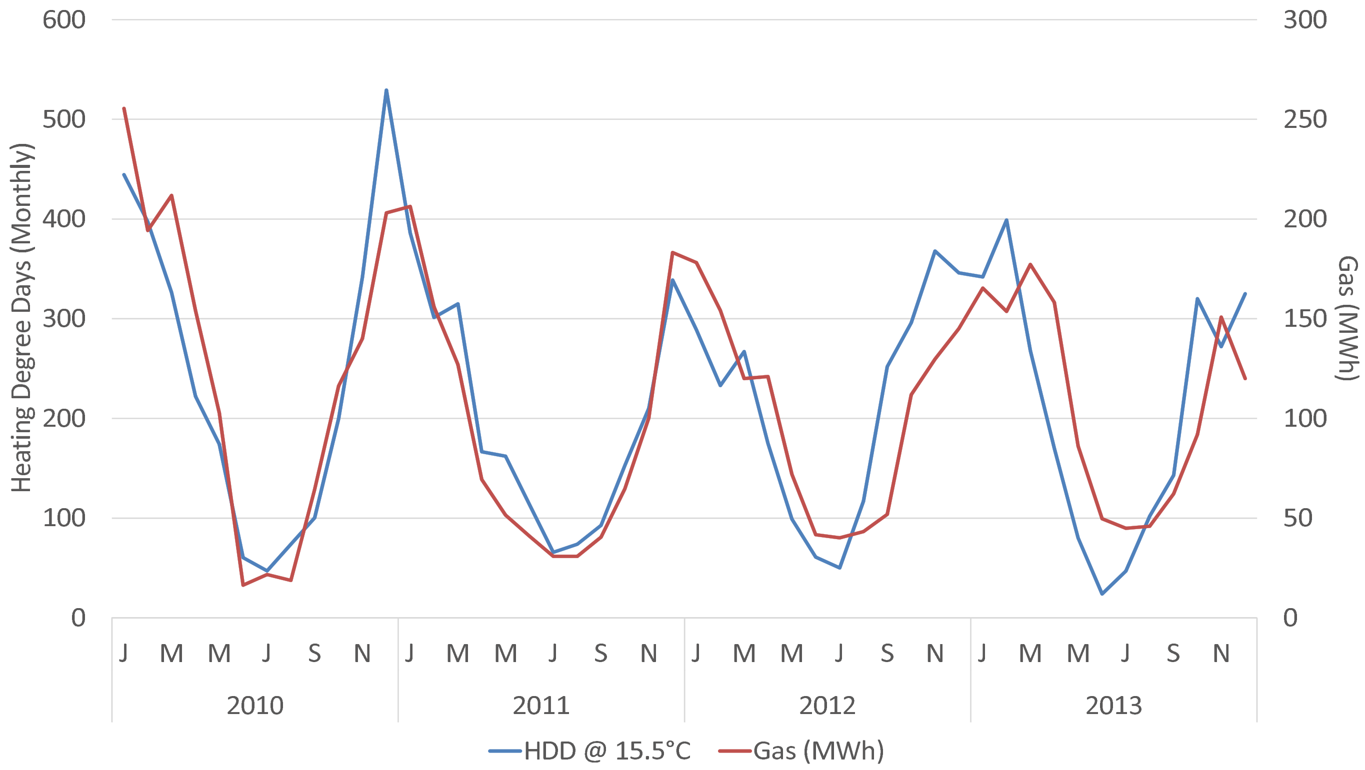


Figure 6.6: Gas usage and HDD at 15.5°C over 4-year monitoring period

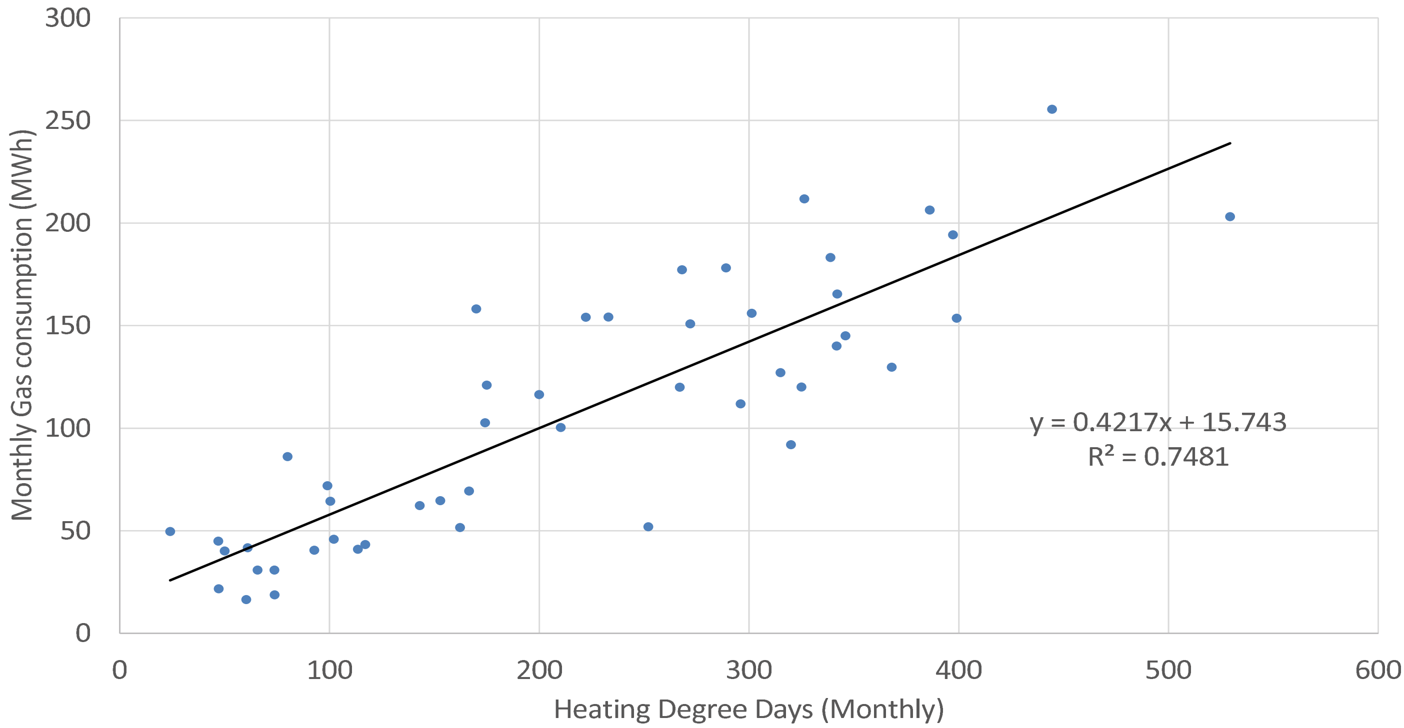


Figure 6.7: Gas usage against HDD at 15.5°C over 4-year monitoring period

Figure 6.8 shows a cumulative sum (CUSUM) analysis of the HDD data. In this analysis, the fit line of the scatter plot is used to generate expected gas usage, and the difference between this and the actual usage is calculated. The cumulative sum of these differences is then plotted. An upward slope indicates that the heating is running less efficiently than average, while a negative slope shows that savings are being made in the weather dependent usage.

It is evident that for the majority of the 4-year monitoring period the heating is operating less efficiently than average. However it appears that the overall year-on-year trend is improving. This could be down to the FM team understanding the building better, however the summer of 2013 shows there is still some work to be done.

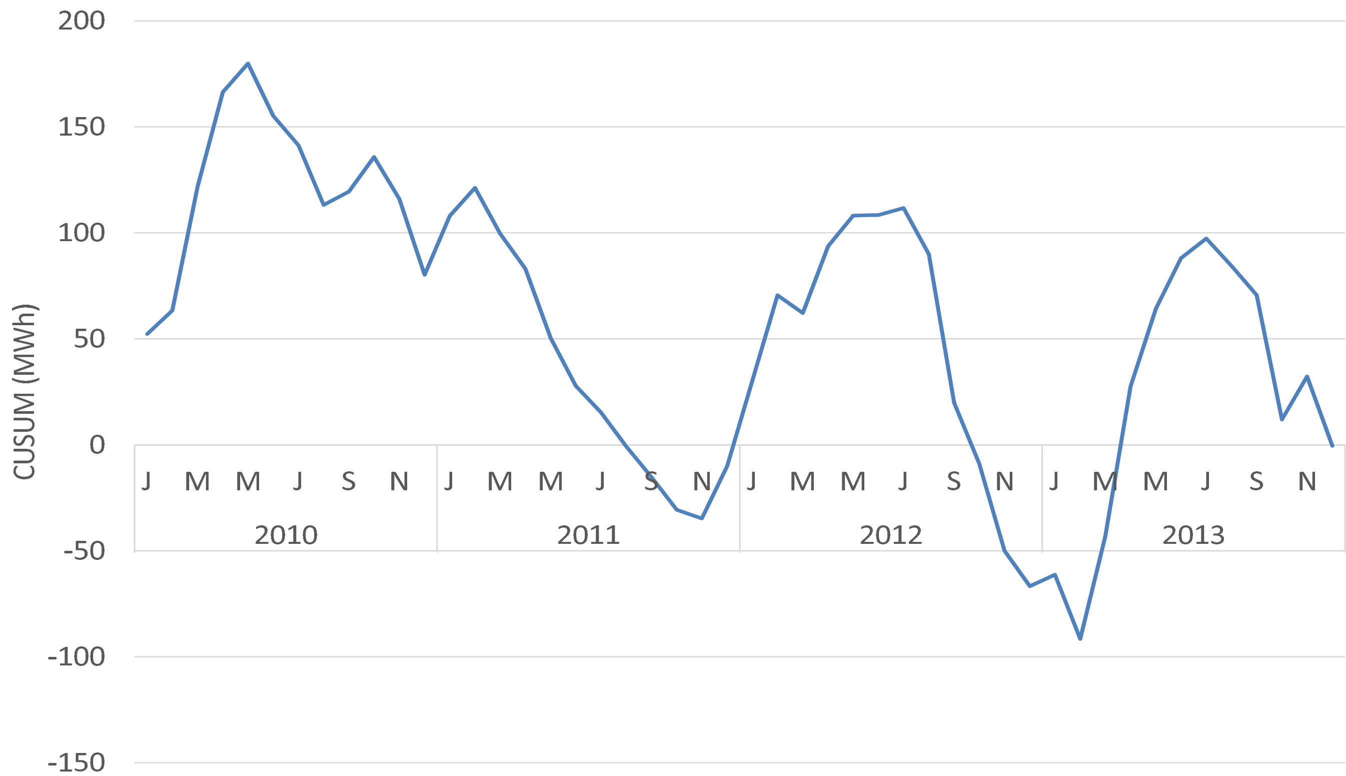


Figure 6.8: Gas usage against HDD at 15.5°C over 4-year monitoring period

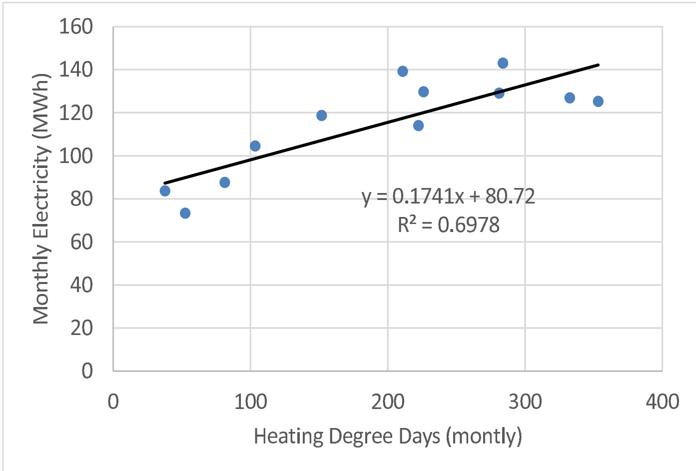
The graphs on the following page (Figure 6.9) illustrate regression analysis (also known as R-squared analysis) for different climate and energy comparisons.

Regression analysis is a statistical process for assessing the relationship between two variables. The process involves plotting two variables on a standard X-Y graph and then applying a line of best fit to the data. The R-squared can then be calculated in order to determine how close the data is to the line of best fit. An R^2 value of zero indicates that there is no linear relationship between the variables and an R^2 value of one indicates that the linear relationship between the variables is exact. R^2 values in-between zero and one show an indication of how strong a relationship is between two variables.

Figure 6.9 investigates the link between monthly gas consumption with hours of sunlight and hours of daylight. Both figures indicate a relatively strong negative correlation, suggesting that increased hours of daylight and sunlight reduce the demand for gas consumption. Although passive heating via solar gain can potentially reduce heat loads, these correlations are probably due to the fact that winter months require more space heating and also have the shortest days in terms of daylighting. This is further highlighted by the weaker relationship between gas consumption and sunlight; as sunlight varies less considerably throughout the year.

As well as sunlight and daylight analysis, figure 6.9 also looks at the relationship between electricity consumption and heating degree days. This correlation is also relatively strong, and is probably due to some electricity consumption being used for the ground-source heat pumps. The sunlight and daylight relationships are less strong, which may suggest that the daylighting strategy may not reduce electrical load as much as was hoped.

Although some relationships are apparent when conducting regression analysis on the limited data that has been gathered the BPE team would expect much stronger relationships if the HDD data had been able to be compared with sub metered data.



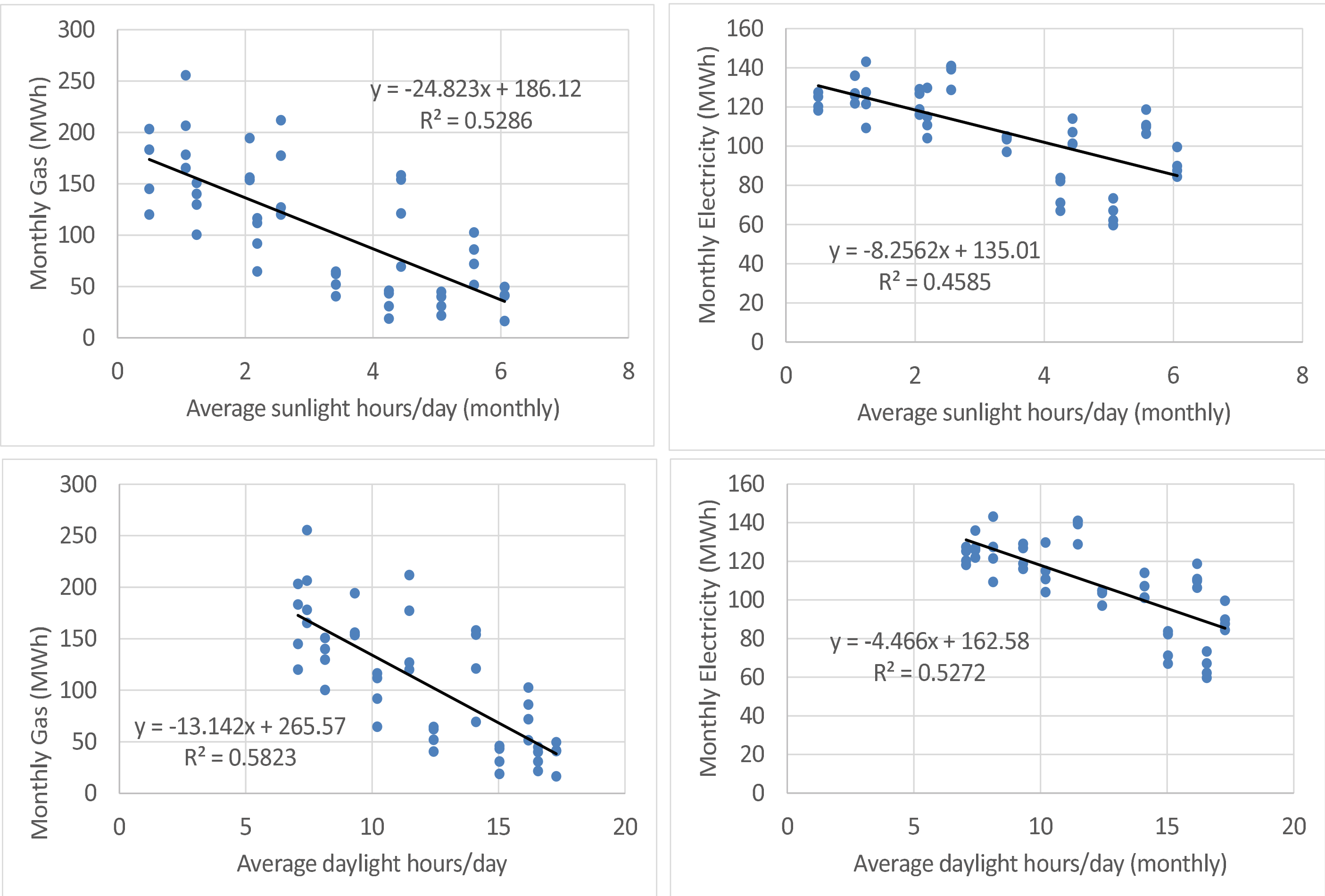


Figure 6.9: Further HDD, sunlight and daylight analysis for electric and gas consumption

6.4 TM22 Detailed Energy Assessment

As discussed previously inaccurate and inconsistent sub metering data has meant that carrying out an accurate detailed TM22 assessment has not been possible. Instead, a detailed energy audit was carried out in order to gather data on expected energy use profiles and base plate electric loads of all electrical equipment in the school. This predictive method of energy analysis has been used to estimate the split of energy by end use for electricity and gas use. Figure 6.10 on the following page shows the predicted split of energy use via the TM22 methodology for electricity and heat demand. The split of end-use via energy and CO_2 is also shown in the table below.

End-use	Predicted proportional split	
	Energy	CO_2
Space heating	32.4%	21.3%
Hot Water	22.3%	11.7%
Cooling	1.0%	1.5%
Fans	9.0%	13.3%
Pumps	3.3%	4.8%
Int lighting	7.0%	10.5%
Ext lighting	0.7%	1.0%
Small power	9.7%	14.4%
ICT equipment	12.1%	17.9%
Vertical transport	0.1%	0.1%
Catering	1.8%	2.4%
Refrigeration	0.7%	1.0%

Table 6.2 : Energy and carbon split for the different end-uses

The results of this predictive energy analysis should be used with caution since their accuracy is not able to be confirmed by comparison with sub metered energy data. For this reason it is not considered suitable to draw conclusions from this data.

6.5 Air leakage testing

Air leakage testing was not a mandatory part of the Scottish Building Regulations at the time of construction and therefore an air tightness test was not completed upon practical completion as would have been the case in England and Wales at the time. It should be noted that as of October 2010 air tightness testing has become a part of Scottish Building Regulations with a maximum threshold of 10m^3/hr m^2 @ 50Pa.

Air leakage testing was carried out at the school on the 17th October 2012 as part of the BPE study. Due to the size of the building and therefore the number of vents and openings, it was not possible to carry out the test for the whole building. In addition, as the building was already occupied, the test had to be carried out within the limited available time during half term.

Testing was carried out at two locations; Block C and the 'rotunda' (shaded red and green respectively in Fig.2.2). These areas were selected since Wing C was seen as representative of the other teaching wings and the Rotunda had negative feedback from building users with respect to thermal comfort.

Results indicated an infiltration rate of 10.29 m^3/m^{2}hr in Wing C and 19.54 m^3/m^{2}hr in the rotunda. Put in context, buildings with an infiltration rate above 15 m^3/m^{2}hr at 50 Pa would be considered as leaky in general. Therefore, the rotunda part of the building is considered to be very poorly sealed and is likely to result in large infiltration heat losses. Wing C would also not meet current building regulations.

The air tightness level of the spaces tested is particularly disappointing given the low air tightness target for the site (5m^3/hr m^2 @ 50Pa) and highlights that significant lessons can be learnt with respect to achieving better standards of building fabric performance. Such lessons include: marking of a line of air tight barrier on architectural sections with a continuous red line, further use of air tightness membranes, sealing and details around junctions and service penetrations. Further details are provided in appendix H. Specific areas of infiltration loss are discussed in Section 7 of this report.

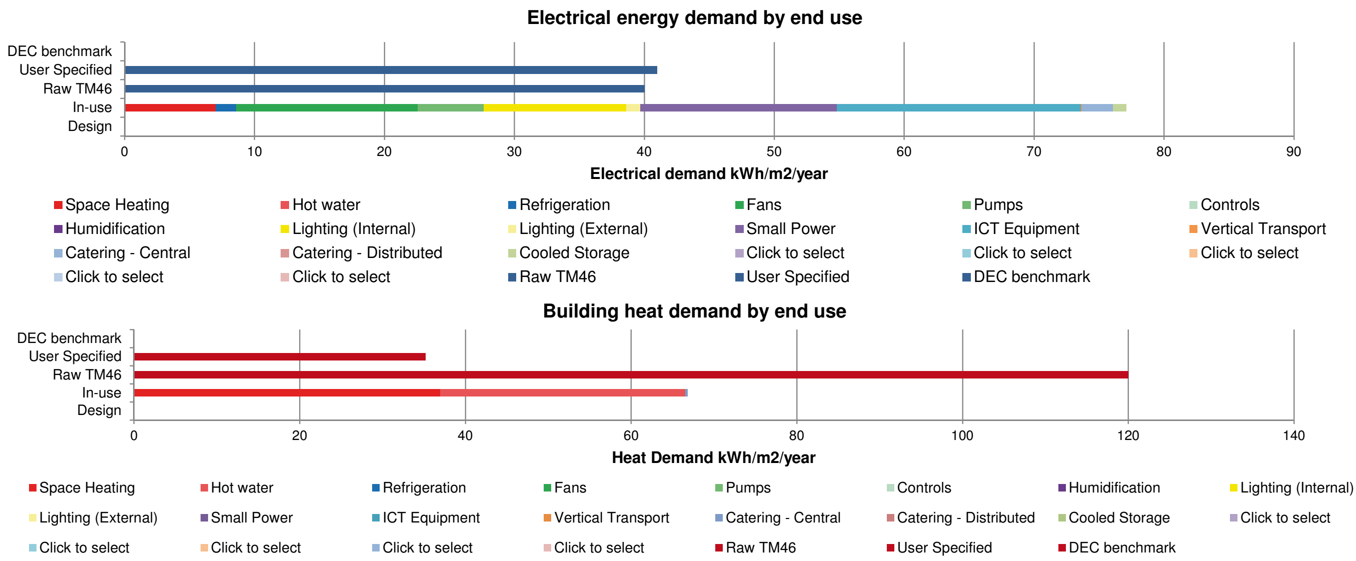


Figure 6.10: TM22 detailed analysis including splitting of end-uses based on energy profile estimates rather than accurate sub-metering

More details on the subjects discussed in this section can be found in *Appendices C Review of Historic Energy Data, I TM22 Accompanying Notes* and *H Thermal Imaging and Air Tightness Report.*

4.4 Findings from this section

In summary the findings from this section are as follows:

- Overall energy consumption is similar to actual measured data from recently built schools. However, it is likely that significant reductions in energy use could still be made via the identification of energy waste through better energy management.
- The ability for the BPE study to identify energy waste and complete an accurate TM22 model was severely hampered by the quality of the installed metering
- Winter heating performance was generally good over the 2012-13 heating season.
- Use of heating in winter correlates strongly with HDD data, however more recently summer gas usage has been higher than expected. It is unclear whether this is down to increased DHW use or heating plant being left on over the holidays.

7. Technical Issues

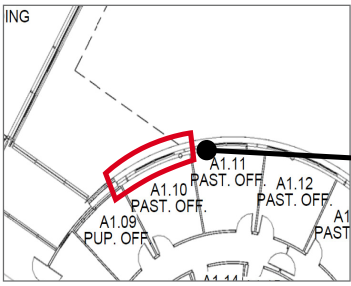
7.1 Thermal Comfort

As discussed in Section 6.5 an air tightness test was carried out as part of the study and the results highlighted that the thermal performance of the building with respect to infiltration was poorer than expected particularly in the Rotunda. The increased infiltration rate is likely to be a factor in the low occupant satisfaction results for winter temperature that were highlighted as part of the BUS survey results. This is particularly the case for office and administration staff who are largely based in the Rotunda and from analysis of the BUS survey (see appendix G and section 4,1) rated thermal comfort particularly poorly.

Following the air tightness test, smoke pencil tests were carried out at a number of locations in the 'rotunda' to visualise inflow of air through defects in the building fabric whilst the building was under negative pressure. Significant draughts of cold air were detected in front of the electric sockets in the rotunda, particularly those that have been placed on external walls.

A larger scale smoke box test undertaken when the building was under positive pressure also enabled visualisation of air leakage pathways through the building fabric.

During the smoke box test carried out at Room A1.10, a significant amount of smoke was to be observed emerging from the connection between the roof above Room A1.10 and the adjoining external overhang for the building entrance. This may be due to the presence of an air gap between the two elements (see figure 7.1). Further investigation should be carried out to determine the cause of excessive air leakage at this location and then rectify the defect. It is probable that the infiltration at this point is impacting the comfort in room A1.10 and also increasing heating energy use. Thermal imaging was also carried out as part of the BPE study in order to highlight any further areas of



Junction between ceiling of room A1.10 and overhang near building entrance where leakage was detected

Figure 7.1: Location of leakage found in the rotunda during the smoke box test.

infiltration as well as the presence of any significant thermal bridges.

The following thermal image (Fig.7.2) shows that the plastic electric cable ducting along the room appears to provide a pathway for cold air to travel from an external wall into the depths of the room. Particularly cold patches are detected at the connections between ducts where cold air can leak out of the encasement. This image was taken in room A1.05, but the same phenomenon has been observed in areas of the 'rotunda'.

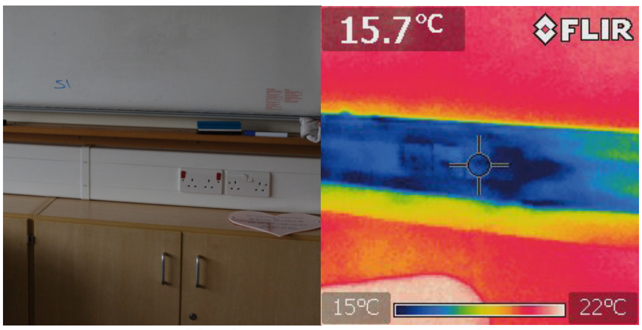


Figure 7.2: Cold bidge along power sockets.

The infra red thermography survey highlighted that the structural columns in the rotunda act as a thermal bridge which increase the heat demand of the spaces that they pass through and may also create thermal comfort problems in these rooms.

Figure 7.3 shows the high level windows in the first floor corridor of the 'rotunda'. The thermal image shows low temperatures in the suspended roof space after removal of a ceiling tile. This might be due to insufficient insulation at roof level and potential air ingress through gaps and holes in the roof construction. Cold air (~16°C) also leaks through the joints between ceiling tiles into the space below as shown by blue coloured patches along the ceiling tile grid.

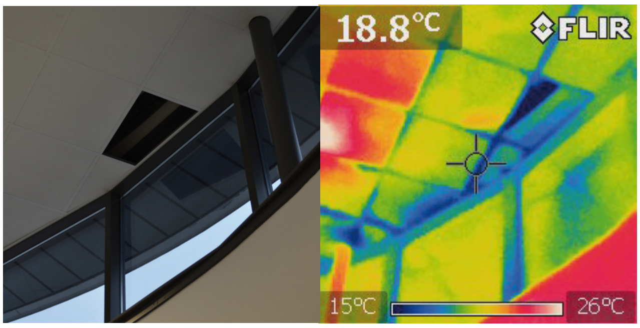
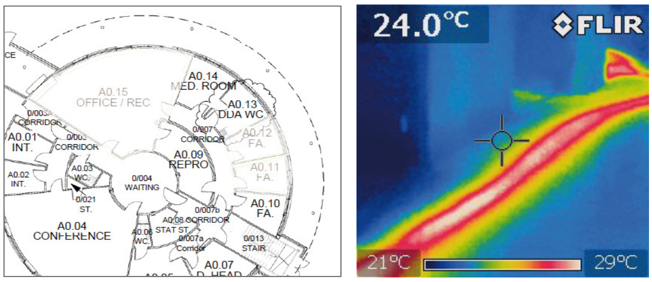


Figure 7.3: Air leakage in the roof of the rotunda.

The thermography survey also showed that some of the ground floor spaces may not have been covered by the heating system, these included room A0.11, room A0.12, and possibly the reception office. The image below shows a view from room A0.13 (towards the south) of the heating pipework along corridor 0/007, with underfloor heating pipework bypassing rooms A0.11 and A0.12 before being directed into room A0.10. It is possible that at the time of photographing, heating in this apparently bypassed section was switched off for some reason, however this is thought to be unlikely.

The lack of underfloor heating in rooms with no alternative heat source will create thermal comfort problems within these rooms.



Rooms without underfloor heating on ground floor of 'rotunda'.

Figure 7.4: Apparent bypassing of underfloor heating in some rooms within the rotunda.

For further details of the air tightness test and infra red thermography analysis please see Appendix H.

7.2 BMS

The BMS was designed to provide the FM team with a useful way of controlling the building. However, the BMS does not have the desired functionality to closely control the building's heating and cooling systems. The BMS at the school provides a very basic service with a limited number of temperature sensors and controls for systems.

A survey was carried out by Siemens (see Appendix E) in accordance with BS EN 15232 in order to ascertain the level of control the BMS and users have over the building systems via an A to D rating system. The results of their findings were that the BMS overall is very poor and does not allow for the efficient and comfortable running of the school. They classified the efficiency of the controls at the lowest rating of a D. Recommendations were then provided by Siemens to upgrade the system to a B level which could potentially achieve energy reductions of around19%.

The building has one BMS temperature sensor per floor per teaching wing to control the heating in all classrooms on the floor. The radiant panels in each classroom can then be fine tuned by up to 2°C using a wall thermostat in each classroom. The BMS has currently been set to turn on the heating when the temperature sensors in the corridors are reading below 25ºC.

The BMS only has timer controls for the underfloor heating. There is a separate thermostat that also controls the underfloor heating but the BMS is not connected to it.

The basic set-up of the BMS, sensors and controls results in very limited control of the heating in the building. The heating in the classrooms and the underfloor heating in the corridors is therefore more likely to be turned on than off. This also leaves the FM team with very little control of the heating in individual classrooms and corridors.

The lack of BMS linked room thermostats in classrooms that may experience quite different internal heat loads (e.g. solar gains at different times of the day or ovens in HE classes) means that maintaining a constant temperature across different classrooms is extremely difficult. There is also a lack of sensors for the underfloor heating and ground source heat pumps resulting in a lack of control at the BMS. It would appear that the BMS is blindly controlling the heat in spaces that have few sensors.

Due to the set-up of the PPP contract the FM team are also more likely to over-run the heating to ensure that the temperatures in the building do not drop below the specified temperatures in the contract. A BMS that allows the FM team to closely monitor their building would have allowed them to run the building more efficiently within the parameters of the PPP contract.

It is likely that many of the issues with the BMS are a result of not having a strict specification combined with sub-contractors seeking to reduce the cost of the installation.

Controls specifications should be carefully detailed at the design stage with assistance from a controls specialist and the client. The specification must then be tracked through to completion to ensure that what is delivered fulfils the initial brief. The sub contracting of the controls package by BAM to the M&E subcontractor followed by further sub contracting the package to a controls contractor is likely to have caused a disassociation between designed and delivered controls. Value engineering at each of these sub contracted stages may have had a significant detrimental effect on the efficient operation of the building.

Further technical detail on the controls and BMS can be found in Appendix E, Review of Controls.

7.3 Underfloor Heating

The underfloor heating runs through the majority of the ground floor providing heat to the sports halls, fitness gym, assembly hall, cafeteria, main corridor and rotunda. The BMS is able to set the underfloor heating on or off on a timer, however there is no separate control of the zones or local temperature sensors to display how warm or cool a space is. The underfloor heating is set via a manual thermostat located in the main corridor. This reduced control of zones means that all areas either have the underfloor heating turned on or off. Due to the slow response

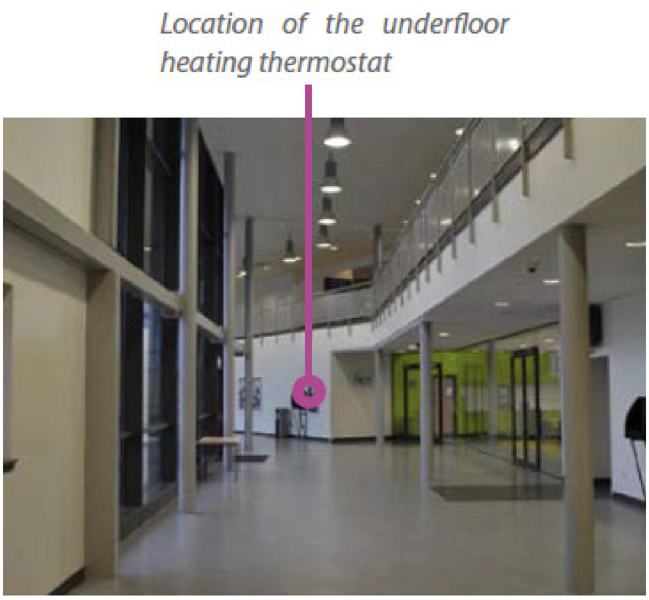


Figure 7.5: Central corridor which is served by underfloor heating.

time of the underfloor heating it is predominantly turned on.

The way the underfloor heating is connected to and controlled by the BMS also means that there are conflicts with the cooling system in the fitness gym. The underfloor heating is often on and attempting to heat the space as set by the thermostat in the main corridor, whilst the cooling system is set to cool the gym to a set temperature. This creates a constant battle for the underfloor heating to warm the room until the corridor reaches temperature and fan coil units to cool the room, resulting in an increase in energy consumption.

7.4 Ventilation

In areas where natural ventilation is used manual controls have been specified. In general these controls are not labelled and no instruction is provided on how and when to use them. Although the FM team are available to provide instructions to teachers it is not known whether the natural ventilation is used to its full potential or whether excessive natural ventilation is used unnecessarily during the heating season.

The FM team should consider issuing further instruction or labelling of natural ventilation controls. This would be particularly useful before the heating season or before periods of particularly warm weather in the summer term and could help to reduce space heating loads and/or overheating.

Particular spaces that could benefit from further instructions are in the sports hall where a hand control can operate high level windows. It is unclear when or whether these windows should be opened, particularly given that mechanical ventilation with heat recovery also operates in this same space.

7.5 Lighting

The main corridor connecting all blocks together has light switching arrangements that control whole sections of the corridor. Where parts of the corridor are lit by daylight the lights are generally not needed, however, where parts of the corridor do not have full height glazing and have a lowered ceiling, lighting is generally needed. The design of the corridor with parts of it receiving daylight and parts needing artificial lighting combined with a lack of controls results in the lights often on when not necessary. The corridor lights rely on the FM team switching them on and off, therefore there is potential for lights to be left on unnecessarily.

Figure 7.6: Corridor lighting showing full height glazing to the left and in the background a lowered ceiling with no access to daylight.

PIR sensors should be considered for installation in certain circumstances, e.g. in circulation spaces that are currently manually switched. Daylight sensors should also be considered for circulation spaces with large amounts of glazing.

The information detailed at construction stage and post construction stage did not adequately cover the operation of the lighting controls in the different spaces of the school. The information does not make it clear why two light switches are necessary in the classrooms or what they control. In addition it is not clear to where the dimmable lights have been provided.

7.6 Findings from this section

In summary the findings from this section are as follows:

- This section has illustrated a series of considerably problematic technical issues that have effected the energy performance, thermal comfort and operation of St Peter School.
- The presence of cold bridges and evidence of air ingress within the building, especially the rotunda, has lead to heat loss. This has a negative impact on thermal comfort and increases energy use.
- There seem to be various underlying issues associated with the BMS. A lack of correctly linked controls and meters means monitoring of temperature variability and energy usage within separate sections of the school is not possible.
- Issues with the BMS consequently impact on the running of the underfloor heating system. With only one sensor influencing the temperature of the system, varying temperatures in individual spaces is impossible without impacting on additional energy use.
- The natural ventilation strategy seems to work well when used correctly, however there is an issue with user understanding and willingness to operate the windows in summer.
- The design intended to optimise natural light within the school, however this has not translated into considerable energy savings due to the lighting controls. Daylight sensors and additional light switches should ensure artificial light is only used when neccessary.

More details on the subjects discussed in this section can be found in *Appendices H Thermal Imaging and Air Tightness Report, B Review of Design and Construction Data, F Walkthrough Report* and *A Metering Strategy Review.*

8. Key Messages for the Client, Owner and Occupier

8.1 Recommendations

The following are a summary of the key recommendations for the school being made as a result of the BPE study:

- Additional sub-meters: To ensure that the building can be accurately submetered and have the relevant data recorded a number of updates will need to be made to the metering on site, these include: 1x additional electric meter on the GSHP - to measure power consumption by the heat pumps; 2x additional heat meters on the GSHP - to measure heat generated by heat pumps; and 3x additional gas meters for the VT circuit, CT circuit and science hot water - to be able to differentiate between space heating and hot water use.
- Connections to BMS: Connection of new electricity meters and woodwork classroom meters to the BMS.
- Calibration: Calibration of physical meter readings with BMS so that the FM team can rely on the BMS read out rather than individually check physical meters.
- Tracking: The current BMS does not allow for detailed logging and analysis of metered data. A metering analysis package should be installed onto the St Peter BMS. A metering analysis package should also be partof the standard BAM specification for new buildings.
- BMS compatibility: The stand alone under floor heating controllers should be replaced with BMS compatible alternatives. This will allow underfloor heating zones to be controlled better. The thermal wheel controller should also be linked to the BMS.
- Thermostats: Additional BMS linked black body thermostats should be installed in classrooms. This will help the FM team to maintain closer control of classroom temperatures.
- Calendar review: The BMS calendar should be reviewed in order to identify main plant being left on when the building is empty or only partly occupied. Plant operation times should then be changed in order to try and optimise the energy performance of the building. Should comfort conditions drop below acceptable standards due to the calendar change made then the system can be adjusted to suit. System setting during weekends and holidays should be reviewed as a matter of priority.
- Fan coil unit: The settings of the sports hall fan coil unit and underfloor heating should be checked in order to ensure that the two systems are not on concurrently.
- CO_2 sensors: Sports halls would benefit from the installation of CO_2 sensors linked to the BMS and air handling units. Demand controlled ventilation in this manner could reduce fan usage.
- Presence detection: PIR sensors should be considered for the teaching wing corridors and stairwells in order to reduce lights being on when they are not needed.
- Fixing leaks: The school should consider undertaking remedial work to improve the air permeability in the 'Rotunda'. Worthy of particular attention are the cable ducts along walls, other plug sockets directly fixed to walls, and the suspended roof space.
- Detailing: The smoke test in the rotunda demonstrated that there is an air leakage path from room A1.10 directly to the outside. This will result in significant heat loss from this area of the building and should be investigated further.
- Underfloor heating: The thermography survey also shows that underfloor heating may potentially be absent in Rooms A0.11 and A0.12, as well as in the reception office. This is likely to be a cause for occupant dissatisfaction in these spaces. Further investigation is recommended to determine if heating is provided and effective in these rooms.

- Consider replacing the stand alone under floor heating controllers with BMS compatible controllers.
- Install CO_2 sensors in the extract ducts of all ventilation plant to allow demand based control of fans to reduce energy consumption
- Consider reprogramming the control system to generate demand from the room which engages the plant. This can only be implemented if the under floor heating controls are changed to BMS compatible controls.
- Include presence detection for system operation
- Provide additional advice to building users on the different modes of operation for the natural ventilation controls which are dependent on the internal and external conditions. The aim of this advice is to improve thermal comfort in teaching classrooms.

8.2 Lessons for West Dunbartonshire Council

- Ensure that contracts for managing buildings include energy efficient operation as one of the key priorities. Ensure that energy performance targets are robust and incentivise energy optimisation from the outset.
- 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.
- 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.
- Consider the implications of increasing the occupancy of a building beyond its designed capacity. Energy performance and thermal comfort is likely to be impacted by over occupation.

8.3 Lessons for Designers and Contractors

- Controls specifications should be carefully detailed at the design stage with assistance from a controls specialist and the client. The specification must then be tracked through to completion to ensure that what is delivered fulfils the initial brief.
- A detailed metering design should occur at RIBA Stage E using TM39. Logical meter labelling should be used and maintained consistently through to delivery.
- The sub contracting of the controls package by the contractor to the M&E subcontractor followed by further sub contracting the package to a controls contractor is likely to have caused a disassociation between designed and delivered controls. Value engineering at each of these sub contracted stages may have had a significant detrimental effect on the efficient operation of the building.
- When designing buildings with complex geometry, extra care is required to detail for air tightness and cold bridges as has been demonstrated by the relatively high air permeability in the 'Rotunda'.
- 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.
- Ensure that building user guides are simple and easy to understand so that they will be used.
- 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

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

- 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.
- 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

- Ensure that there is a clear understanding of needs and expectations of the relevant parties and that these are managed carefully throughout the project.
- Avoid unnecessary complexity in building form since it can create difficulities during the construction period
- Where the building form is complex ensure that the architectural details of insulation and air tightness barriers are considered carefully by the design and construction team
- 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.
- Define a clear controls strategy and BMS specification at an early stage and ensure that it is followed through to delivery
- 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.

10. BAM's learning from TSB BPE

BAM have used their involvement in this and other studies to help develop their on-going approach to BPE. Information has and will continue to be fed back to design and construction teams and some lessons learned have already had an impact on new projects. While the level of detail involved in the Technology Strategy Board studies is not necessarily suitable for all projects, BAM are developing a flexible approach which they hope would allow some level of BPE on all projects in the future. It is intended that this will form part of BAM's approach to soft landings and could also be integrated with BIM, to ensure accurate information is available to assist in monitoring and managing performance of buildings once completed.

Some specific lessons learned and comments are provided below as a response to the study findings.

10.1 Learning from the BPE Process

The process which TSB has developed over the last 4-5 years has provided some useful tools and methodologies, but many of the requirements of the TSB BPE process are not suited to the timescales of a commercial design and construction project. Timescales are too drawn out and while ongoing monitoring should always be part of the BPE process, there is a need to provide staged information back to client and project teams more quickly. This could be delivered through an initial 'light touch' BPE to identify areas which may require further investigation, rather than committing to carrying out a full and detailed review of design and construction. However, certain aspects could and should be replicated on any project e.g. BUS, energy monitoring and benchmarking, building walk around, review of building controls and commissioning.

Initiating a BPE only once a project has been completed and handed over (in some cases a year or two after) is not easy and from the experience of the St Peters study, can leave a range of questions unanswered. BPE needs to be a clear objective from the start / early stages of a project.

BPE needs to be part of the contract / deliverables from the tender stages of a project. Clients need to define the requirement and how they plan to deliver it. Without this, it is unlikely there will be wide spread take up. At present BAM sees the benefit of conducting BPE on some projects, especially where we have a design and/or FM role, however this must be driven by the client.

10.2 Learning from study findings and recommendations

Specific findings from the study have already and will continue to be disseminated internally at BAM, to design, construction and FM teams. Findings related to the thermal performance of some areas of the building (e.g. where thermal bridges were identified) have been passed back to designers and construction teams and this has informed the development of future projects (e.g. when considering similar details). Remedial measures were also taken on site to improve thermal comfort for occupants. The site specific recommendations for improvement (focused on improved controls for lighting and heating for instance) will be considered as part of the lifecycle maintenance of the building and can be used to engage with the school when discussing future improvements to energy efficiency. More broadly, these findings can be fed into future projects, to show the impact (during the use of a building) that enhanced controls can have (e.g. highlighting the potential for increased capital expenditure leading to future savings in running a building).

The study has also highlighted that PFI operating requirements can sometimes be in conflict with energy efficient operation, especially where there is a lack of sufficient control. Given the broad range of comfort conditions experienced by occupants and the strict requirements on temperature levels set through the PFI contract, it would be better to allow more zoned and automated control of individual classroom / working spaces. In addition, PFI contracts must seek to ensure that all parties involved in managing and using the building have an incentive / driver to reduce energy consumption. This means both incentives for building management teams and clients to invest in measures to improve efficiency over time (allowing for this in lifecycle budgets for instance) and incentives for building users to take an active role in minimising energy consumption. Subsequent PFI contracts have now been set up with joint incentives and in use targets for carbon. This will continue to be considered for future PFI contracts to ensure that operating requirements are not in conflict with achieving high levels of energy efficiency.

Another key finding for BAM is the need for more direct engagement with BMS manufacturers to ensure that the right specifications are delivered. Input from Siemens (directly) as part of the study highlighted a number of improvements that could be made, including using the BS EN 15232 standard to inform the design (and also to 'audit') of BMS system specifications. BS EN15232 effectively outlines best practice for control systems (rating them from A to D). A number of the recommendations for improved controls have already been implemented at St Peters and at the time of writing, the BMS software was undergoing an upgrade.

One of the key issues highlighted by the study is the need for robust and detailed energy metering as this is not only a key component to enable energy efficiency but is a key enabler for BPE. Learning from St Peters highlights the importance of correct labelling of meters and setting out a robust metering strategy which is updated at each stage of the project. It has also highlighted the importance of continual checking / commissioning of metering following hand over. This will be integrated into future projects that BAM delivers.

10.3 Taking BPE forward

Dissemination has already taken place in the form of internal CPD sessions providing project managers, design managers, designers and FM staff an overview of the studies processes and findings. BAM and XCO2 have also disseminated externally through articles, blogs and presentations.

Specific findings from St Peters will be distilled and further disseminated within BAM.

As a result of their involvement in the TSB BPE studies, BAM hope to develop their own approach to BPE to gather key learning from projects and to promote the wider take up of BPE within the industry. Going forward, BPE will form a key part of BAM's approach to soft landings / Government soft landings and follow on studies have already been planned to inform the development of this approach.

A number of the issues identified through the St Peters study have already been addressed through improvements to business processes and through development of new services. In particular, BAMs industry leading adoption of BIM will help to improve the availability of information which is critical to future BPE.

Development of BAMs FM offering includes computer aided facilities management systems and linking asset management software with BIM. This improves the information available to building owners / managers post-handover, facilitates more effective and efficient maintenance and management regimes. A help desk system is now used on all BAM FM projects and increasingly, this is offered to clients on construction projects as part of an aftercare package. Research is also in progress to develop systems which allow occupants to provide direct feedback to building mangers e.g. identifying when an occupant is too hot or cold or where a facility isn't working as intended.