Staunton on Wye Endowed Primary School

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

Innovate UK project number	450064
Project lead and author	Architype, E3 Consulting Engineers, and Roderic Bunn
Report date	2014
InnovateUK Evaluator	Ian Mawditt (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Schools (primary)	Staunton on Wye	Traditional	2010
Floor area (809 m^2 GIA) 652 m^2 main school 157 m^2 pre-school	**Storeys** Single	**EPC / DEC** A (10.4) / N/A	**BREEAM rating** N/A

Purpose of evaluation

The study involved an occupant survey, a thermographic survey, energy analysis, electrical energy data logging, heat meter logging, indoor air quality and temperature assessments, semi-structured interviews; and user group reviews.

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

Estimated electricity use: 37.6 kWh/m² per annum GIA (main school: 26.9 kWh/m² GIA and pre-school = 30.6 kWh/m² per annum). Thermal (biomass boiler): 22.9 kWh/m² per annum GIA (calculated from 18.592 kWh per annum quoted). The school utilities are mains electricity and mains water. There is no gas on site. There was a mixed performance for the metering accuracy. The local distribution boards (DB) meters for lighting and power tied up with the BMS however there was is a discrepancy between the total DB metered power and the incoming mains power.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	12	Unknown

Overall, the school was shown to perform well in many of the variables. Perceived health and productivity scored lower, being just above the median. A common complaint was about the lack of storage space. The pre-school staff were unhappy that the heating is controlled by the main school and they think the pre-school is cold. Some spaces suffer from glare from the sun.

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About this document:

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

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

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

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1 Introduction and overview

1.1 Report background - TSB building performance programme

This report presents the findings of a two-year Building Performance Evaluation (BPE) study of Staunton on Wye Primary School in North Herefordshire. It is amongst a wider programme of research, with approximately 100 similar studies led by the Technology Strategy Board (TSB), an agency primarily funded by the government department for Business Innovation and Skills.

The Technology Strategy Board's stated purpose is "*to accelerate economic growth by stimulating and supporting business-led innovation'* (TSB:2013) As part of this mandate, the TSB set up the Building Performance Evaluation Programme in 2010, in order to find innovative solutions to a dual challenge: the UK government's commitment to achieving an 80% reduction in carbon dioxide emissions by 2050 (HM Government, 2010: p23) and the well-known and, alas, significant gap between design predictions and actual performance in new and refurbished buildings constructed in the UK.

The Building Performance Evaluation Programme defined the following aims:

- Assembling a substantial body of comparable data from across the UK in order to draw out wider lessons about the performance of design strategies, construction methods, build processes, modes of operation, and handover techniques; and aiming to identify potential innovations and improved processes, which can narrow the gap between theory and practice.

- Helping the construction industry to improve the performance and efficiency of buildings, thus making it more likely for the government to be able to adhere to its commitments to cut emissions, whilst also stimulating competition in the industry.

Building capacity and knowledge in the UK construction industry in the field of building performance evaluation. The TSB has funded a number of companies to undertake case studies on buildings which they have designed, built, own and/ or operate, using a common set of tools and protocols. Case studies were funded where there seemed to be a potential for obtaining useful insights into innovative methods, techniques or processes. Undertaking such studies generates benefits for the companies involved. Indeed, the TSB's aim of building capacity entails the up-skilling of UK industry, thus enhancing its global competitiveness.

1.2 Executive summary

Key findings of this two year study are as outlined below:

- The process of Post Occupancy Evaluation – which aided a ‘soft landing’ into building use, was valuable to the building users, and enabled a number of ‘teething problems’ to be overcome.

- Getting adequate indoor air quality in a school classroom with Natural Ventilation requires pro-active intervention by the teacher, especially during winter months. CO2 monitors have proved valuable as a prompt to the teachers, a ‘traffic light’ system would have been a good idea in the initial design.

- Straight forward, accessible Building User Guides are useful tools in aiding effective use of the building; the study found that a simple, one sheet, illustrated guide in each room was most effective.

- A longer commissioning period would have been beneficial, before completion to iron out problems with the services in the school. A secondary ‘off season’ re-commissioning post completion would also be a good idea in future projects.

- A robust metering strategy is necessary to review energy use within a building, and together with an assessment tool such as a TM22, is useful in analysing energy by use and making interventions where necessary.

- TM22 methodology is dependent on good metering data and/or accurate assumption for equipment loads and usage profiles and these can honed with greater experience and understanding of the process. TM22 training is essential in setting up an accurate TM22.

1.3 Report structure

The report is structured into 9 chapters and there are a set of appendices attached to the end of this report.

Chapter 1 introduces the report, the original brief and a summary of the methodologies used. The introduction also summarises any alteration from the original brief.

Chapter 2 and 3 discuss the building, design and performance of the building.

Chapter 4 and 5 discuss the building in-use. The occupants were surveyed to establish their views on the building; and a walkthrough of the building was undertaken by the BPE team and certain elements of the building were investigated with a critical eye.

Chapter 6 looks at the in-use energy performance of the school and evaluated it using TM22 methodology. The results are compared to existing benchmarks for similar buildings and design predictions.

Chapter 7 looks at the technical issues at the school and these have been reviewed in detail. Many of the recommendations have led to interventions by the school and the BPE team to improve the performance of the building.

Chapter 8 and 9 provide key messages to the school stakeholders along with wider lessons learned for future projects and the industry in general.

1.4 TSB brief, Original programme and interventions

The original proposal for this study outlined that:

> *Staunton School will be able to provide a wide ranging monitoring programme which will cover a number of the key aspects of school environment and energy design. The size of the school, with 3 main classrooms in the same south facing cluster, and the excellent staff and student commitment to energy reduction and environmental awareness, will allow a number of environmental monitoring programmes to be followed effectively and quickly, and allow quick feedback into any operational changes that may be required during the 24-month programme.*
>
> *This study would give an in depth understanding of how this design compares with other schools of a similar type but with different approaches. The choice between wholly natural ventilation, mixed mode, and MVHR systems is being debated throughout the industry, and we believe that the information and feedback from the Staunton School programme will be valuable to the debate. We would like to see this school as part of the overall mix of schools studied as part of this application phase, including where possible a comparison to Passivhaus type school buildings which are on site and now soon due for completion (and being delivered by the same design team and contractor).*
>
> *The scale of Staunton School will allow us to study a range of environmental and energy parameters in the building. The work will focus on the three main classrooms to the south of the building, and allow us to carry out a range of detailed studies, all linked into the overall programme. The integration of the work into the school curriculum will provide an link between the BPE research and the improvements to the understanding and operation of the building.*

The following studies were proposed as part of this TSB project

1. *BPE programme, assessing internal environment, comfort, and performance. Logging to include temperature, relative humidity and CO2.*

This has been done throughout the two years of the study with robust data being accumulated, this is summarised in chapter 7.6, with additional reports in the appendices

2. *Energy assessment, using TM22, for the whole building.*

Again, successfully undertaken throughout the study and reported on in chapter 6.4, 6.5 and in the appendices.

3. *Specific energy assessment of the biomass boiler installation, to include fuel and system efficiency.*

This is addressed in chapter 7.2

4. *A study of the school's use of natural materials.to investigate the benefits of a breathing construction on internal environment, testing for the control of VOCs, relative humidity and temperature. This will involve a study of hygroscopic materials in the building.*

The positive effects of the natural materials used in the design are reported on in a number of areas of this study. Testing for VOCs was not included in the study as the necessary equipment or expertise were not available and seemed too cost prohibitive to the team; there was also an assumption that the level of VOCs present in the indoor environment would be low due to the materials and finishes specified. There was an avenue of study started on the hygroscopic materials, and their positive impact on controlling relative humidity levels, however, this was abandoned due to difficulty in drawing any reliable conclusions; this is expanded on in chapter 7.

5. *Thermal imaging/material assessment, to assess insulation performance and air leakage.*

A thorough thermal imaging survey was undertaken as part of this study, and the results are summarised in chapter 5.5, the full report is in the appendices.

6. *Beneficial solar gain, overheating and external landscape heat input, using temperature, thermal imaging and solar sensors.*

The overheating potential has been monitored through the temperature and humidity logging as reported in chapter 7.6; this is also brought up as part of the forensic walkthrough (5.4), and the Occupant Survey (chapter 4)

7. *Management and maintenance monitoring programme, with detailed logging of inputs and results of inputs.*

The Management and Maintenance of the school have been closely monitored throughout the project, and reported on regularly through various reports and minutes of regular meetings with the Head Teacher; some key inputs implemented by this study in this area are the production of 'user friendly user guides', as reported on in chapter 5.6, and alterations to the BMS and heat metering, as reported on in chapter 7.1 & 7.2.

The original program for the study was a 24 month period. This was extended due to various delays and pressures on the research team to a 28 month study period.

1.5 Methodology

This report has tried to add to the body of knowledge in this relatively new field and has been a multi- disciplinary task, requiring the development of new approaches. The following techniques and primary data sources were used:

- Building User Survey Methodology (analysis by Arup);
- Thermographic Survey;
- TM22 Energy Analysis Tool;
- Electrical energy data logging;
- Heat meter data logging;
- Gas and Electrical Utilities bills and historical meter readings;
- Indoor Air Quality & temperature data logging;
- Forensic walk through;
- Semi structured interviews;
- User group reviews;

Wherever possible, best endeavors were made to ensure the accuracy of information however, this new field of study and therefore some inaccuracies may exist due to unreliable equipment, calibration problems and or human error. Further data and details of methodologies can be found in the appendices.

2 Details of the building, design, and delivery

2.1 Site and location

The school is located in Staunton on Wye, a small rural village off the A438 between Hereford and Hay on Wye. The site was previously a 1.5 hectare arable field. The site is bounded to the north by a public footpath (Coffin Path) and Scar Lane. A mixed hedgerow delineates the east boundary and there are seven adjoining properties whose gardens extend to meet the edge of the site. The A438 runs along the southern boundary of the site. The west boundary is marked by fencing with an agricultural field beyond. The site is completely open to the South aspect.

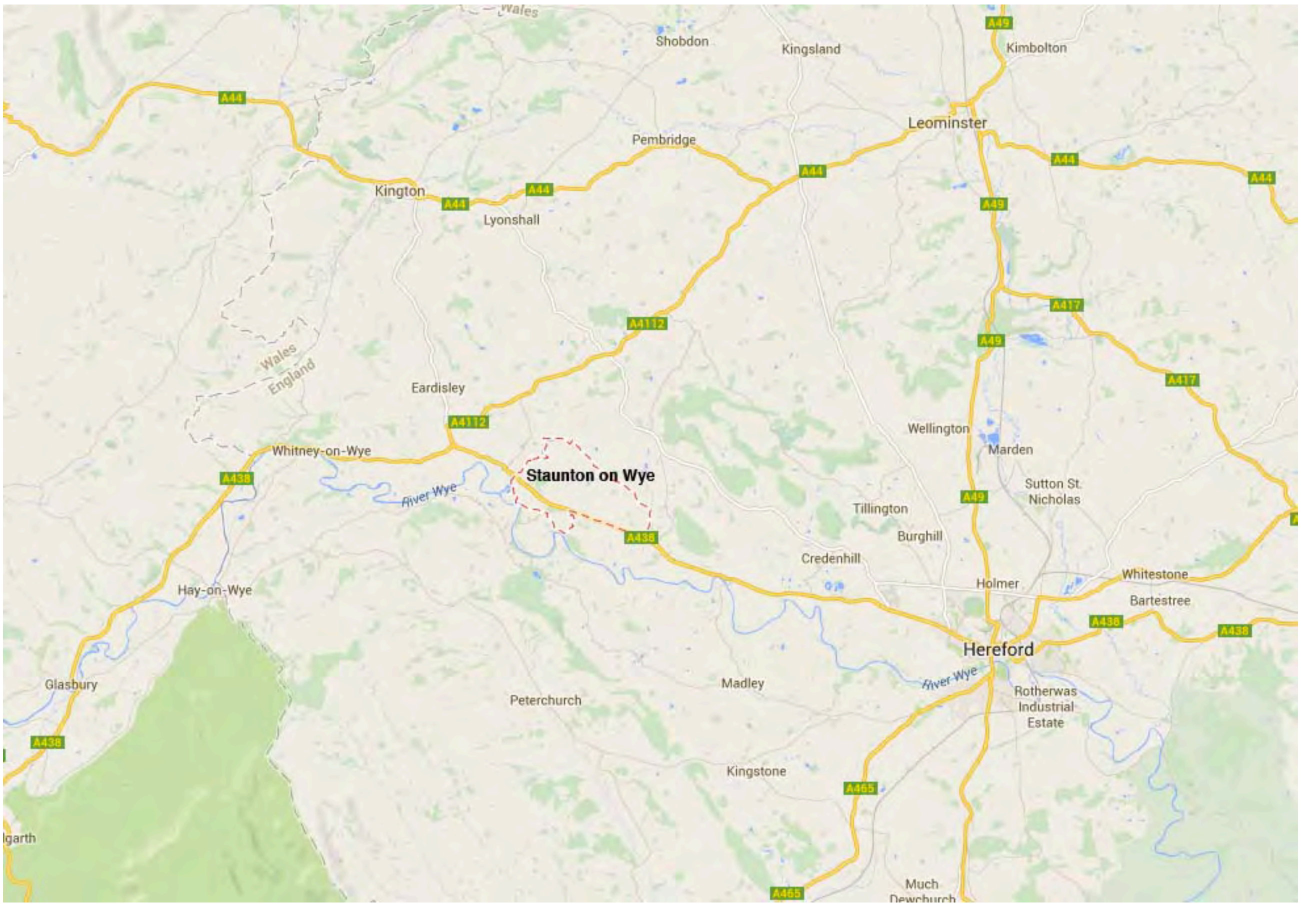


Figure 2.1.1 Site Location, from Google maps

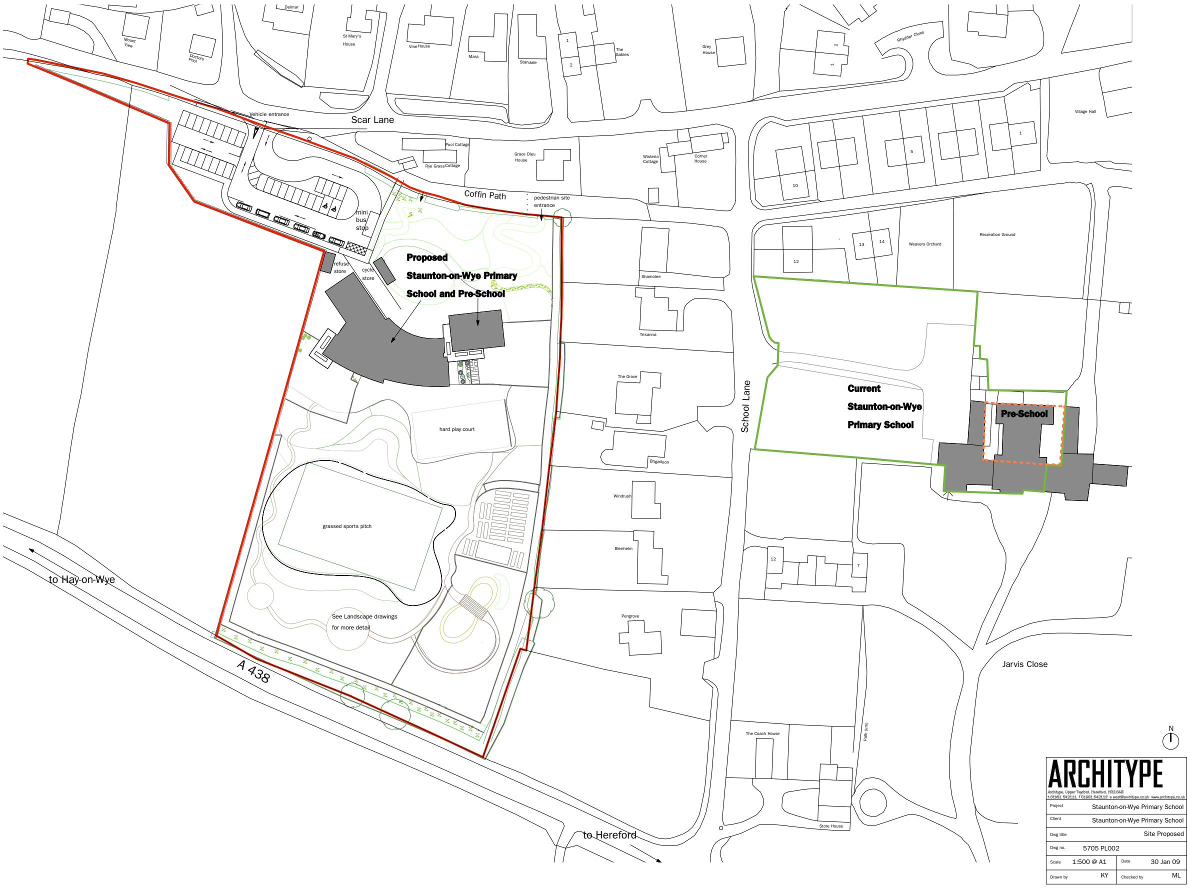


Figure 2.1.2 Site plan showing new school on the Left and the old highlighted on the Right

Figure 2.1.3 View of the Site looking north, pre-commencement

Figure 2.1.4 View of the Site looking south, pre-commencement

2.2 Background

Staunton-on-Wye Endowed Primary School is a Voluntary Aided School originally built as a charity school a hundred years ago. The School has around 85 pupils on its role, the privately run nursery which uses part of the school building has 22 places. The new school building was opened in 2010, relocating the school from a three storey Listed Victorian building located on a nearby site in the small rural village.

Figure 2.2.1 The New School Building

Staunton-on-Wye primary school is a small school with a real and caring community. The school is very proud of its green credentials and was committed to creating a new school that was not only user friendly and sustainable but could also be used as a learning tool for the children. The brief was for a new three classroom school for 90 pupils with an adjoining pre-school facility providing 26 places. The new primary school was part funded by the Department for Children, Schools and Families, with the Pre-School being independently funded.

The old school occupied a third of a Listed Victorian building. It was seriously inadequate for the provision of 21st Century education. The classrooms were arranged vertically over three floors and there was no lift or opportunity to locate one. The old school premises failed to meet disabled access standards. Ventilation was poor and day lighting was below the Department of Education & Skills guidance levels.

The design team for the new school was selected through an Open Invitation to Tender submission, and subsequent interview; the experience of the design team in delivering low energy, sustainable Primary school buildings, in similar rural locations, was one of the key factors in them being selected.

The Main contract was let through an invited tender list as a traditional JCT building contract with the Architects as contract administrator.

During the construction of the building the electrical contractor went into administration during the commissioning stage which had knock on effects at a crucial time. A new electrical contractor was brought in to commission the work which was difficult as they were no fully up to speed with the design.

Following the handover, and during the defects period, the mechanical subcontractor went into administration which raised some difficulties. However, by this stage most defects had been rectified.

Figure 2.2.2 The Old School Building (the school occupied one half with the rest being unused)

2.3 Building summary

Building type

The new school is a single storey building with a timber framed principle structure. Externally, the building is clad in a simple and robust palette of natural materials, including: local stone, timber cladding, timber windows & doors, green roofs externally
timber screens, natural linoleum, and organic paints and stains, internally

Figure 2.3.1 The School from the South

These materials along with good day lighting and ventilation should help create a healthy, vibrant and humane environment that supports and enhances teaching and learning. The materials, detailing and language of the architecture is intended to deliver a contemporary building, which is designed specifically for its purpose and to fit comfortably within the landscape.

The roofs have generous overhangs which link with traditional architecture and give the building an open and welcoming feeling. The location and size of windows has a playful feeling expressing how the internal spaces are to be used, such as low level windows in Class One. The internal glazed screens to the classrooms have been considered in that they provide somebody looking in with a view of the activity taking place in the class but do not distract the children within.

The primary structure and the roof structure are timber - a timber building clad in timber. The north elevation is clad in a locally sourced stone. Timber was chosen for use on this project for its sustainability credentials (low embodied energy, stored CO_2) and for the warm and friendly feeling that can be created with timber architecture. The building was designed to be a highly efficient, low energy, low water use, naturally ventilated, healthy and comfortable school.

Layout

The main considerations when developing the internal layout of the school were the school's needs, and environmental strategies articulated in sections and plans. More specifically, the school was designed to be 'passive' (though not Passivhaus) and make the most of the building orientation for beneficial solar gain in the winter, and minimise solar gain in the summer, supported by an effective natural ventilation strategy.

The circulation is simple and legible. From the main entrance it is possible to see right through the school to the landscape beyond. There is a central zone that everything is connected from. Within the zone it is possible to see out of the building to the east and west.

Figure 2.3.2 Ground Floor Plan

The accommodation consists of:

A clear welcoming entrance sheltered by the roof overhang and protected by an airlock. The school office is adjacent to the entrance and allows for observation of all visitors entering the site. The entrance area opens into the central space from where all of the spaces are accessed. An open plan library space can also form an area for visitors to wait or breakout space for a performance in the hall.

The head teacher's office is located next to the school office for ease of communication. The staffroom is on the south side allowing the staff to observe the playground. Adjacent are the shared facilities including stores and a Special Education Needs/music room.

Staunton-on-Wye have their school meals delivered by van daily. The kitchen is therefore of a domestic scale easily and accessible from the outside. The kitchen acts as a servery area at lunch times, allows for the teaching of food technology in groups and provides some catering facilities for the hall when used for private functions.

The classrooms are all south facing, with overhangs providing shading in the summer, reducing solar gain which can cause overheating. The overhang is sized to maximise the beneficial winter solar gain, when the sun is lower in the sky throughout the day. The north side of the classrooms have high-level clerestory windows to encourage natural cross ventilation when the low level glazing is also open.

The rising and setting sun is lower om the sky to the east and west and passes across the window at an angle making it much harder to shade. Through consultation the design team learnt about Staunton's style of teaching, often dividing the mixed aged classes into groups. With this in mind we allocated each class their own group room with Classes 2 and 3 having adjacent group rooms with the possibility of opening them up to create one larger space. The classroom is shaped to create shaded areas for the whiteboard and an intimate corner lit by clerestory glazing for small group activities.

Class One is positioned away from the pre-school to provide acoustic separation when the youngest children are playing outside. They have their own toilets, cloaks, group room and space for their play loft. A separate timber canopy is accessed directly from the classroom and provides covered outdoor play space.

The pre-school is located on the east side of the site to maximise the exposure to the warm morning sun and benefitting from the solar heat gain. The pre-school is connected to school by a covered link which also provides a place for sheltered buggy storage. The pre-school is organised to have its own entrance to minimise disruption to school by the differing drop-off and pick-up times. From the lobby area both of the play spaces can be accessed. The two play rooms can operate independently when a toddler or community group is taking place or sliding doors open the space up into one. The kitchen is accessible from both rooms for the preparation of refreshments. The office is located on the south-east corner to allow observation of the playroom and the outdoor play area. The south playroom has sliding doors, which open onto a designated play space, covered and open. The room is flooded with natural light from the doors, high-level glazing above and roof lights.

Daylighting strategy

Daylighting analysis results, and the targets for the levels of daylight to the spaces are outlined in the M&E Stage D report contained in the appendices. The targets were based on British Standard 8206 Part 2, Building Bulletin 87: Guidelines for environmental design in schools, and also the requirements to satisfy the daylighting credits for BREEAM (HW01). These are summarised below:

- BS 8206 advises that if electric lighting is to be used during the day the daylight factor should not be less than 2%. An average daylight factor of 5% or more will ensure that an interior looks substantially daylit.

- BB87 guidelines suggest a space is likely to be considered well daylit if there is an average daylight factor of 4-5%.
- BREEAM credit Hea01 "Daylighting": One credit is awarded if 80% of occupied spaces achieve an average daylight factor exceeding 2%. Two credits are awarded if 80% of occupied spaces exceed an average daylight factor of 4% (for single storey buildings) and 3% (for multiple storey buildings).

For the purposes of design, a minimum daylight factor of 2% was required in all spaces, with a desire to achieve a target of 4%.

The average daylight factors for most of the analysed spaces (classrooms and hall) were all well above the required level of 4% at design stage while other spaces are just below the required level.
The BREEAM report included in the appendices shows that both credits were awarded for daylighting.

Ventilation

The building was designed to provide natural ventilation to the all of the spaces using openable windows and vents; In the early design stage there was discussions around making the building Passivhaus, and using MVHR to ventilate the building. This was ruled out at RIBA Stage D due to Value Engineering and uncertainty around Passivhaus design from the design team and the client – this was before Passivhaus expertise had been developed by the design team, and it was considered it was too risky to commit to at the time. It was, however, decided to leave in dropped bulkheads to each of the classrooms, to provide future provision for installing mechanical ventilation if there was a future desire for retrofit.

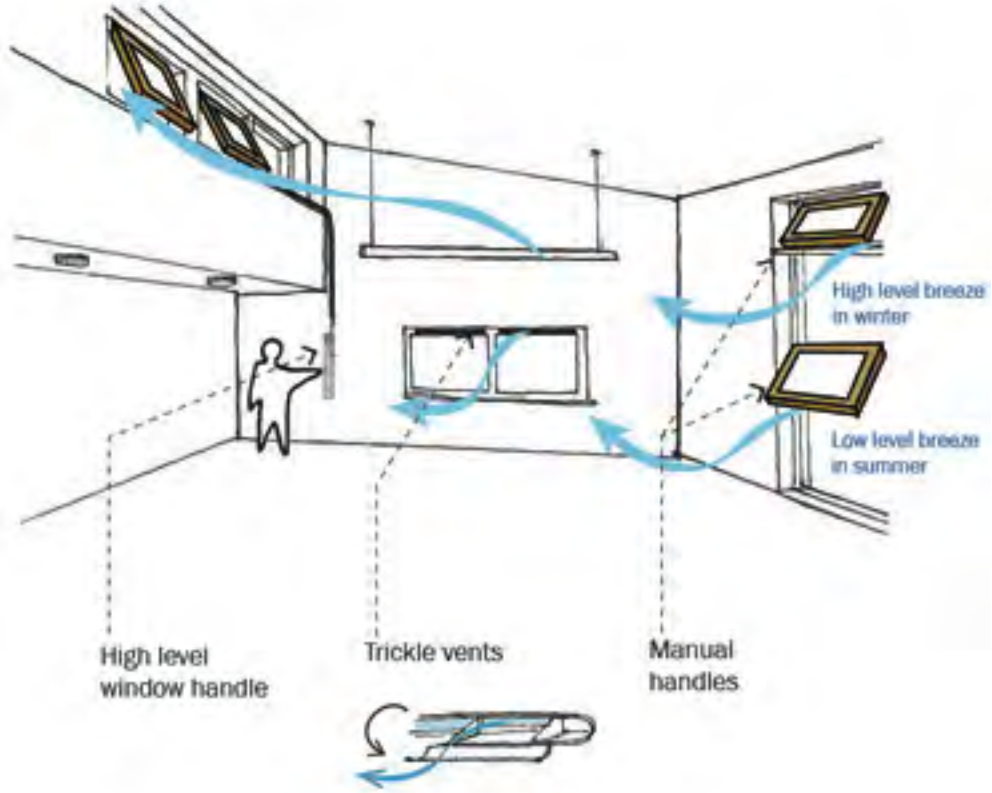


Figure 2.3.3 Natural Ventilation diagram from Classroom User Guide (produced as part of BPE & reported in chapter 4.5)

Access

The schools' rural location dictates that it is not accessible by public transport. Most of the pupils come from within the village meaning that pedestrian and cycle access is common. All other access is by car so there is a generous car park and drop off area with separate pedestrian and cycle access. There is covered cycle storage available. The cycle racks are set back from the pedestrian route sufficiently to avoid being a trip hazard. All pedestrian routes onto the site are level with the surrounding highways pavements and have suitable way finding and visually contrasting markers with associated change of surface texture to signify entrance. All pedestrian routes are 2000mm minimum width with a cross gradient no greater than 1:40 and a running gradient no greater than 1:20. Exterior lighting provides even illuminance of the site.

All entrances provide a level threshold. Clear entrance signing and way marking strategies clearly signify the main entrance. The entrance is free of any obstructions.

Figure 2.3.4 Access to the main entrance (Pre-school on Left, Main school on Right)

A roof overhang provides inclement weather protection at the main entrance. The entrance comprises double glazed swing doors with a clear width of 1650mm. The glazed elements display manifestations and visual contrast strips for clarification of presence. All entrance and threshold treatments comply with App. Doc M. Circulation. All horizontal circulation routes are 1800mm minimum width with larger open spaces at junctions.

Sustainable design & materials

The building was designed using 'fabric first' principles. The external fabric of the building is highly insulated with good air-tightness and minimal cold bridging to reduce heat losses and therefore minimise the heat input requirement to create a comfortable low energy building. The windows are low E glazing triple glazed, with solar control to balance heat losses and heat gains. The construction details included below outline the general principles of the build, including levels of insulation, materials, and thermal bridge reduction.

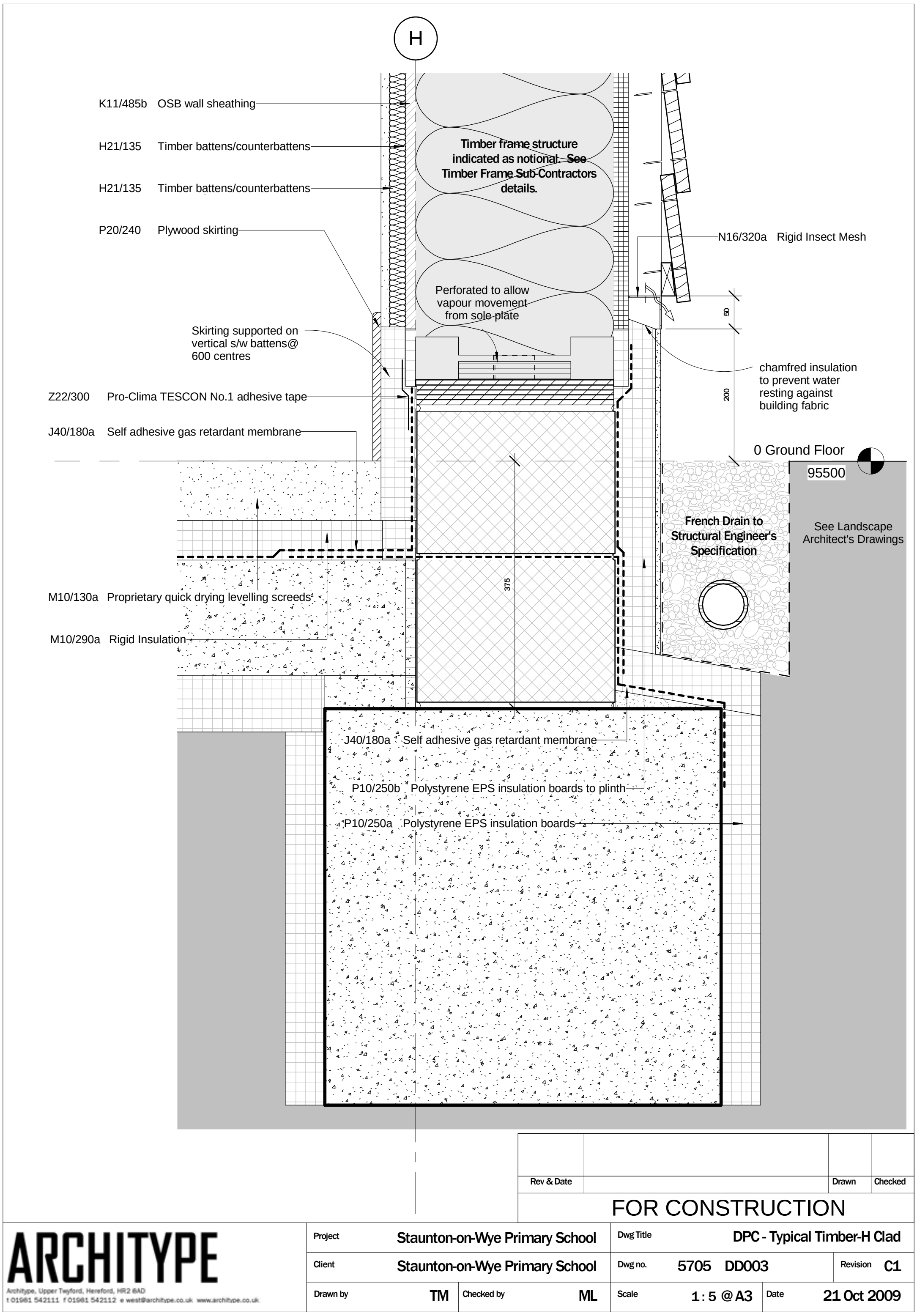
To summarise the key elements of the sustainable design approach:

- High levels of insulation
- Wall U Value = 0.12
- Roof U Value = 0.10
- Glazing U Value = 1.00
- Roof-lights U Value = 1.40
- Good airtightness
- Air permeability of 1.34 m^3 / m^2.hr @ 50 Pa
- Minimal thermal bridging
- Glazing to maximise day lighting to reduce artificial lighting requirement
- Good surface area to volume ratio
- Naturally ventilated
- Zoned under floor heating to suit the operational requirements of the school
- Low water use fittings
- Natural materials, where possible locally sourced to reduce embodied energy from transportation.

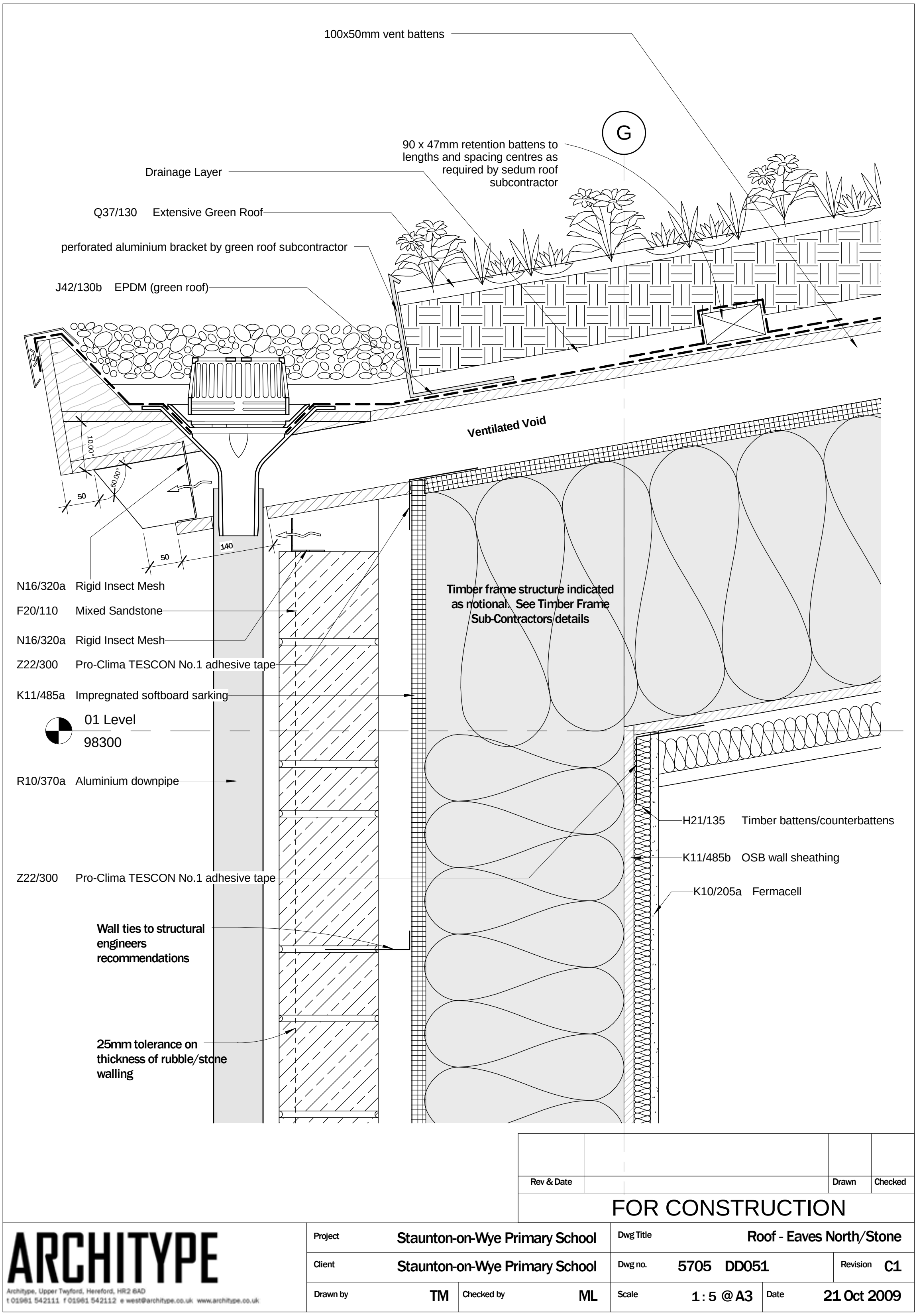
Typical construction details

•External wall: 36mm timber, 75mm cavity, 22mm timber, 302mm Warmcel insulation (recycled newspaper), 15mm plywood, 25mm cavity, 13mm Fermacell. U value = 0.12 W/

•Ground floor: 85mm rigid insulation, 175mm concrete, 65mm rigid insulation, 85mm screed. U value = 0.125 $W/m^2.K$



• Roof: 100mm soil, 0.5mm EPDM, 18mm timber board, 100mm cavity, 22mm plywood, 400mm Warmcel insulation, 15mm plywood, 75mm cavity, 13mm Fermacell. U value = 0.10 W/m^{2}K



2.4 Performance targeting and modelling

The building performance was designed to meet Building Regulations Part L 2006. The Buildings fabric was developed using passive design principles to reduce the reliance on mechanical and electrical systems and exceeded the targets set in Part L. The systems design, particularly the heating with Biomass, helps the building achieve a low kgCO2 / m^2. year against the notional building modelled in SBEM.

Analysis was completed using software called Virtual Environment by Integrated Environmental Solutions (IES). This allows the analysis of the thermal performance, daylighting and energy for an accurate 3D model.

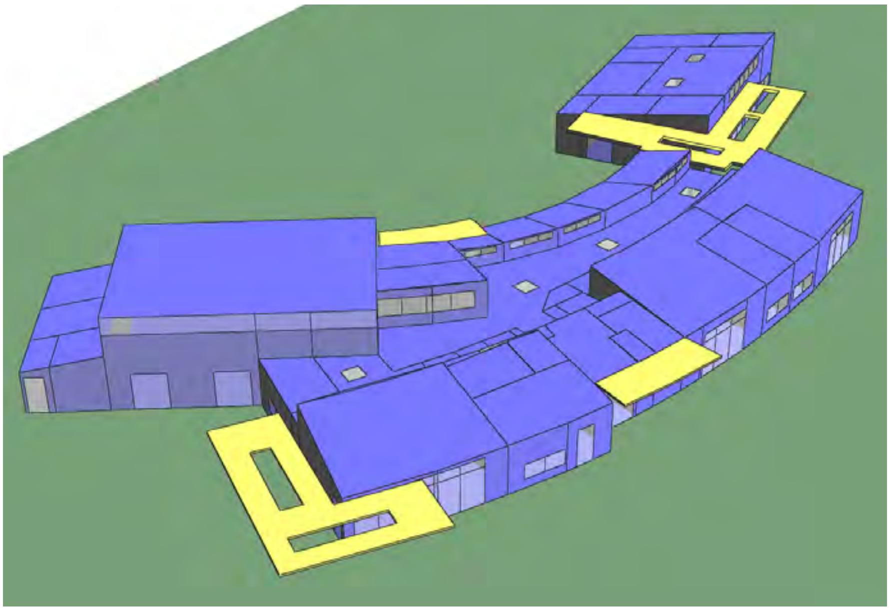


Figure 2.4.1 Isometric view of the IES model

Design Target U-Values

Construction	U-value W / m^2.K
External Walls	0.12
External Floors	0.125
Roof	0.10
Glazing	1 (G-value = 0.56)
Rooflights	1.4 (G-value = 0.56)

Air Infiltration

The building was designed to passive design principles and calls for an air infiltration of 0.6 m^3/hr.m^2, or better, and was used as the design target for the building analysis.

Part L Energy Compliance Analysis

IESVE provides an estimation of the annual energy consumption for the building using the National Calculation Methodology (NCM) data used to predict the CO2 Building Emission Rate (BER) for the actual building and Target Emission Rate (TER) based on a notional building. This analysis is used to demonstrate compliance with Part L in terms of the energy efficiency of the building.

	Notional Building	**Target Building (TER)**	**Actual Building (BER)**
Carbon Emissions kg CO_2 / m^2	**31.4**	**24**	**10.4**

The results of the Part L compliance are discussed in more detail in chapter 6. A copy of the BRUKL document can be seen in the appendices.

Daylighting Analysis

The minimum daylight factor in all spaces was 2%, with a target of 4%.

Analysis was completed using IES FluxDL.

Overheating Analysis

The design targets for overheating were set according to school Building Bulletins (BB) BB87 and BB101.

- The requirement under BB87, Guidelines for Environmental Design in Schools, recommends that the number of hours exceeding 28°C may occur for up to 80 occupied hours in a year.

- The requirements under BB101 for overheating recommends that the air temperature should not exceed 28°C for more than 120 occupied hours each year. None of those hours should exceed 32°C.

Analysis was completed using IES Apache and achieved better figures than the targets.

3 Review of building services and energy systems.

3.1 Introduction

This chapter gives an overall review of the installed building services in the school by discipline i.e. heating, ventilation, water, lighting, power, controls and utilities. This can be quickly summarised as follows:

The school is divided into two buildings; the main school and pre-school. It has been built to a high level of airtightness and has a highly insulated thermal envelope. This fabric first approach reduces the reliance on building services and minimises overall energy consumption. The services are low energy and low carbon, such as a biomass boiler and underfloor heating. The school is naturally ventilated through high and low level opening windows. The school's kitchen use is very low and school dinners are brought in by external caterers. The school has a Building Management System (BMS) to control the heating and monitor the systems and energy use. Each distribution board (DB) is metered by power and lighting.

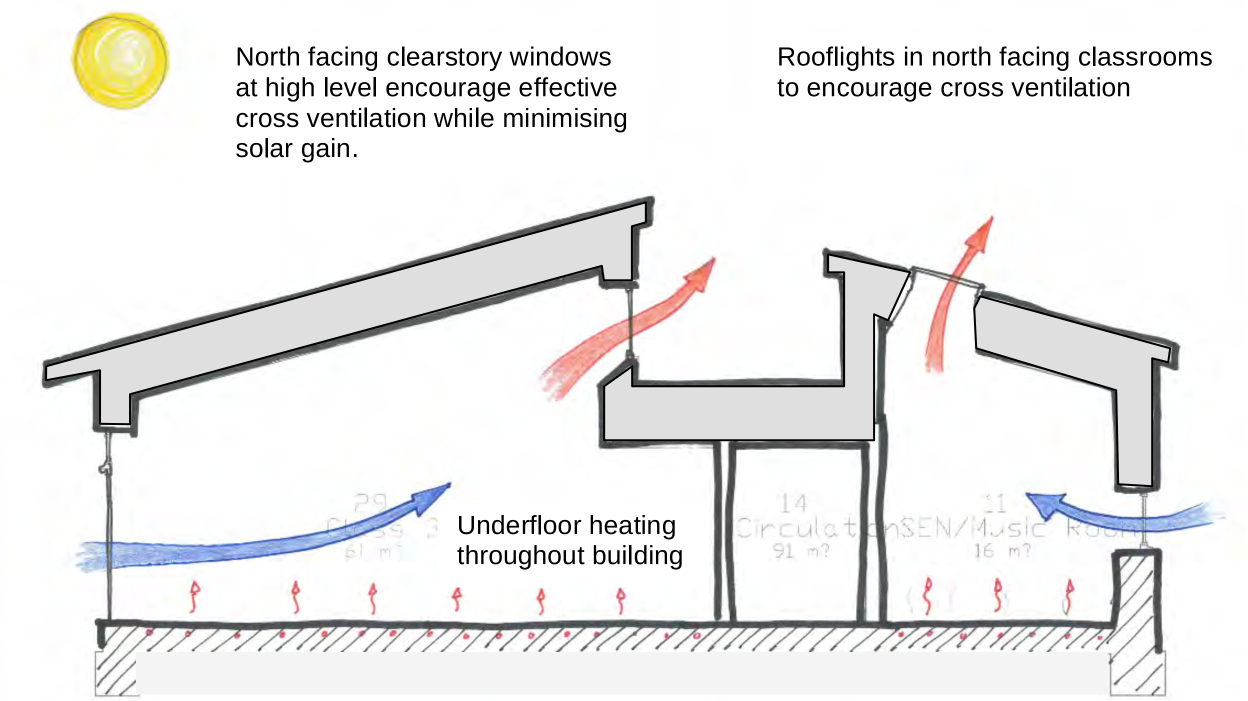


Figure 3.1.1 Strategy diagram for heating and ventilation through a typical section through the school.

The school was designed to exceed the requirements of Building Regulation Part L 2006 and Building Bulletins.

Each chapter is concluded with a discussion of the key findings.

3.2 Heating

The school's primary source of heat is from a Froling 48kW biomass boiler with a 2,200 litre heat storage buffer tank. Biomass heating was selected as the town is off the gas network and energy grants made the biomass a viable financial option with a reasonable payback.

The boiler charges the buffer tank and the heating is circulated around the buildings to each heating manifold and heat emitter. The intention of charging the buffer vessel is to reduce cycling of the biomass boiler, improving the overall efficiency of the system and reduce wear and thus maintenance. The heating system is controlled through the BMS and has been commissioned for all seasons. The room temperature set points and time clocks have been set up in the BMS according to the head teachers preferences.

During the initial discussion of the heating operation with the headteacher, it was found that the classroom heating setpoints were set to achieve 18^{o}C for the beginnning of the school day i.e. 8:30am, and turn off at 11am. The headteacher was satisfied with an uncontrolled temperature after 11am as the main school classrooms held in heat very well over the remainder of the day. The headteacher manually turned off the boiler over the holidays and outside of the heating season.

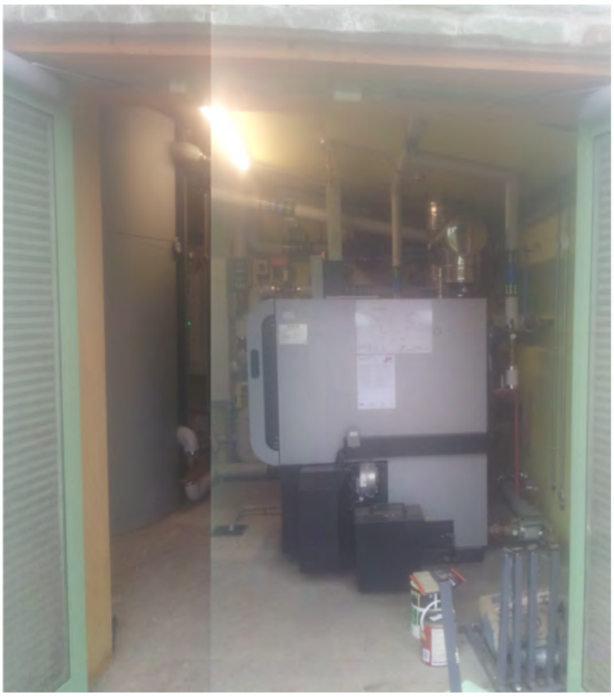


Figure 3.2.1 Image of biomass boiler and buffer vessel in plantroom

The main heating system is underfloor heating which serves both the main school and pre-school. Some spaces have radiators to supplement the heat output which are also controlled on the underfloor system i.e. no local thermostatic radiator valves (TRV). All the spaces with underfloor heating have a room temperature sensor which is linked to the BMS and the set points can be adjusted on the BMS. There are locally controlled thermostats in each room which can adjust the temperature within a dead-band set at the BMS, typically +/- 3^{o}C.

The intention for the heating controls was to allow the BMS operator i.e. the head teacher, to have full control over the room temperature set points and time-clock settings in each space. Local wall thermostat are in each room to give the teachers some control, but only to a limited extent. The design intention for the heating plant was to remain under the control of the BMS throughout the year to optimise comfort and efficiency, and also provide frost protection to the building and plant. The headteacher manually turned off the boiler outside of the heating season, which is subjective, and also meant the building could not react to cold snaps.

As part of the BPE process additional metering and control has been installed to;

1. Examine the efficiency of the biomass heating system, and;
2. To allow the pre-school separate control of heating set points and time-clock settings as it has different needs to the main school.

The BMS controlled the heating for the whole school and was solely under the headteachers control, with the preschool having to ask if they wanted the heating on outside of the main school heating hours. The biomass alone was metered and the heating bills were divided on an area prorata basis between the main school and preschool. This meant the headteacher was relunctant to turn on the heating for the preschool as the main schools heating bills would also go up. The preschool would have benefitted from having seperate metering and control from the main school. However, this was not in the the design brief and not brought to the attention of

A heat meter was installed on the heating branch serving the pre-school as part of the BPE to allow separate control and to accurately monitor the energy use in kWh. This also allowed the preschool to pay for their actual kWh energy use rather than pro rata based on area as before.

Figure 3.2.2 Image of pre-school controller installed in pre-school store as part of the BMS modifcations intervention.

The heating generally worked well in the main school, achieving the setpoints and having very low running costs. However, it was apparent that the preschool were not happy with the lack of control and found the the preschool building setpoints too cold.

There were also a couple of rooms in the north of the main building that were cold and was simply a case of the setpoints not being setup correctly.
the design team at any stage before handover of the building. Additional metering and control was installed later as part of the BPE.

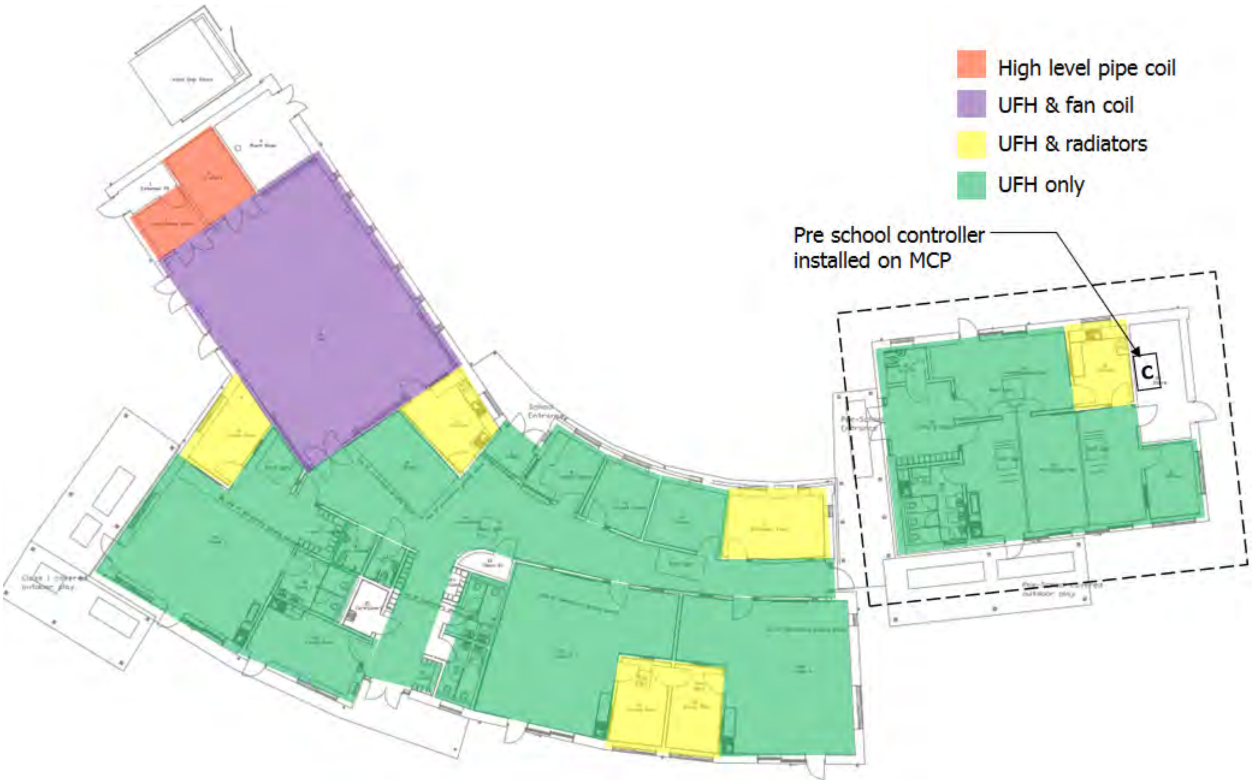


Figure 3.2.3 Zone diagram of heating zones within the school. Generally all underfloor heating with some areas having additional heating emitters.

3.3 Ventilation

The school uses natural ventilation via opening windows for cooling and ventilation in the main occupied areas i.e. classrooms, group rooms, hall, library. Cross ventilation of each space is encouraged by openings on both sides of the room i.e. glazing/doors on south elevation and clearstory glazing on north elevation, manual controlled by Teleflex winding mechanism.

Figure 3.3.1 Typical classroom ventilation with high level clearstory lighting and openable doors and window. Clearstory windows are opened using teleflex opener, which can just be seen on the far wall below the clearstory windows.

Extract ventilation is via zoned fans and is used in the WC areas. These are controlled on presence detection with overrun timer. The fan's time controls have been set so that they only operate during occupied periods and are off at night.

There are cooker hoods in the main school and pre-school kitchen which are manually controlled.

The ventilation of the school has shown to be effective and no complaints have been raised by the school due to overheating or poor air quality. However, the air quality has been raised as a potential concern as part of the BPE and is discussed in chapter 7.The school was initially designed to use mechanical ventilation heat recovery (MVHR) but this was taken out of the scheme at design stage as part of a value engineering exercise.

Figure 3.3.2 Zone diagram of ventilation zones within the school. The main ventilation strategy is natural ventilation vis openable windows. WC areas and kitchen areas have a decentralised extract ventilation.

3.4 Water

The school's water supply is mains fed from the road which is divided to serve each building. The mains cold water is distributed around the school in insulated pipework
Domestic hot water is supplied by point of use water heaters. One 75 litre point of use electric water heater is in the main school and another one in the pre-school. Each water heater has time clock control which is generally set to operate 24 hours and has a local isolation switch. The main pipe run is trace heated and can be isolated manually adjacent to the water heaters. The water heater and trace heating are generally turned off manually during school holidays by the caretaker, although on one visit it was found that the trace heating had been left on over the summer and was heating the water in the pipe to its design temperature.

There are four 10 litre electric point of use water heaters used locally in the two kitchens and in two of the main school classrooms. Each water heater has time clock control which is generally set to operate 24 hours, and a local isolation switch. These are not trace heated as the pipework runs are very short.

Decentralised electric hot water was the best approach for the school as it was not viable to generate hot water using the biomass boiler to heat water due to its load profile and the generally low hot water demand and distribution distances. A possible consideration to improve the energy efficiency of the hot water would be to reduce the amount of trace heating tape by minimising pipework distribution lengths

Figure 3.4.1 Zone diagram of hot water zones in the school. Each building has a variety of water heaters and there is one central point of use water heater with temperature maintnence tape in each building.

3.5 Lighting

The main school uses several lighting control systems:

1. Daylight dimming in the classrooms Lighting is provided by linear fluorescent suspended fittings with ballast.

2. Presence detection (PIR) has generally been applied to stores and WCs. It was also applied to the circulation areas, which are generally lit by recessed downlighters but have since been modified to be manual on/off. This was following feedback from the school saying that the lights would come on unnecessarily and would be on for most of the day when not needed.

3. Manual on/off with dimming in the staffroom controlled with a momentary switch.

4. The majority of spaces with in the buildings are manual on/off. The hall lighting is on suspended luminaires with manual on/off.

The pre-school lighting is linear recessed in the occupied rooms, surface mounted linear fluorescent fittings in the WCs and surface fixed IP rated linear fittings in the store.

Figure 3.5.1 Zone diagram of lighting zones within the school. Daylight dimming is used in the classrooms, presence detection in the WCs and stores manual on/off in the remainer of the school.

The external car park lighting consists of pole mounted luminaires which were designed to be on time clock and photocell control. However, the school found that the lights were on when not required e.g. once all the staff had gone home and holidays, and, conversely were not always on when needed e.g. if staff stayed on later and for out of hours use. This control issue is likely to have arisen due to the staff not understanding how the analogue time clock controller worked and was also out of the way in a cupboard in the hall. A simple manual on / timer switch was introduced instead and has proved simple and effective. It is timed to come on for 15 minutes when pushed and is only used when required.

Fig.3.5.2 Car park external light switch installed by the school (right), is an improvement on timeclock system (left)

The pre-school path external lighting is controlled on a time-clock and photocell and the school was considering using a similar approach to the car park lighting.

3.6 Catering, IT and specific processes

In the main school, a PC is located in each office, group room and classroom. The pre-school has a PC in the office and in the classroom. There is also a mobile laptop charging unit complete with laptops.

Fig.3.6.1 Laptop charging unit in corridor.

Electrical appliances in the school are generally manual on/off. It was noted that most of the items were turned off at the wall when not in use which is good practice.

The server room is not operating with a large load so there is no requirement for cooling in the space. A small extract fan ventilates the room when the temperature reaches a set point and can be controlled on a local thermostat.

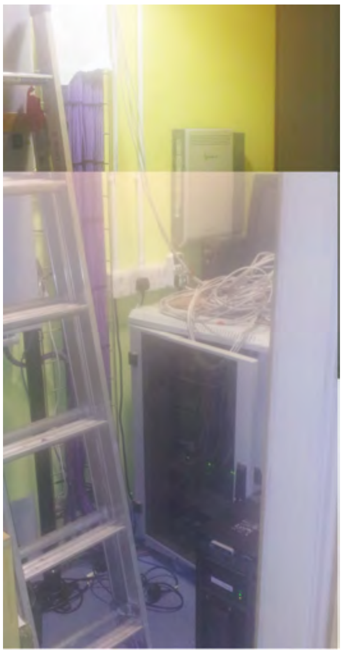


Fig.3.6.2 Server room

There are no large catering facilities in the main school – lunches are delivered and kept warm on hot plates – these are turned off after lunch. There is a small kitchen facility for catering events and food technology lessons.

There are also domestic kitchen appliances in the staff room and in the pre-school kitchen. These consist of a fridge, microwave, toaster and a kettle. With the exception of the fridge, these are turned off at the end of the day.

Catering, IT and other processes can often contribute significantly to a buildings overall power use but the low demand and low intensity of use mean these do not impact on energy use significantly.

3.7 Power

The school's main incoming power comes into the main school plantroom. From here it is distributed to 3no split metered distribution boards located around the school.

The school bought a 10kW PV roof array which was installed following the start of the BPE. This caused some issues initially has it want possible to determine how much of the power generated by the PV the school was using.

3.8 Controls and metering

The school BMS, as manufactured by TREND, control and monitors several of the school's systems.

The BMS can be controlled from the plantroom control panel, the head end PC in the head teacher's classroom and, following the BMS modifications noted in chapter 6.3, limited control in the pre-school.

Fig.3.8.1 Image of control panel BMS readout in plantroom (left) and screen print of BMS head end title screen (right)

The main school head teacher has full control over time and temperature set points in the main school and pre-school. Following the BMS modifications, the pre-school has control over heating set points in the pre-school but can still be overridden by the main school.
The BMS has the ability to control heating set points, monitoring of a number of systems and monitoring of meters installed in the building.

The meters include the following:

- Main heat meter, monitors heat produced by the biomass boiler and for RHI readings.

- Main electricity meter, monitoring main panel electricity consumption.
- 6 no. electricity meters, on 3 distribution boards, monitoring lighting and general power consumption.
- 2 no. water meters, one for the main school and one for the pre-school, for measuring water use.

Additional meters have been installed as part of the BPE and include the following:

- Heating circulation heat meter, metering total heat circulated to both main school and pre-school.
- Pre-school heat meter, metering pre-school circulation only.
- PV meter
- Water heater clip on meters installed on 75 litre POU water heaters (not on BMS)
- Plug in meter on server and head teachers PC (not on BMS)

The school records the meter readings manually on a monthly basis. The BMS is capable of recording 15 minute readings for a period of up to 10 days. The school has not policy to keep the 15 minute readings but these are useful for interrogation of the systems for particular periods such as stand by energy use over holidays and heating loads and building warm-up.

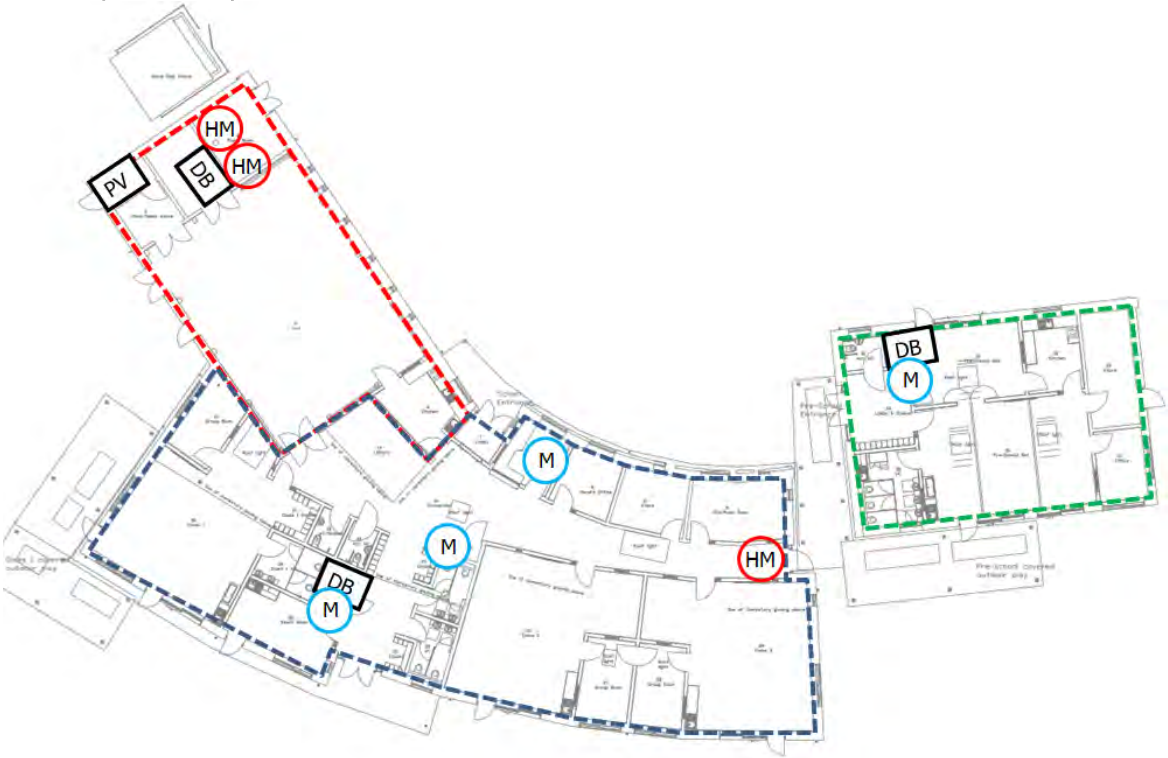


Figure 3.8.2 Layout drawing showing positions of Distribution Boards (DB), PV inverter (PV), Heat Meters (HM) and non BMS meters (M).

The BMS has a good level of functionality and allows the head teacher to control time clocks, set points and view meter readings easily. However, if the equipment running on the BMS is manually turned off e.g. the boiler, issues may arise with equipment downstream such as heating circulation pumps running when a room calls for heating but no heat is available because the boiler is off, and therefore wasting energy.

3.9 Utilities

The school utilities are mains electricity and mains water. There is no gas on site.

The mains incoming electricity is metered by the utility provider (EDF) and distributed to 3no distribution boards, motor control panel, fire alarm panel and security panel.

The mains water is metered by a utilities (Welsh Water) meter at the site boundary. The water pipe then splits on site to serve the main school and pre-school and is sub-metered to each.

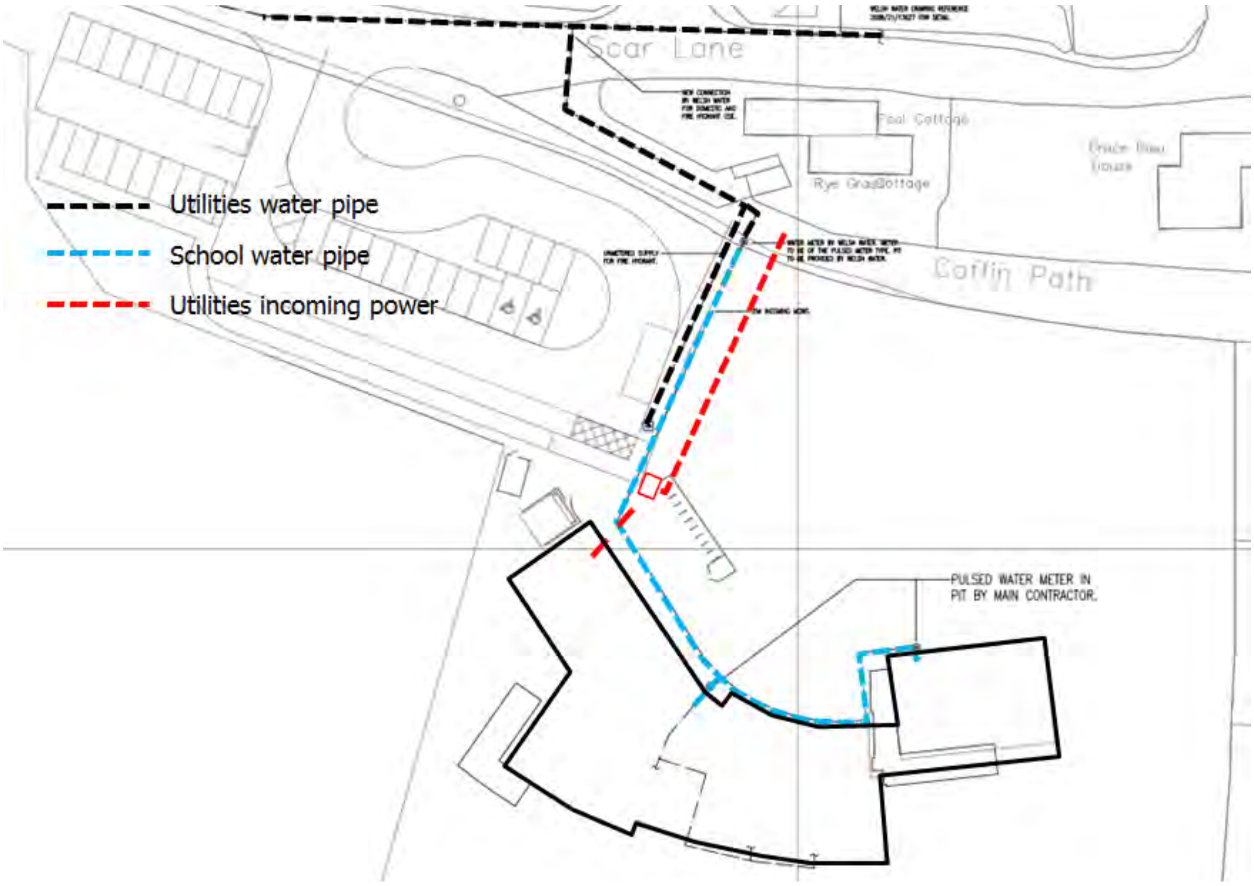


Fig.3.9.1 Site plan detailing incoming utilities to school building.

4 Key findings from Occupant Survey and Forensic Walkthrough

4.1 Introduction

The BUS methodology aims to highlight the occupant's key issues and reveal features that are particularly valued in a building. The methodology was introduced to the team as part of BPE training event which discussed how it works, the survey form and the best techniques for the best survey results.

As part of the BUS, a survey was carried out at Staunton on Wye Endowed School on the 29th June 2012. Twelve staff members individually completed a questionnaire and answered questions concerning the building's image, functionality, the conditions inside the building, and the control over the services.

The survey results were then compiled into a spreadsheet and sent to Arup for evaluation. The results are compared with a benchmark building set from the BUS methodology database and presented in various charts as figure 4.2.1 and 4.2.2
This chapter also reports the findings from the TSB 'forensic walkthrough' (and how this influenced the direction of the study), and the production of more user friendly building guides which has been a key part of the TSB work.

4.2 Overall satisfaction and Comfort

The schools occupant satisfaction was found to be very high from the Building User Survey (BUS) and appeared in the top percentile against similar BUS surveyed buildings as seen in figure 4.2.1.

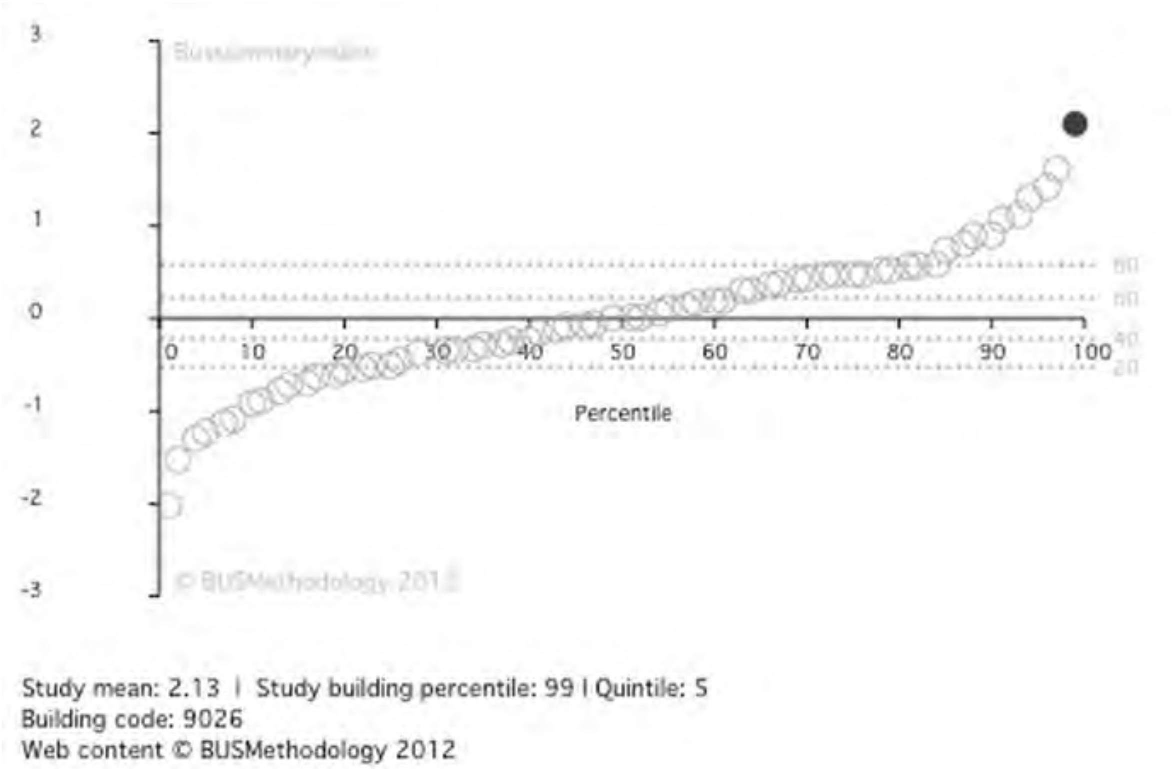


Figure 4.2.1 This chart compares rating of similar buildings using BUS methodology. Staunton school is represented by the black dot, showing the school in the top 99th percentile for schools.

The overall variables summary can be seen in figure 4.2.1 and breakdowns each of the question categories, as described by the staff, and identifies where the building performs well.

Overall, the school was shown to perform well in many of the variables. Health and productivity appeared to perform less well, being just above the median, and this is likely to be related to the heating. However, both of these variables can be seen as subjective and hard to obtain accurate results. See figure 4.2.2.

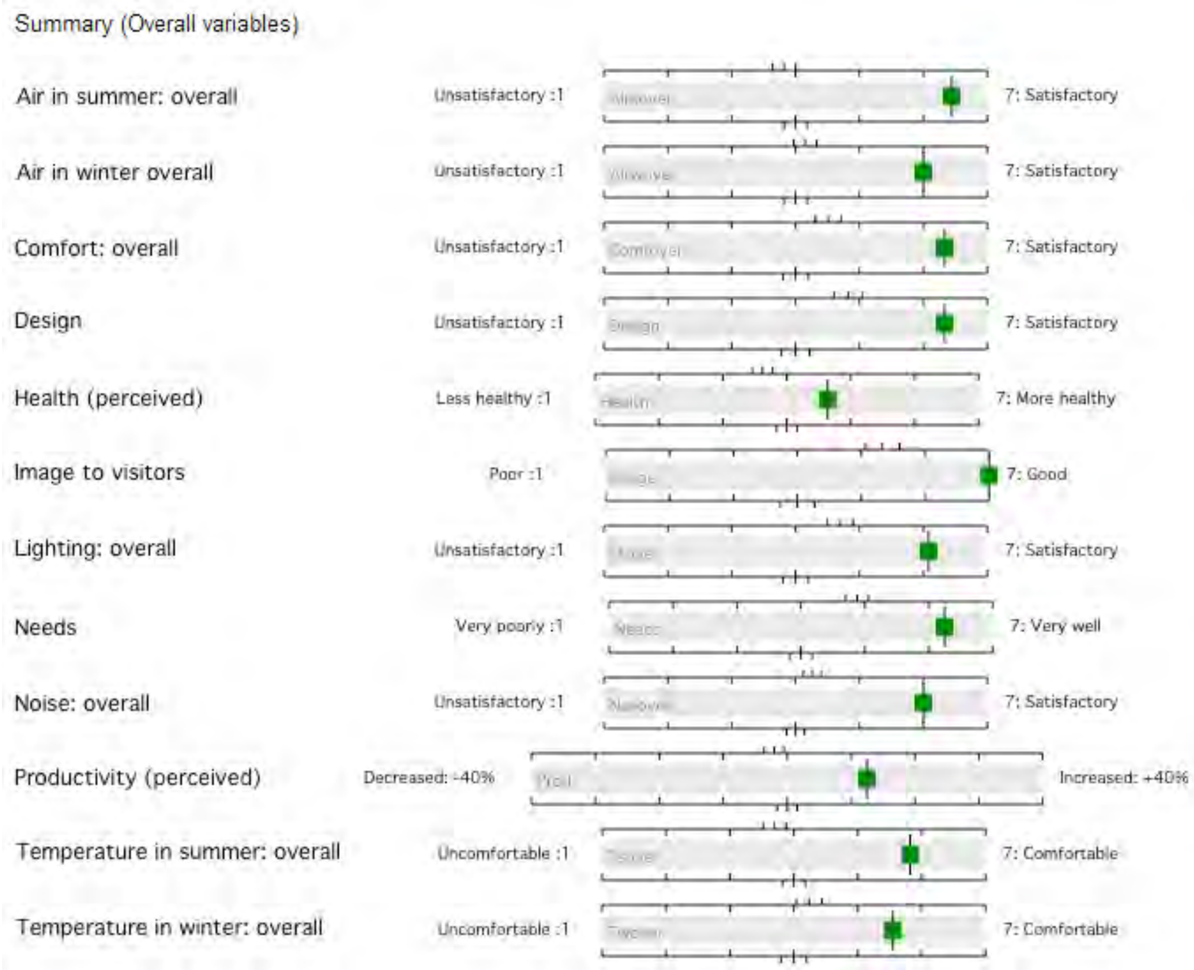


Figure 4.2.2 The chart displays a summary of the variables as responded by those questioned.

Some members of staff responded with written comments on their survey forms. A summary of which follows below and is discussed in chapter 4.3

- In general, the occupants are pleased with the overall design of the building.
- A common complaint is about the lack of storage space.
- The pre-school staff are unhappy that the heating is controlled by the main school and they think the pre-school is cold.
- Some spaces suffer from glare from the sun.

Some members of staff also raised points during the survey process verbally which are as follows.

- The children should be able to see how the services in the school work i.e. clear panels in floor to see underfloor heating loops.
- Lighting control should be manual so children understand importance of when to turn lights on and off.

4.3 Key findings and observations from the BUS

4.3.1 Storage needs

A number of comments were made regarding *not enough storage space*. Whilst there were concerns from some, others were happy with the amount of storage space, including the head teacher who thought the provision was adequate when asked subsequently. Additional shelving units have been installed in the main store located off the corridor and off the Hall, following these remarks.

4.3.2 Heating

There were several comments about the perceived temperature being too cold, particularly from the pre-school staff. This is also likely to have an impact on the perceived productivity and health results in the BUS. This can be attributed to several factors, such as :

- Different operation of the main school and pre-school
- Control of heating in main school only, therefore lack of control in pre-school, and;
- Diligent control of heating by main school head teacher.

The pre-school and main school operate quite differently;

- The main school building is sealed in winter with set times for the children to go outside via the main circulation routes. This allows the building to hold in the heat well throughout the day.

- The pre-school building is a lot smaller and the children play outside throughout the day. The main room opens up directly to outside allows the heat to escape. The underfloor heating is slow to respond and it takes time for the building to recover.

As discussed in chapter 3.2, the head teacher had optimised the heating to suit the main school based on the conditions outlined above i.e. doors and windows sealed. Therefore the heating is turned off after 11am as the building maintains a steady temperature for the rest of the day. The pre-school operation means it loses its heat quickly and takes time to recover as it uses underfloor heating. With the heating turned off at 11am there is little chance of the temperature recovering using the main heating system.

This was addressed in the BMS modifications noted in chapter 6.3 with the addition of a pre-school controller. With the addition of the controller it is strongly recommended to operate the biomass boiler under the dictates of the BMS as designed which will allow each building to be heated and allow frost protection of the building.

4.3.3 Glare

The user survey was conducted at around the same time as the Forensic walkthrough, reported on in chapter 5.4. As reported, there was a problem with glare in the classrooms at this point, which was quickly remedied by installing permanent roller blinds.

4.4 Observations from forensic walkthrough

At the start of the 2 year TSB BPE study, a forensic walkthrough was undertaken by Architype and E3, with Pippa Lloyd, the head teacher of the school. The purpose of the walkthrough was to tease-out apparent and underlying issues that can only be observed with a physical tour of the building. The main findings from the walkthrough are listed below, with the full report from the walkthrough available in the appendices:

- The main issue reported by the users with regard to user comfort was the north rooms – i.e. The offices and group teaching room, being colder than the south rooms. On investigation it was determined that the heating set points had not been set up correctly at the BMS for this zone and was amended during the BMS modifications.

- The south façade curtain walls were causing problems with glare – makeshift blinds had been rigged to solve these problems, these were evident at the time of the walkthrough, but it was reported that they have been in place throughout the year – permanent blinds (eg, simple manual roller blinds) would be a better solution – these were not part of the original design. Note – blinds were not installed as part of the original build as they were Value Engineered out, the school installed blinds shortly after the walkthrough which solved this problem

Figure 4.4.1 Makeshift blinds due to glare photographed during forensic walkthrough

- There appeared to be confusion as to when the clerestory windows should be opened. They were not open in the classrooms during the walkthrough, whilst the low level windows were and little ‘cross flow’ was being achieved as a result. It was suggested that a simple sign could be placed next to the Teleflex control to remind the teachers how the ventilation system was designed. Note: this finding went on to inform the BPE work that was done on developing the ‘Classroom User Guides’, as reported on in chapter 5.5.

- The external lighting is on time clock (located in cupboard) and photocell controls which is confusing to some users and was simplified for the car park to a simple push button switch with an overrun timer..

- The light switch in the staffroom was reported as being unintuitive. The lighting was controlled on a momentary action switch and does not have an obvious on/off position and if it is bright day, but the lights have been left on for some reason, you had to be looking directly at the lights to see that they were on. It was suggested that a simple on/off switch would give the staff a visual reminder if the lights were on or off and this was actioned by the school during the BPE process Moving forwards, lighting with manual control should be made as simple as possible or have a local user guide detailing its operation.

- The O&M manual was found in the head teacher's office, but reportedly rarely used. No user guide has been produced so not available. It was suggested that creating one would be a good idea and benefit the school, particularly if there is a change in head teacher/caretaker. This was developed as part of the BPE, as reported in chapter 4.5.

- There was a water cooler on 24/7 and it was questioned whether this is necessary. It is a mains water dispenser with a chiller unit integrated. The BPE team were to check the original spec to confirm if this was included and also if any measures could be taken to reduce its energy use such as a timer. As it turned out the chiller broke down and was not replaced by the school which has unintentionally resolved this issue.

- Electric shower had been left in standby which will have drawn a small amount of energy continuously.

As part of the walkthrough the Building Management System (BMS), metering and controls were reviewed. The BMS includes for monitoring of a number of meters installed in the building. These include the following.

- Main heat meter, monitors heat produced by the biomass boiler.

- Main electricity meter, monitoring main panel electricity consumption.

- 6 no. electricity meters, on 3 distribution boards, monitoring lighting and general power consumption.

- 2 no. water meters, one for the main school and one for the pre school, for measuring water use.

Not all of these meters are picked up by the BMS front end PC, but can be accessed via the BMS control panel in the plant room. Additional meters were added to the BMS and are discussed in chapter 6.

General observations from the walkthrough for the energy and metering systems are as follows;

- There was a mixed performance for the metering accuracy. The local distribution boards (DB) meters for lighting and power tied up with the BMS however there was is a discrepancy between the total DB metered power and the incoming power by EDF, that could need further reconciliation if possible? The water meter sensitivity is too low and the readings provided to the BMS are not very useful.

- A reconciliation exercise was carried out by the BMS specialist when the school was handed over and no further reconciliation has been carried out since. The head teacher had previously questioned higher than expected figures on the BMS. However, these figures were correct and it was in fact an issue on the control of the external lighting, which had been left on when not needed and used an unexpected amount of energy which has been acted upon as discussed. They now have confidence in the readings.

- The staff are able to breakdown the overall energy loads using the BMS PC. The PC provides the total zonal loads for power, lighting and the water. However, the water meter sensitivity was not to the right level and did not show the usage clearly. The heat meter readings were only available on the BMS panel and not on the BMS PC. The heat meter reading was added to the BMS as part of the BMS modification as discussed in chapter 6.

- Additional sub-meters are intended for the school including; 2 no meters for the 75litre hot water heaters, to measure electrical consumption and report back to the BMS; 1 no heat meter for the pre-school, to measure heat energy consumption; 1 no heat meter for the main heating circuit, to measure delivered heat to the two main buildings and to establish the efficiency of the main biomass boiler plant; A PV array has also been installed since the building and this was added as part of the BMS modifications as discussed in chapter 6.

- The staff generally have a good understanding of the meters and their locations. The school already has in place a system by which they manually record meter readings for educational purposes and also for billing of the pre-school. The readings can be taken from the BMS control panel in the plant room, from the BMS PC, which is located in a classroom, as well as at the meters themselves.

- There is no user friendly trend logging software and the staff and students manually write down weekly meter readings for power and lighting. There was nothing in place to evaluate them before the BPE study. The BMS had not been set up to for trend logging beyond 10 days and it was planned that this period will be increased by up to a year as part of a BMS modifications. However, it was found that the BMS was limited to 1000 readings and it was not possible extend the period without increasing the intervals from 15 minutes to hourly readings, which could have provided data for 40 days.

- The school had been benchmarked against other schools in the district and it was found to be an average performer for its first year since opening. This was unexpected as it was designed to achieve a much better performance. The unexpected results for the power energy use were partly due to control issues, such as the car park lighting and the hot water operation, are discussed in chapter 5. There will have also been teething problems as the staff become used to their new environment and understand how best to operate each space.

- At the time of the walkthrough no specific targets or reduction percentages had been set.

4.5 User guide production

It was apparent from the start of the BPE study that insufficient user guide information was available to the school. A number of comments were made and 'errors' witnessed which highlighted the need to improve the information available to the building users. In particular:

- The Forensic Walkthrough identified that the only user manual was the O&M manual, which is a dense ring binder full of product information, technical manuals, sub-contractor contact details etc. Not a user-friendly document, and not a concise guide to using the building. Basic information, such as how to operate the heating system, and how the ventilation had been designed were lacking from the manual.

- It was observed during the walkthrough that the clerestory windows were not being used in conjunction with the low level windows. Although this was the design intent to maximise the natural ventilation of the classrooms, this design intent was not apparent to the users, i.e. the teachers. Once the principle for ventilation was explained, it became obvious to the teachers, but it was pointed out that this was not documented in any way.

- It was observed on a subsequent visit that windows had displays mounted on them with blue tack. This was cutting out natural light that necessitated the lights being on, despite the day being bright.

- One member of teaching staff made the remark that the group rooms could become much warmer than the classrooms. When it was pointed out that the group rooms had their own (controllable) radiators, which could be turned off altogether when necessary, as opposed to the classrooms which are heated by separate underfloor heating, it became apparent that this had been overlooked. Note; this is another area which was addressed by the BPE User Guides, as reported in chapter 4.5.

- The head teacher suggested that it would useful to have a concise reference guide for supply staff that explained the basic practicalities of the classroom.

The research team decided to develop a series of user guide documents to be put in place before the end of the study. It was decided that there were four guides required, of different detail, but all to be graphic, and non-technical. The guides produced are listed below, and are available in the appendices:

1. *Classroom Guide* – an A4 laminated sheet, to be fixed to the classroom wall in an obvious location, to cover ventilation, heating & lighting.

2. *Group room Guide* – another wall mounted, single A4 sheet, covering the same as above, as well as roof light controls.

3. *Hall Guide* – a larger, A3 laminated sheet addressing the same points but specific to the main school hall.

4. *Building Guide* – a simple A4 booklet to be kept in the staff room & school office, available to all staff, covering in more detail specific building controls including BMS operation, Heating systems & control, Internal lighting, External lighting, Sedum roof maintenance.

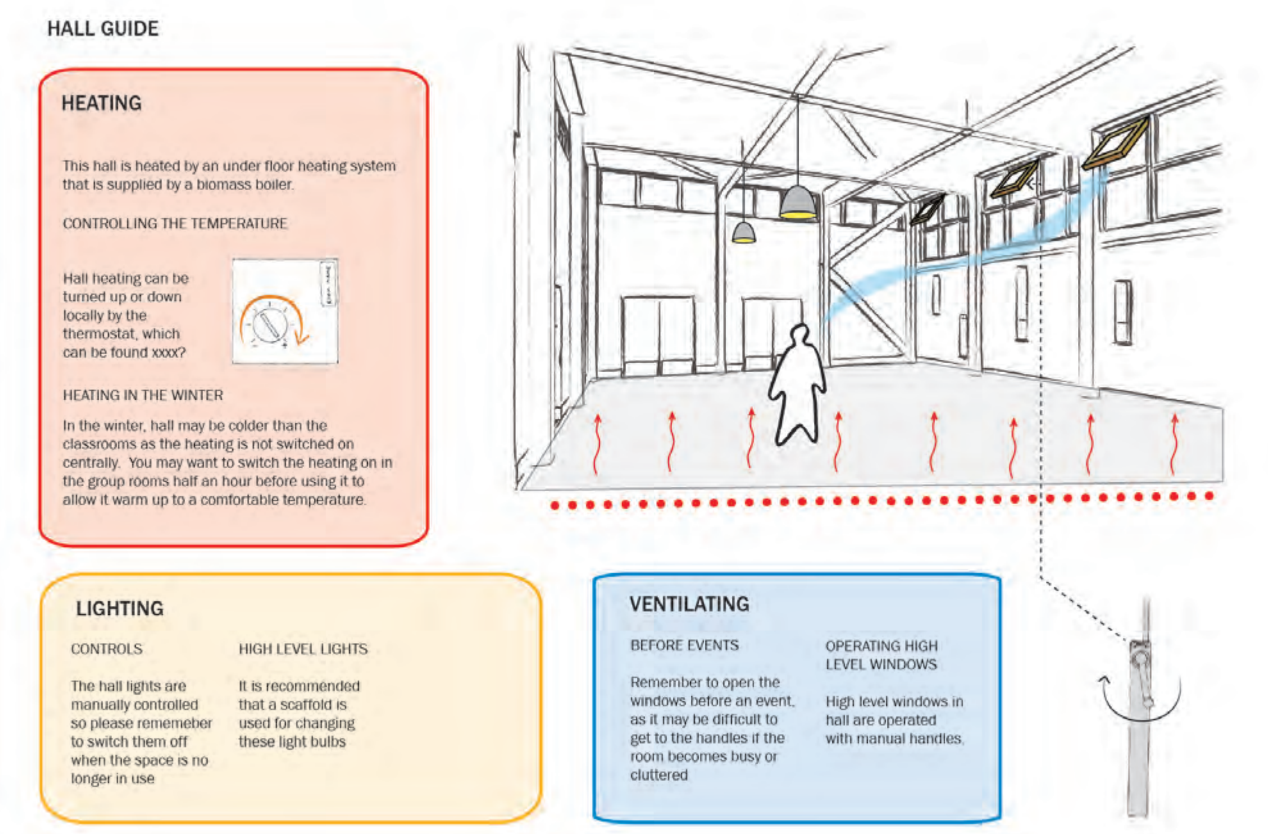


Figure 4.5.1 – 'Hall user guide'

4.6 Conclusion and key finding for this chapter

Overall, the building user study showed a well performing building which was thought of highly by the school staff and performed well against BUS benchmarks.

Technology Strategy Board
Driving Innovation

5 Details of Building Aftercare, Operation, Maintenance & Management

5.1 Introduction

This chapter looks at the specific user issues identified during the study, and interventions which have been implemented or at least proposed as a result of the study. There is a brief description of the handover process, and the informal ‘soft landings’ approach that was initially taken; the chapter then looks at operation issues such as metering and BMS controls. Additional, more technical operation issues are outlined in chapter 7.

5.2 Building handover

The building was handed over on the client on the September 2010 and the defects period ran between November 2010 and November 2011 The building has operated continuously since handover.

The following information was provided as part of the handover package:

- A health and safety file
- Operation and Maintenance manual
- Staff demonstrations,

Handover process

Handover of the New Building was fairly typical with certificates being provided from sub-contractors and suppliers and then the design team and client inspected works and signed off practical completion. However, snagging was protracted as no timescales were contractually specified and both the original mechanical and electrical subcontractors went into administration; the electrical subcontractor in the 2nd fix stage and the mechanical contractor during the defects stage.

The design team remained committed to the project (especially with the architects close proximity to the school) and were closely involved with managing the handover and defects period throughout the first year of occupancy.

The BPE process was also important in evaluating the building operation post occupancy and making interventions to improve the performance of the building.

Operation and Maintenance manual

The O & M file produced by the main contractor was issued in the form of an A4 lever arch file with details of product data sheets and record drawings, as well as the design team’s specifications and a detailed electrical and mechanical services manual.

The information provided was comprehensive but it was not user friendly. There was little to explain the building and its systems in a clear and concise manner for the client and it was not easy to comprehend. The mass of the information consisted mainly of general product literature, contact details for subcontractors, drawings and detailed technical information.

Building Log Book

No Building log book appears to be available at the school. A log book gives simple descriptions of the building systems and how to operate the building as designed. It also provides information on energy benchmarks for the user to compare the actual energy usage against and is a useful tool in understanding the building.

Maintenance

Generally, the school has a reactive response to maintenance and they have said that it was never made clear what required regular maintenance and what didn't. The caretaker has, over time, set up a maintenance schedule by wading through the O&Ms, although it is not apparent how thorough this was.

In the O&M manual you will find schedules for preventative maintenance tasks which is based on manufactures recommendations and industry guides.

On speaking to the head teacher, it was apparent that the school caretaker found the O&M manuals difficult to manage and find the relevant information to determine what maintenance should be carried out and when. The client was offered no support in this process and found it difficult to set up a maintenance schedule.

The school does have external maintenance contracts for several items as listed below. All other items are taken care of by the school caretaker.

- Biomass boiler and heating system
- Security systems
- Fire systems
- Sports equipment
- Fire extinguishers
- School grounds

*It is **recommended** that the contractors discuss all the relevant maintenance requirements and associated schedules with the appropriate staff as part of the handover process. This should be made as clear as possible and also advise the client on what external maintenance contracts they should seek so the client can hit the ground running from handover.*

5.3 Metering strategy

The metering strategy for the school was designed to CIBSE TM39 and Part L building regulations 2006 and the following meters were installed.

- Each distribution board separately metered power and lighting and relayed the reading to the BMS.

- The heating power generated by the biomass boiler was metered using a calibrated heat meter and picked up by the BMS. This was also a requirement for the renewable heat incentive (RHI) scheme.

- Incoming water to each building was metered by separate meters.

The main school and pre-school have separate budgets and divide the incoming utilities and fuel bills using the metered energy. The electricity meters and the heat meter values are regularly manually recorded by the school and pre-school to ascertain their bills. The heat meter billing was originally divided on a square meter basis i.e. the pre-school paid for their heating as a proportion of the building area, which did not work for the school as discussed in chapter 3.2.

As part of the BPE process additional meters were added to improve the strategy.

- Additional heat meters added to whole school and pre-school heating circulation to accurately bill pre-school for heating based on kWh.

5.4 Building systems operation

The main school head teacher takes a keen interest in the schools energy use and casts a diligent eye over all the systems in order to minimise energy, and therefore utility bills.

Examples of this are discussed below.

Heating

The BMS has control over the main systems in the school; however several of these building systems are turned on/off manually by the head teacher on occasions such as school holidays and heating seasons. This primarily applies to the biomass boiler and the water heaters and is reasonable in practice but takes elements of control away from the BMS system such as the building and boiler frost protection routine.

After the initial walkthrough and TM22 it was established that the pre-school was billed for their heating use on a square meter basis. This caused some issues between the main school and pre-school due to the different operating conditions of each building i.e. the pre-school required higher room temperatures for comfort.

As an example, the biomass boiler typically begins its heating cycle at 6:30am to charge the buffer vessel and warm the buildings up to temperature for 8:30am; school opening time. The head teacher programmed the heating to remain on until 11am and from then it is off until the next weekday morning. This provided acceptable temperatures in the main school classrooms as the well-insulated and airtight construction held in the heat well. However, the same heating regime applied to the pre-school was not as effective because the pre-school operation differed significantly. Doors were often intentionally left open to allow children to move freely between the classrooms and outside and losing all its heat on a cold day. After 11am the buildings heating is turned off, leaving the building cold for the remainder of the day.

Before the BPE, the pre-school did not have full control over its heating set points, this being controlled from the BMS in the main school. It was also expected that the pre-school was using more heat than it was billed for. As part of the BMS modifications, discussed in chapter 6.3, heat meters and a pre-school controller were installed to allow the pre-school heating to be separated and set points to be adjusted locally.

These operational incidences were discovered during the first year after handover and brought to the attention of the head teacher. With an improved understanding of these systems, the head teacher can now give BMS more control, although not full control e.g. the boiler will still be turned off manually outside of the heating season.

Recommendations related to the heating and control are as follows:

It is recommended that head teacher is given training on the BMS frost protection routine and advised to keep the boiler turned on, instead adjusting the heating time settings to holiday mode on the BMS.

It is recommended for future projects should seek clarification the billing needs of the client in the brief and determine the metering strategy accordingly.

It is recommended that a review of the heating set points and timings and opening operations should be addressed to maintain a good Indoor air quality and air temperatures in the classrooms. This may require a level of training.

Hot Water

Water heaters could be time clock controlled, however it was thought that did not really save much on energy. Also, on holidays the water heaters and trace heating would be turned off manually by the head teacher or caretaker. However, in one instance it was found that the trace heating, installed along the hot water pipe was on throughout the summer, heating the water and being a potential legionella risk. and wasting a considerable amount of energy. Another issue was that some water heaters would unintentionally be left off when the school was back, leaving the occupants with no hot water until someone raised the issue. These are largely school management issues.

*It is **recommended** that the maintenance person and relevant staff are trained on legionella risks, if not already. The school should implement a holiday checklist of systems and equipment to turn down/off to make sure nothing in missed.*

Lighting

Lighting would generally be turned on and off manually when required in most areas.

Classrooms had daylight dimming although some teachers would still have lights on when other had lights off.

The main circulation was installed with presence detection. However the school requested this was changed to manual control after the lighting was found to come on when not required. This was completed before the walkthrough.

The staff area lighting was on a dimmer switch which the users found unintuitive. However, this area benefitted from manual on/off switch as on a bright day it was very difficult to see if the lights were on and the switch position did not give any clues.

The car park lighting hours were originally set on an analogue time switch. However, the lighting would still be on if staff left early using unnecessary energy, and conversely switching off too early if staff stayed later. Lighting would also remain on over school holidays if it was the timer was not adjusted. In this instance the car park lighting was changed to a push button timer adjacent the reception which allows staff/visitors to walk to/from their car under the lighting. Feedback from the school suggested they did not understand how to operate the time switch and its location was not obvious although you would not want all staff to have access to this, only the maintenance person and head teacher.

Recommendations for the lighting are as follows:

*It is **recommended** to use very simple lighting controls for this school e.g. so the user can clearly identify how to turn on/off the lighting and visually identify if the switch is in the on/off position. Feedback from the school also suggested manual on/off lights were a good educational aid for the pupils.*

*For this case, it would have been **recommended** that training to the relevant staff was provided for use of the time switch and an on/off override master key switch provided in an prominent location to turn off all lights when the school is closed.*

Glazing

All opening glazing was on manual control and opened to the user's needs. Typically all windows and doors would be closed in the winter to keep in the heat. In the warmer months the windows would be opened to naturally cool the building. The window opening strategy was investigated during the internal environment investigation as described in chapter 5.3

*The production of user friendly guides to aid effective use of the building proved beneficial and has been well received by the school. This is **recommended** for future schools.*

6 Energy use by source

6.1 Introduction

This chapter gives an overview of the in-use energy before and after the initial BPE interventions. The in-use energy is evaluated using the TM22 methodology which reviews the energy loads and profiles for a building. A comparison of the initial and final TM22 are discussed in this chapter.

6.2 Building energy consumption and benchmarking

Staunton School uses a combination of mains electricity, photovoltaics and Biomass fuel to meet its power and heating requirements. There is no backup gas boiler. Photovoltaic panels were added by the school following the handover of the building.

Two TM22s have been carried out during this project; the initial TM22 ran from April 2011 to April 2012. The final TM22 ran from April 2013 to April 2014 and both TM22s are discussed in this chapter.

The school has been benchmarked against CIBSE TM46 and the Department for Education Services (DFES) data which contains energy consumption benchmarks for different categories of school building. The 25th percentile has been used as the benchmark comparison for a well performing new build school.

Table 6.2.1 The table shows the **benchmarks** used to compare the supplied energy to the school. The benchmarks were taken from TM46:2008 and DFES:2007.

	Electricity kWh / m2	Fossil fuel kWh / m2	Electricity kg CO2 / m2	Fossil fuel kg CO2 / m2
TM46	40	150	22	28.5
DFES 25th %	31.7	107.5	13.6	21.1
CIBSE Guide F (Good Practice)	22	113	n/a	n/a

Table 6.2.2 The table compares actual in-use **energy** for the initial TM22 and the final TM22.

	SOW electricity kWh	SOW biomass kWh	SOW exported PV kWh	SOW electricity kWh /m2	SOW biomass kWh / m2	SOW exported PV kWh / m2
Initial TM22	30,459	21,270	0	37.7	26.3	0
Final TM22	22,786	18,592	3,284	21.2	23	4.1

Table 6.2.3 The table compares actual in-use **carbon emissions** for the initial TM22 and the final TM22.

	SOW electricity kg CO2	SOW biomass kg CO2	SOW PV kg C02 offset	SOW electricity kg CO2/m2	SOW biomass kg CO2/m2	SOW PV kg C02 offset /m2
Initial TM22	16,752	532	0	20.7	0.7	0
Final TM22	12,532	465	-1,806	15.5	0.6	-2.2

The 'As built' Part L 2006 analysis for the school (see appendices) has a building emission rate (BER) of 10.4 $kgCO_2/m^2$.year (8,413 kgCO2 / m^2.year) against a target emission rate (TER) of 24 $kgCO_2/m^2$.year. The values in table 6.2.3 show the in-use emission rate for the final TM22 as 16.1 kg CO2/m2 which exceeds the Part L BER but is still better than the TER. However, the Part L calculation does not account for unregulated loads such as small power, kitchens, servers and out of use hours. This accounts for the extra emissions and contributes to what is also known as the performance gap.

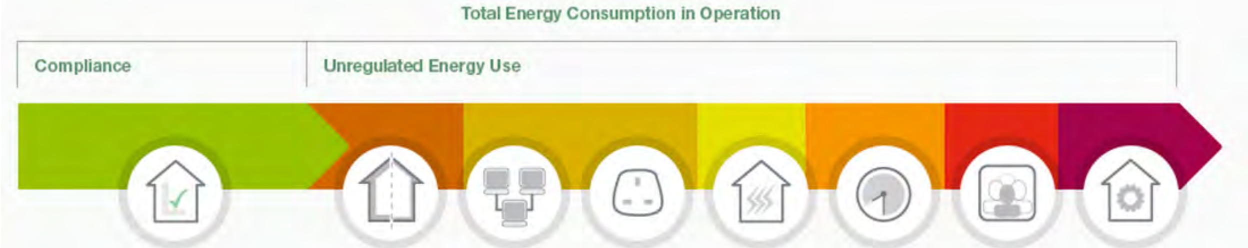


Figure 6.2.1 The chart sets out the regulated energy use in green (accounted for in Part L2) against the unregulated energy use. The unregulated energy contributes significantly to the total energy consumption and is not considered in the Part L analysis. (CIBSE TM54: Evaluating Operational Energy Performance of Buildings at the Design Stage, 2013)

Table 6.2.4 The table details the BRUKL results generated from the 'As designed' Part L analysis.

	SOW electricity kWh (regulated only)	SOW biomass kWh	SOW PV kWh offset	SOW electricity kWh / m2	SOW biomass kg kWh /m2	SOW PV kWh kg kWh /m2offset
Part L BRUKL	13,232	21,832	0	16	26.4	0
Final TM22	22,786	18,592	3,284	21.1	23	4.1

Table 6.2.4 compares the 'as-designed' Part L simulation analysis with the final TM22 data. It demonstrates the heating energy consumption is significantly below the benchmark data. This is due largely to the schools high insulation, airtight construction (1.34 m^3/m^2.hr @ 50Pa) and the control regime. In the winter the orientation of the schools glazing means the school can benefit from solar gain from the low winter sun reducing overall boiler load.

The electrical energy consumption in the initial TM22 falls between the TM46 and DFES benchmarks. In the final TM22 the electrical consumption has been reduced considerably which has arisen due to several factors such as improved controls, increased staff awareness and the introduction of solar panels.

6.3 Initial TM22 analysis

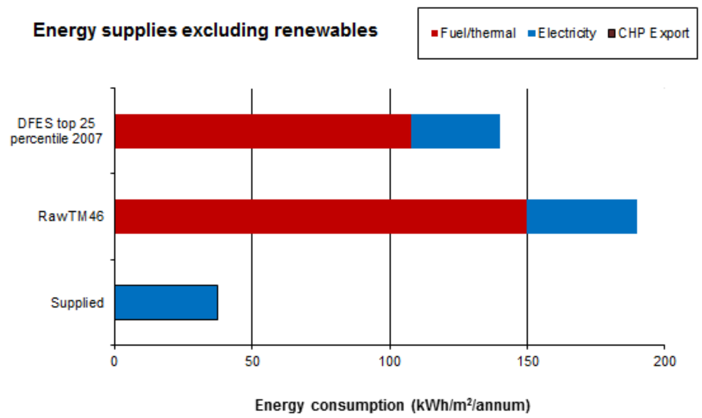
The initial analysis was derived from data recorded since the school was handed over in April 2011 up until April 2012, and has continued since then. The key figures are:

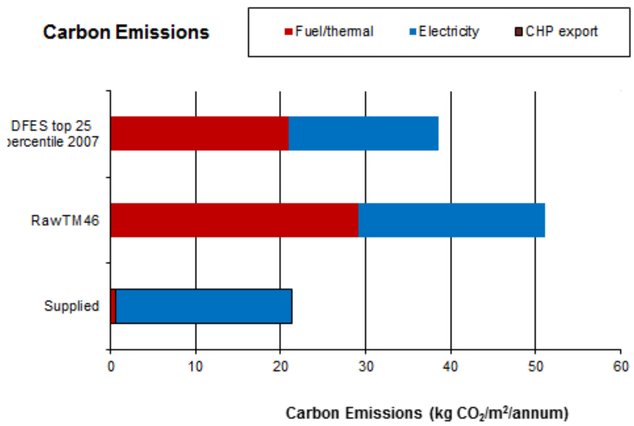
- Supplied electricity for the 12 months to April 2012 was 30,459 kWh. This equates to 37.6 kWh/m^2 GIA (Main school = 26.9 kWh/m^2 GIA and pre-school = 30.6 kWh/m^2 GIA).

- The resultant carbon dioxide emissions for electricity the 12 months up to April 2012 was 16,752 kgCO2 per annum (at the default carbon factor for electricity of 0.55 kg CO2/kWh).

- Actual renewable heating energy consumed was 21,270 kWh per annum with the resultant carbon dioxide emissions for the 12 months to April 2014 was 532 kgCO_2 per annum (at the default carbon factor for biomass of 0.025 kgCO_2/kWh).

The figures below represent the energy supplied to the school against the benchmarks noted in chapter 6.2. Figure 6.3.1 represents the energy supplied and carbon emissions excluding renewables. Figure 6.3.2 represents the fossil fuel equivalent i.e. if the school was heated by gas instead of biomass.

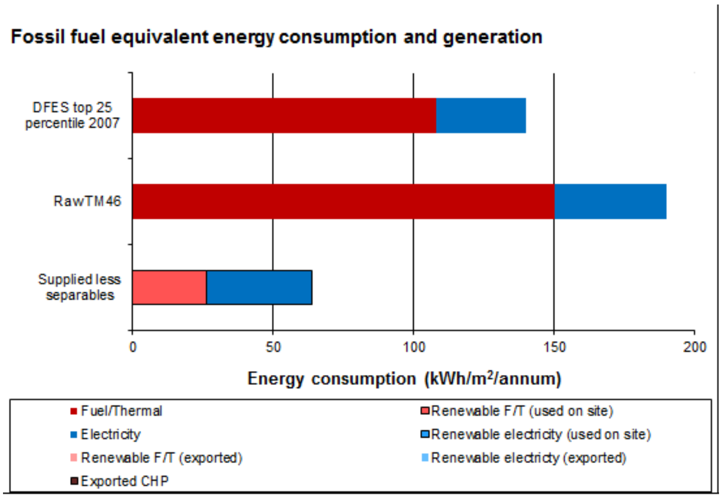


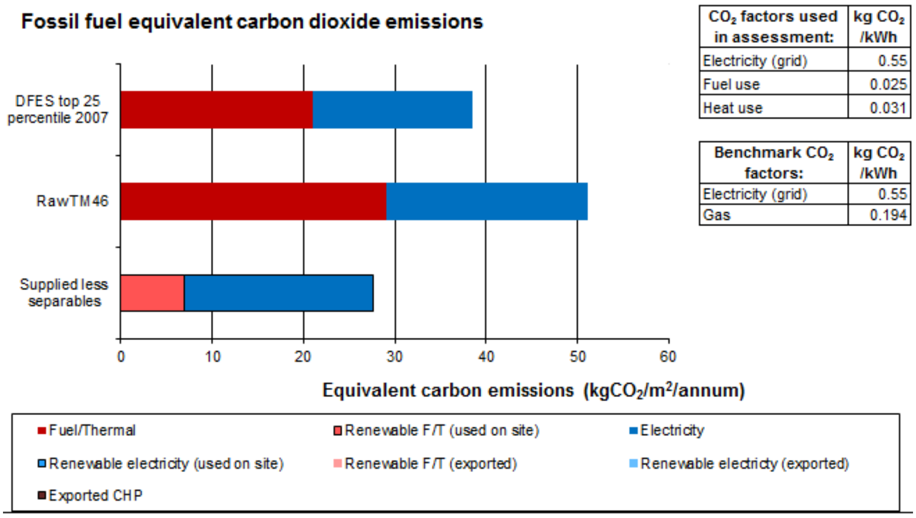


CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Biofuels	0.025

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

Figure 6.3.1 The graph represents the total energy supplied to the school between April 2011 and April 2012 and excludes renewable fuels. Staunton school is compared to DFES top 25th percentile and raw TM46 data.





CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Fuel use	0.025
Heat use	0.031

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

Figure 6.3.2 The graph represents the total energy supplied to the school between April 2011 and April 2012 for fossil fuel equivalents. Staunton school is compared to DFES top 25th percentile and raw TM46 data.

Figures 6.3.1 and 6.3.2 show mixed results when compared to benchmarks. The heating energy used by the school performs very well against benchmarks (26.3 kWh/m^2 against 108 kWh/m^2 for DFES and 150 kWh/m^2 for TM46). This is largly influenced by the building construction, the BMS and also the diligence of the head teacher.

However, the electrical loads performs less well (37.6 kWh/m^2 against 32 kWh/m^2 for DFES and 40 kWh/m^2 for TM46). The initial TM22 was performed in the first year of use for the school and issues were still being ironed out such as external lighting controls and domestic hot water heater operating hours. Figure 6.3.3 demonstrates the significant impact this had on the school overal electrical energy use.

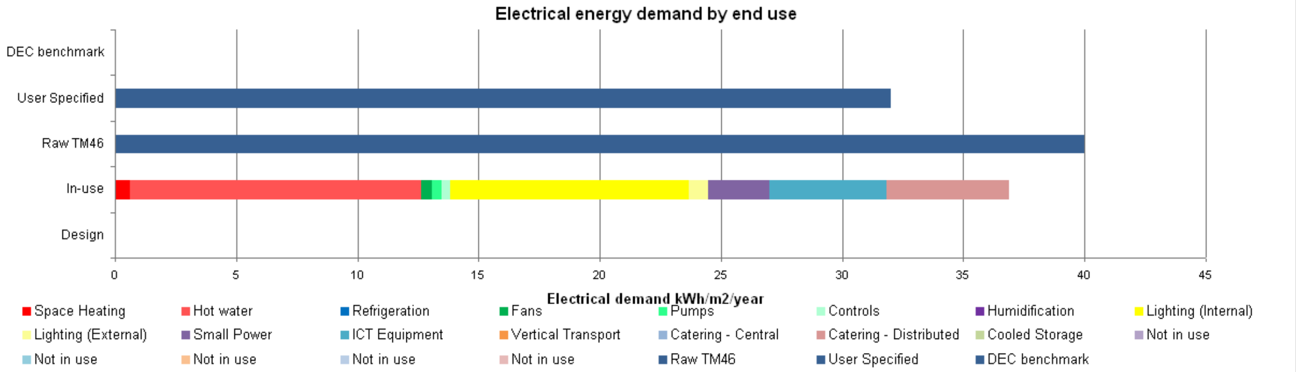


Figure 6.3.3 The graph represents the total electricity used by the school between April 2011 and April 2012. Staunton school is compared to DFES top 25th percentile and raw TM46 data. The electricity use is broken down by end use as indicated in the key.

Table 6.3.1 The table shows the electrical demand for the initial TM22.

		Heat demand (kWh/m2/year)		Electricity demand (kWh/m2/year)		
System	Description	Design (kWh/m2/year)	In-Use (kWh/m2/year)	Design electricity (kWh/m2/year)	In-use electricity (kWh/m2/year)	In-use electricity (kWh/year)
Space Heating		0.0	0.0	0.0	0.6	487
Hot water		0.0	0.0	0.0	12.0	9,744
Fans		0.0	0.0	0.0	0.4	354
Pumps		0.0	0.0	0.0	0.4	308
Controls		0.0	0.0	0.0	0.4	303
Lighting (Internal)		0.0	0.0	0.0	9.9	7,970
Lighting (External)		0.0	0.0	0.0	0.8	617
Small Power		0.0	0.0	0.0	2.5	2,044
ICT Equipment		0.0	0.0	0.0	4.9	3,942
Catering - Distributed		0.0	0.0	0.0	5.0	4,077
Total		0.0	0.0	0.0	36.9	29,846
Metered building energy use			0.0		37.6	30,459
Variance TM22 versus metered total			0.0		-0.8	-612
Variance TM22 versus metered total			#DIV/0!		-2%	-2%

6.4 Interventions

Several interventions were carried out, both during and following the initial TM22. The interventions can be put under three heading

- Interventions instructed by the school (including the initial defects period)
- Interventions following the initial TM22 monitoring period
- Interventions for BMS modifications

Interventions instructed by the school (including the initial defects period)

- A 10 kW PV array was installed on the south facing roof of the school after the school won the 2011 Rolls Royce science prize (installed May 2012).

- The car park lighting control strategy was adjusted from time clock and daylight sensor to manual push button with timer as the lighting was found to be on excessively (adjusted during the initial TM22 (installed February 2012)

- Corridor lighting amended from PIR to manual control.

Interventions following the initial TM22 monitoring period

- CO_2 monitoring and alarms were introduced into all three classrooms after CO_2 data loggers found higher than recommended levels of CO_2. Teachers and Pupils were encouraged to monitor the CO_2 levels and open windows accordingly (November 2012)

- 2 no heat meters were added to the heating circuit to record heating energy to the main school and pre-school separately (December 2013). The intention of this was to establish the efficiency of the biomass system circuit and also determine the energy required to heat each of the buildings.

- 2 no clip on energy meters were added to the water heaters to monitor the actual e nergy usage of the 75litre water electric point of use water heaters (December 2013) to understand the actual in-use energy profiles.

- The headteacher was made aware of the high DHW loads and took a more hands on approach to reducing the energy consumption by manually turning of the water heaters when not needed e.g. holidays.

- 2 no plug in energy meters were fitted to monitor the server power and the head teachers PC.

Interventions for BMS modifications

- The BMS was modified to monitor the additional heat meters and the PV meter.

- The BMS head end software was updated to pick up the new meters.

- A BMS controller was installed in the pre-school building to give the pre-school staff more control of the pre-school heating set points. This was previously to the discretion of the head teacher in the main school who still has overriding control.

- The head teacher was briefed on the biomass boiler running procedure and the frost protection routine was out of the heating season and holidays.

6.5 Final TM22 analysis

The final TM22 analysis was derived from data recorded between April 2013 up until April 2014. The key figures are:

- Supplied electricity for the 12 months to April 2014 was 21,974 kWh compared with 30,459kWh in the initial TM22. This equates to 27.2kWh/m^2 GIA (Main school = 26.9 kWh/m^2 GIA and pre-school = 30.6 kWh /m^2 GIA.

- The resultant carbon dioxide emissions for the 12 months to April 2014 was 12,532 kgCO2 per annum compared with 16,752 kgCO2 per annum in the initial TM22 (at the default carbon factor for electricity of 0.55).

- Actual renewable heating energy consumed was 18,592 kWh per annum compared with 21,270 kWh per annum in the initial TM22. The resultant carbon dioxide emissions for the 12 months to April 2014 was 465 kgCO2 per annum (at the default carbon factor for biomass of 0.025).

The figures below represent the energy supplied to the school against the benchmarks noted in chapter 6.2. Figure 6.5.1 represents the energy supplied and carbon emissions excluding renewables. Figure 6.5.2 represents the fossil fuel equivalent i.e. if the school was heated by gas instead of biomass.

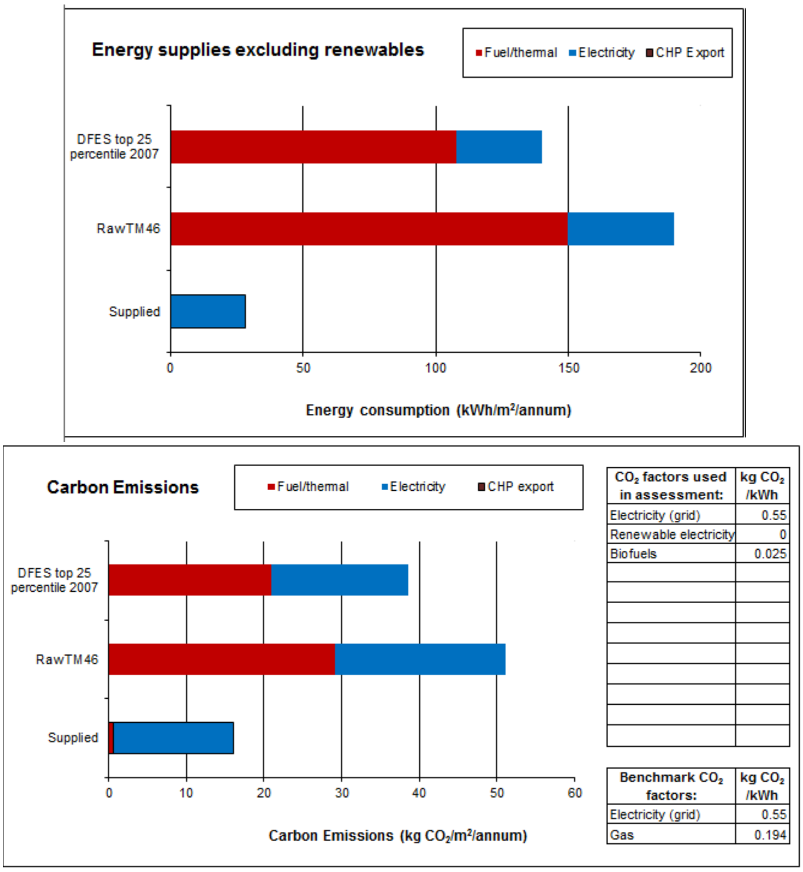


Figure 6.5.1 The graph represents the total energy supplied to the school between April 2013 and April 2014 and excludes renewable fuels. Staunton school is compared to DFES top 25th percentile and TM46.

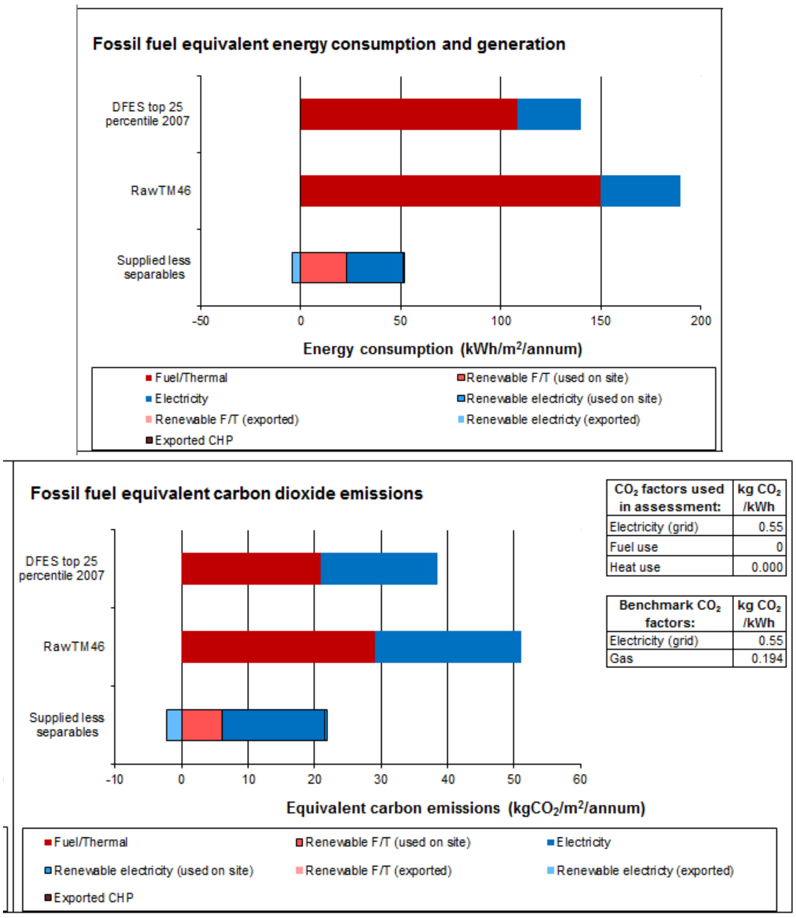


Figure 6.5.2 The graph represents the total energy supplied to the school between April 2013 and April 2014 for fossil fuel equivalents. Staunton school is compared to DFES top 25th percentile and raw TM46 data.

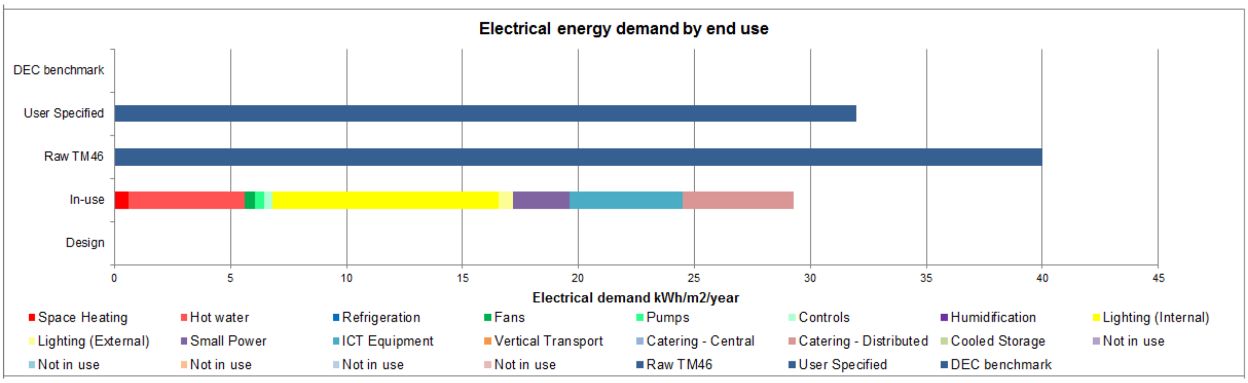


Figure 6.5.2 The graph represents the total electricity used by the school between April 2013 and April 2014. Staunton school is compared to DFES top 25th percentile and raw TM46 data. The electricity use is broken down by end use as indicated in the key.

Table 6.5.1 The table shows the electrical demand for the initial in-use TM22 and the final improved TM22. The overall electrical energy reduction was shown to be 26% based on the initial TM22.

		Design		In-use		Improved	
System	**Description**	**Fuel/Thermal demand (kWh/m²/year)**	**Electricity (kWh/m²/year)**	**Fuel/Thermal demand (kWh/m²/year)**	**Electricity (kWh/m²/year)**	**Fuel/Thermal demand (kWh/m²/year)**	**Electricity (kWh/m²/year)**
Space Heating		0.0	0.0	0.0	0.6	0.0	0.7
Hot water		0.0	0.0	0.0	13.9	0.0	5.0
Fans		0.0	0.0	0.0	0.4	0.0	0.4
Pumps		0.0	0.0	0.0	0.4	0.0	0.4
Controls		0.0	0.0	0.0	0.4	0.0	0.4
Lighting (Internal)		0.0	0.0	0.0	9.9	0.0	9.3
Lighting (External)		0.0	0.0	0.0	0.8	0.0	0.6
Small Power		0.0	0.0	0.0	2.5	0.0	2.4
ICT Equipment		0.0	0.0	0.0	4.9	0.0	4.9
Catering - Distributed		0.0	0.0	0.0	5.0	0.0	4.8
Total		**0.0**	**0.0**	**0.0**	**38.8**	**0.0**	**28.8**
Total predicted saving (kWh/m²/year)						**0.0**	**9.9**
Total predicted saving (%)						**#DIV/0!**	**26%**

6.6 Comparison of TM22 analysis

A comparison of the initial and final TM22 energy figures show an 18% improvement in the total energy consumed and is a significant overall improvement in energy use between the TM22s and can be attributed to the points raised below. This is discussed in more detail in the TM22 report in the appendices.

- Electrical energy demand for hot water system drops from 13.9 kWh/m^2.annum to 5 kWh/m^2/annum. This large reduction has several contributing factors, such as:
    - Increased understanding of energy use following installation of clip on water meters.
    - The school was more aware of the energy demand for the water heaters, as part of the feedback from the initial TM22. The head teacher set a routine to turn off water heaters and maintenance tape in the school holidays.
    - A significant load on the initial TM22 was attributed to the temperature maintenance tape which was found to be on for a long period of the school holidays, effectively trying to heat the water in the pipe to 60^{o}C.
- Overall electrical demand in the final TM22 dropped by 26% compared with the initial TM22. This considerable reduction is largely due to the reduction of the HWS load. This can also be attributed to the interventions in the lighting control, the schools increased understanding of how the building should be operated, and the introduction of the photovoltaics.
- Heating from the biomass reduces from 21,270 kWh/m^2.annum to 18,592 kWh/m^2.annum. This could be attributed to the winter of 2013/14 being mild (Mean temp in winter 2011 was 5.6^{o}C) whereas the winter of 2011/12 was exceptionally cold (Mean temp in winter 2011 was 2.8^{o}C).

The chart below demonstrates the electrical energy demand for both the initial TM22 (in-use) and the final TM22 (improved).

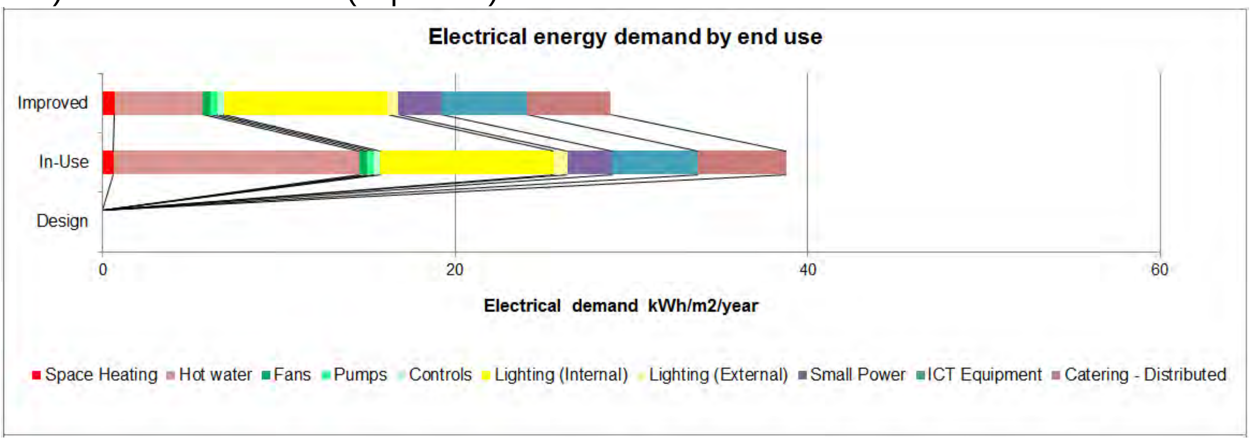
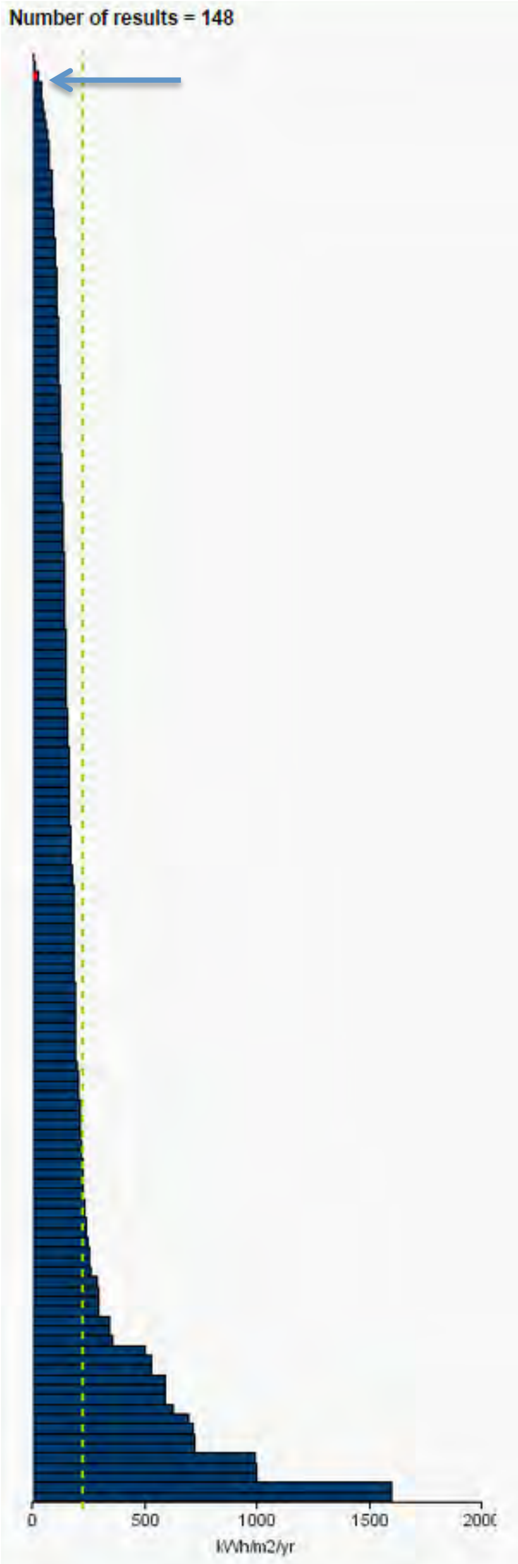


Figure 6.6.1 The graph represents the electrical demand for the initial TM22 against the final TM22. It can be clearly seen that the HWS usage has been reduced dramatically.

The chart below shows how the school performs in comparison to other education buildings. Staunton on wye school performs very well and is shown in the top 3 out of 148 schools however it should be noted that this includes large inner city academies as well as small country schools, such as Staunton. The results can be seen on.



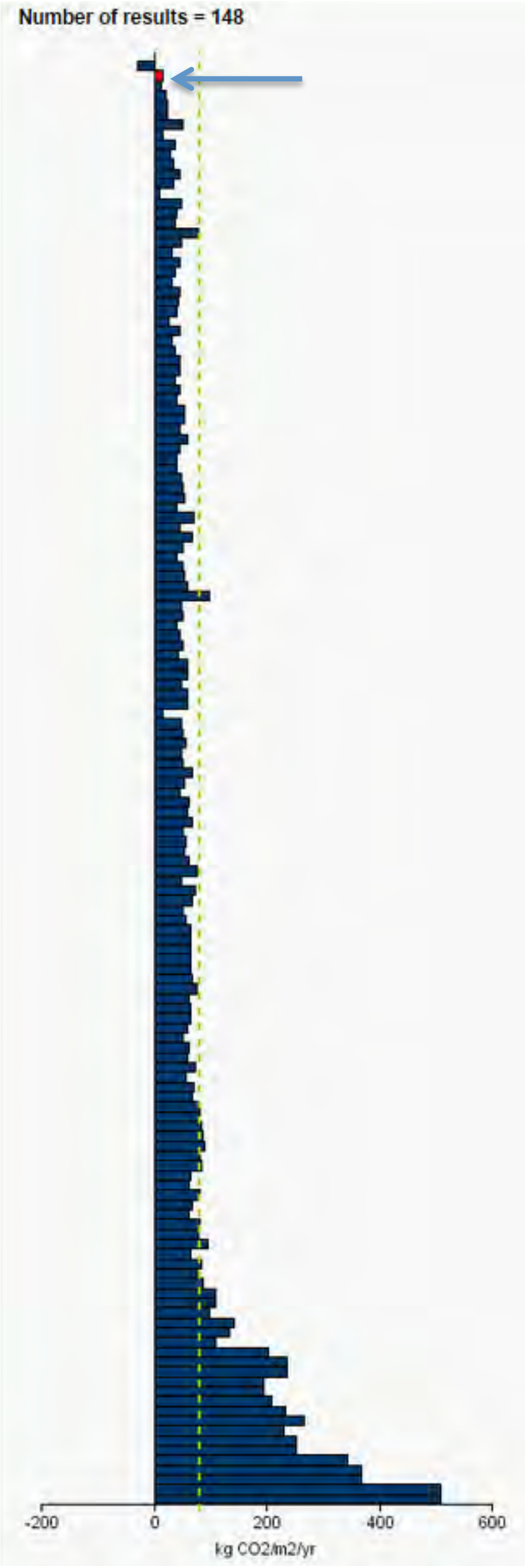


Figure 6.6.2 The graphs shows the total actual kWh/m^2/year and kgCO_2/m2/year from TM22s completed for education buildings uploaded to the Carbonbuzz website. Staunton school sits at the top of this table.

6.7 Conclusions and key finding for this chapter

The TM22 energy performance evaluation shows the building performs well against energy benchmarks. This is particularly true for the heating which is considerably lower than the benchmarks. The school is one of the top performers on the CarbonBuzz website but it must be taken into consideration that a small primary school in the middle of the countryside will have considerably different energy demands to an inner city academy school.

The interventions made during the course of this BPE have made a significant improvement with the electrical energy use for the school which has been reduced significantly. An element of this improvement will also be attributed to the new photovoltaics which were installed during the initial TM22.

The TM22 evaluation has been a good method of evaluating the energy performance of the school and understanding what the major energy users are and investigating how these can be improved. Training given during the BPE process and knowledge gathered from other TM22 has been essential is producing more accurate TM22 results.

7 Technical Issues

7.1 Introduction

This chapter outlines and discusses the underlying issues relating to the performance of the building and the systems.

7.2 Building services commissioning

The school was built at a time when the construction sector was struggling in the midst of an economic downturn and during the construction phase the electrical subcontractor went out of business. During the defects phase the mechanical subcontractor went out of business. This led to several issues.

- The electrical subcontractor went out of business during the 2nd fix stage and before the electrical systems could be commissioned. Another contractor had to be brought in to complete and commission the work and had no prior knowledge of the project. This created difficulties in the commission stage, such as setting up lighting systems, time clocks, training of the end user, log books and the production of operation and maintenance manuals.

- The mechanical subcontractor went out of business during the defects period which affected the seasonal commissioning which was specified. This is a particular issue for training and optimising systems and set points such as the heating.

Had both of the contractors remained in business the commissioning issues that were found during the BPE process would have largely been addressed and the demonstrations provided to the school would hopefully have been more productive.

7.3 Heating

The energy required to heat the school is minimal and lower than that predicted by the “as built” BRUKL. However, this only gives one side of the story and important factors such as comfort and health should also be considered.

The school has set the heating to 18 ^{o}C which is less than CIBSE guide B recommendations i.e. a set point of 19 – 21 ^{o}C in teaching spaces. However, the heating is turned off after 11am and the room temperature relies on the buildings fabric performance. The building is airtight and well insulated which lends itself to maintaining the temperature, especially with heat gains from children and a low winter sun. This also relies on the building being sealed i.e. no natural ventilation. This is potential concern as it can lead to a build-up of CO_2, which was shown to be the case in CO_2 measurements, and is generally accepted as having negative effects on pupil learning performance. This has been addressed as part of the BPE process as discussed in chapter 5 i.e. the development of a classroom guide. A disadvantage of opening the building up to reduce CO_2 levels is there is likely to be a drop in temperature with the heating off.

*It is **recommended** this is addressed by increasing the time the heating is on and letting the BMS take full control. This will use more energy and must be weighed up by the head teacher.*

The pre-school is less simple to resolve due to the operation and layout of the building. In terms of heating, a pre-school building generally has a higher heat demand (See DFES data) because smaller children require a warmer environment and the higher floor area:internal volume ratio i.e. smaller buildings lose more heat per m^2 compared to larger buildings due to a higher proportion of external elements. The building is as well insulated and airtight as the main school, however the current operation of the building means the teachers regularly leave open the classroom doors to outside so the children can run between and play between the spaces. There is no airlock between the classroom and outside and all the heat effectively escapes the building in a short amount of time. When the classroom doors are closed to outside it can take a long time to warm up and will often not warm up significantly at all. This is because the heating response time for the underfloor heating is slow and also the heating is off from 11am. The heating timing and temperature has been partially addressed during the BPE process by introducing a controller in the pre-school.

*There are two main **recommendations** for this building. Firstly, for buildings with a similar use to this pre-school i.e. small building which regularly opens it façade for a significant period of time, a faster response heating system such as radiators is beneficial. However, this relies on the design team having a good understanding of how the users operate the building and thus the second recommendation is that the pre-school staff should evaluate the current practice of keeping the external door open during play time as this can purge all the heat from the space, leaving the classroom cold for when playtime is over.*

The decision to install a biomass boiler was influenced by several factors as discussed previously. However, in retrospect biomass may have not been the right choice for the school. The main school and the pre-school's operation and heating demand profiles are very different. The school would have benefitted by defining the different functions of the buildings clearly in the brief or at the design meetings. As it was, the different requirements was brought to the design teams attention until late in the construction phase. A clear brief may have influenced the choice of heating system to a more building specific system such as an LPG combination boiler or air source heat pumps. This would also have the added benefit of hot water to each building, simpler metering for billing and simpler control.

Some rooms on the north side of the building were found to be cold in the winter months. This was due to the rooms set points not being set up properly during the commissioning period and the head teacher was unable to see how to control these spaces from the BMS head end PC. This could have been rectified immediately with a more effective commissioning and demonstration period.

7.4 Hot water

The hot water is provided by electric point of use water heaters in both buildings. The two larger heaters have been trace heated to minimise the risk of legionnaire's disease. The water heaters were installed with simple analogue 7 day time switches to minimise their energy consumption although it was determined before the BPE process that this does not have a significant effect on the overall energy use i.e. warming up from cold in the morning versus occasional heating the water as required. There have been several issues with the water heater energy consumption including:

- Leaving water heaters and trace heating on over holidays
- Turning off water heaters in the summer holidays but leaving on trace heating
- Users not able to use the time switch effectively.
- Not turning water heaters on returning from holidays

The first two points have led to higher than predicted electricity use and have been addressed. The school head teacher/caretaker will now walk around the school before holidays and manually turn off the water heaters and trace heating. The time switches are installed alongside each water heater, which are generally not easily accessible and are fiddly to operate. However, it has since been acceptable practice to leave them on in term time as there considered to be minimal difference in energy use versus timed operation.

*It is **recommended** that the maintenance person and relevant staff are trained on legionella risks, if not already. The school should implement a holiday checklist of systems and equipment to turn down/off to make sure nothing in missed.*

7.5 Ventilation controls

Monitoring of indoor air quality and temperature, as reported in chapter 7.6, recorded that in general the indoor air quality was good (average CO_2 levels being below the recommended limit of 1500ppm), but that during winter months the temperatures were regularly dipping below the CIBSE recommended minimums.

It was apparent from observing the CO_2 monitors during class time that the trickle vents in the windows did not provide enough ventilation to keep the CO_2 levels below 1500ppm. The teachers opted to have the alarms activated on the CO_2 sensors to alert them when the level reached 1500ppm, and prompt them to purge ventilate the classrooms by opening the low and high level windows. This would typically happen when the classroom had been full for a couple of hours (i.e. once during late morning, and again in the late afternoon). Following on from the study, the school has expressed an interest in having permanent CO_2 sensors installed with traffic light alerts.

Purge ventilation of the classrooms proved effective in rapidly reducing CO_2 levels. However, during winter, this inevitably dropped the room temperature. Additionally, the classrooms are heated with under floor heating, which is slow to respond to a sudden demand for heat as caused in this instance.

It also became apparent that in their mission to keep the energy use as low as possible, the school had decided to have the heating off entirely after mid-morning which meant the temperatures could not be retained. The research team has advised that the heating should be kept on throughout the day during the winter months, in order to respond to the fluctuations caused by naturally ventilating. Ideally, radiators would have been fitted rather than the under floor heating which would be able to respond much faster to the dips in temperature.

7.6 Temperature and indoor air quality

Numerous studies and standards, such as the Building Bulletin 101 (EFA, 2006), have pointed out the importance of indoor environment conditions in classrooms for learning. The impact of thermal conditions on health and comfort of pupils, who spend 1/3 of their time in the classroom has been widely investigated. The ventilation rates and CO_2 concentration has been reported to impact concentration and is associated with symptoms such as drowsiness and headaches. Extended monitoring of indoor hygrothermal conditions and carbon dioxide concentration levels in selected spaces of the school has been carried out to assess thermal comfort and ventilation rates. Actual conditions were compared to ranges and thresholds of existing standards.

In this chapter, indoor air quality (IAQ) is used to describe air freshness, and is represented by CO_2 concentration levels only.
Occupied hours refer to school days (non-weekend, non-holidays) from 9:00 to 17:00 and hence include unoccupied periods (breaks, lunch time etc).
Indoor air temperature (IAT) in ^oC, relative humidity (RH), as a percentage, and CO_2 concentration levels, in ppm, were monitored intermittently for over a year's time, from November 2012 to February 2014. This chapter is based on data collected during winter 2012-13, winter 2013-14 and summer 2013 (May-July). The monitored spaces are marked on the floor plan in Figure 7.6.1.

Figure 7.6.1 Floor plan showing logger locations and monitored spaces: Class 1 (Foundation), Class 2 (Year 2), Class 3 (Year 3) and main Hall (PE), the Library (and the ceiling void above it), and the North Office.

7.6.1 Winter monitoring

Thermal performance: winter 2013-14

In winter 2013-14, 4 'Extech CO210' data-loggers sampled air temperature (°C), relative humidity (%) and CO_2 concentration (ppm) in the P.E. (main) hall and 3 classrooms. Data collected were divided in 2 periods. Winter 2013/14 in Staunton-on-Wye was a typical one, with external air temperature during an average day, ranging between 3 and 9 °C and averaging slightly below 6°C (Weather Underground website).

Assessing thermal performance of the building based on actual measurements of IAT (°C) and RH (%) levels for both occupied and unoccupied hours allowed the investigation of mould growth risk for the building fabric. RH in the monitored spaces exceeded the threshold of 70% (if at all) for a negligible portion of time, meaning that there was an evidently minimal mould growth risk. In agreement to that, based on IAT recordings collected from the classrooms and the main hall, from 17/1 to 12/2/2014, summarised in Table 7.6.1 and Figures 7.6.2 - 3, there was reasonably low, or no risk of condensation and mould growth. This is because, most of the time (95% of loggings), IAT did not drop below: 11.5 °C (Class 1 & the Hall), 13 °C (Class 3) and 15 °C (Class 2). The scatter plot in Figure 7.6.2 shows the combinations of RH and IAT that define the dew point temperatures for any given logging. Condensation is not likely to occur unless the dew point is as high as the internal surface temperatures of each space. Because this building is highly insulated and airtight, surface temperatures are expected to be similar to indoor temperatures. The dew point was constantly less than indoor air temperature and less than 13 °C in all spaces.

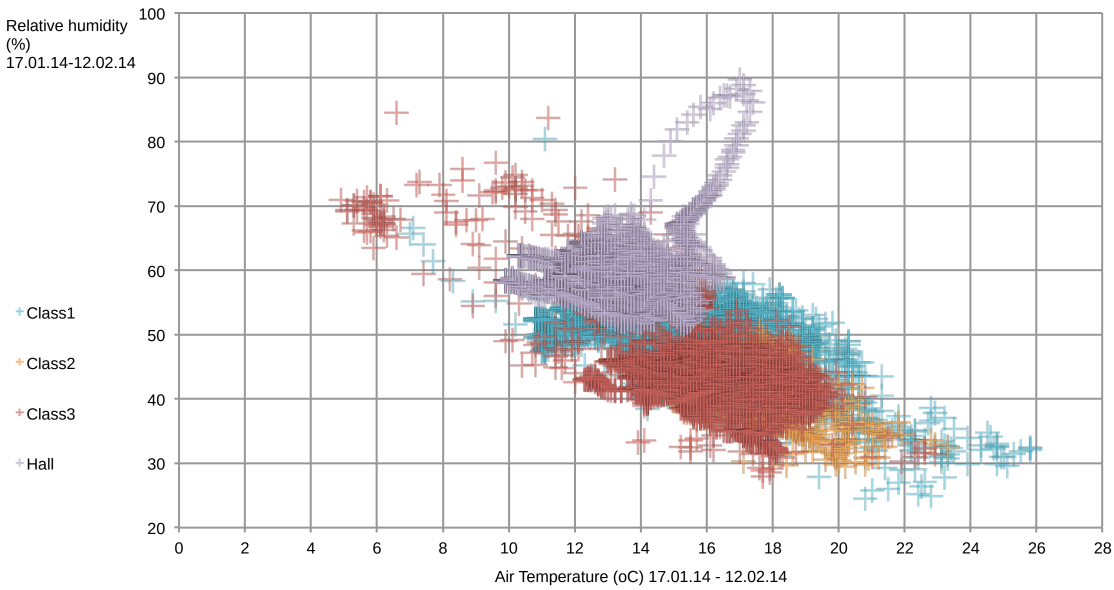


Figure 7.6.2 Scatter plot, hygrothermal conditions are described by each point, paired RH and IAT values.

The Hall was evidently colder than the classrooms, which was depicted in Figures 7.6.3-4, and also indicated in the fact that IAT averaged at 13°C in the Hall while from 15.5 °C to 16.8 °C in the 3 classrooms. 95% of the IAT loggings in the Hall were below 15 °C (Table 7.6.1). The minimum IAT recorded was much higher in Class 2 than in Class 1 and Class 3,

and the recorded temperature range was evidently narrower compared to Class 1 and Class 3. This difference, also confirmed by the 5th percentile (Table 7.6.1) and Figure 7.6.4, can be attributed to the location of the classrooms on the plan (Figure 7.6.1). Class 1 and 3, located on the east and west end of the building, have twice the exposed wall area of Class 2 and probably greater glazing area and window frame length. Class 2 is the middle class, with only one wall exposed to external conditions and the adjacent spaces acting as a buffer zone to the external conditions. Consequently, monitoring confirmed that greater heat loss occurred in Class 1 and Class 3 than in Class 2. In relevant reports, a detailed analysis of the loggings, the driving forces behind this were discussed.
The wide air temperature ranges in the 3 classrooms, are likely to be the result of increased ventilation rates during breaks, when the classrooms are unoccupied. When children go back inside, windows are closed, and the classroom quickly warms up because of high occupancy internal gains and well insulated building fabric.

Table 7.6.1 *Summary of IAT (^oC) loggings for the January-February 2014 monitoring period.*

Air temperature (^oC)	Class1	Class2	Class3	Hall
Mean	15.5	16.8	16.0	13.1
Min	7.0	14.4	4.9	9.9
Max	25.8	23.3	22.9	17.4
Median	15.6	16.8	16.3	13.1
Standard deviation	2.3	1.2	2.0	1.2
1st quartile	14.1	16.2	15.1	12.3
3rd quartile	16.7	17.5	17.3	13.8
95th percentile	19.2	18.7	18.5	15.2
5th percentile	11.8	14.9	12.7	11.4

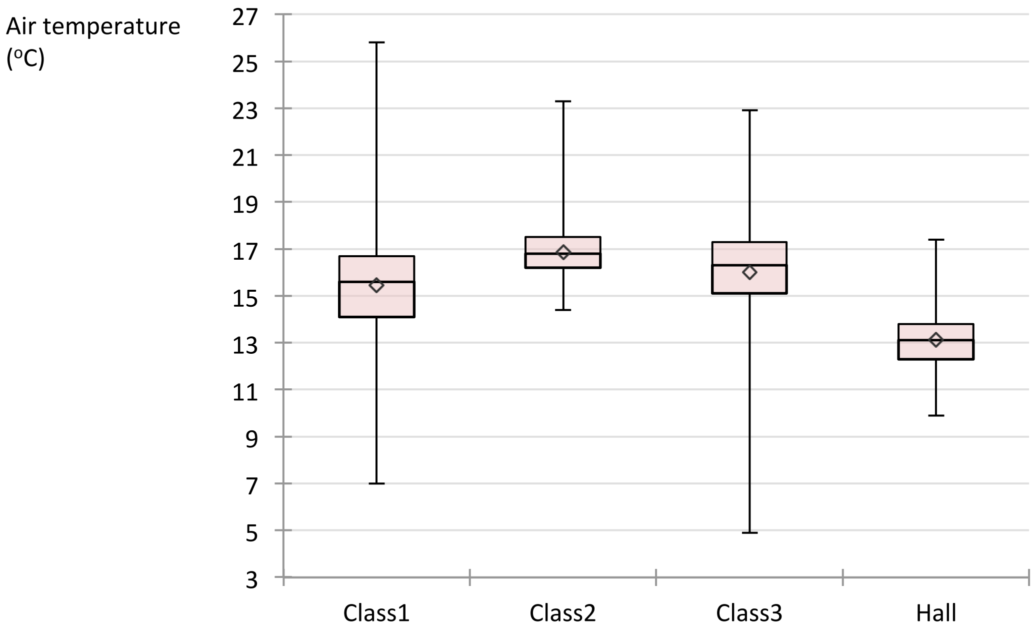


Figure 7.6.3. Air temperature (^oC) box plot: showing Averages, Quartiles and Ranges for 4 loggers, 2nd logging period 17/1-12/2/2014. This graph includes data loggings from both occupied and unoccupied hours.

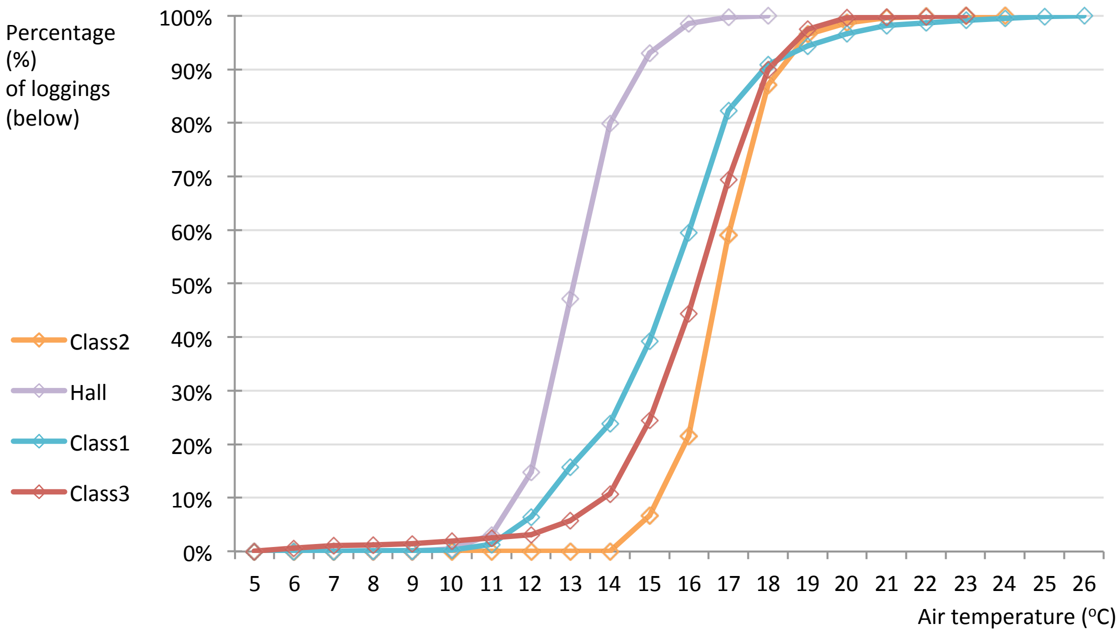


Figure 7.6.4 Air temperature (°C) cumulative distribution: 17/1-12/2/2014.

Thermal comfort: winter 2013-14

IAT and RH loggings during occupied hours (weekdays 9:00-17:00) were isolated to assess hygrothermal conditions in terms of thermal comfort. The vast majority of IAT loggings were below the CIBSE threshold of 21°C for Foundation classrooms and 19°C for other classrooms (Table 7.6.2). None of the classrooms met the CIBSE criterion for thermal comfort, which meant that occupants were likely to vote towards the “cool thermal sensation” in the ASHRAE scale, almost all the time. IAT in the P.E. Hall, remained between 12 and 15 °C for 90% of the occupied time. The hall is multifunctional, as it is used for P.E. classes, assemblies, dining etc, hence the comfort range may be difficult to define. Not very different from the actual monitored range, the CIBSE Guide A comfort range for sport halls, is 13 °C - 16 °C, which makes sense for a space occupied by a high number of occupants (lunch break) or occupants at high metabolic rates and therefore high internal gains. Air temperature samples in the P.E. Hall did not reach the lower comfort threshold for classrooms (19 °C) while a 24.5% of the loggings during occupied hours was below 13 °C.

Class 2 was marginally the best performing classroom in terms of thermal comfort, with the highest minimum, and 5th percentile and with the narrowest range (most stable IAT) among the classrooms (Table 7.6.3 and Figure 7.6.5). More evidence for this can be found in previous more detailed reports. Previous reports observed indicators of high heat loss through fabric or infiltration during unoccupied hours, in Class 1.

RH exceeded 70% only in Class 3 for an insignificant percentage of occupied time (Table 7.6.4). However, RH below the thermal comfort threshold of 40% was recorded for considerable portions of time in the classrooms. RH in the Hall, remained within the comfort range all the time.

Table 7.6.2 *Percentage of loggings during occupied time below 19°C and 21°C.*

	Class 1	Class 2	Class 3	Hall
Percentage of loggings below 19°C	79%	86%	90%	100%
Percentage of loggings below 21°C	93%	99%	98%	100%

Table 7.6.3 *Air temperature (°C) summary for occupied hours, 17/1-12/2/2014.*

Air temperature (°C)	Class1	Class2	Class3	Hall
Mean	17.6	17.7	16.0	13.6
Min	7.4	14.7	4.9	10.1
Max	25.8	23.3	22.9	15.8
Median	17.1	17.6	16.9	13.8
Standard deviation	2.3	1.3	3.3	1.1
1st quartile	16.5	16.9	15.6	13.0
3rd quartile	18.4	18.4	18.1	14.3
95th percentile	22.0	20.2	19.3	15.3
5th percentile	14.4	15.7	8.1	11.9

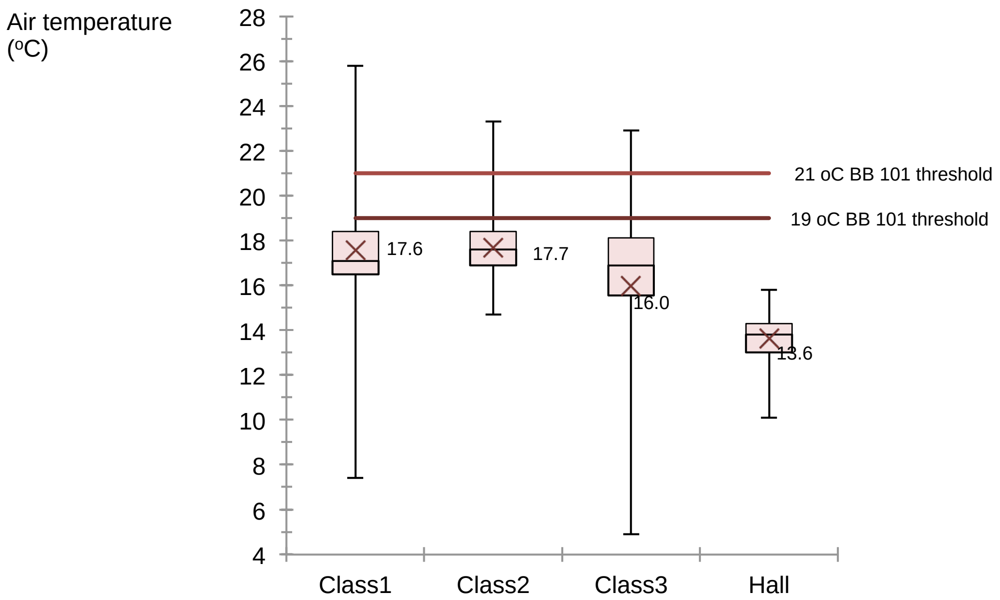


Figure 7.6.5 Air temperature box plot (Averages, Quartiles and Ranges for 4 loggers, occupied hours, 17/1-12/2/2014. The horizontal lines represent the Building Bulletin 101 thresholds at 19 °C and 21 °C for classrooms.

Table 7.6.4 *Percentage of time RH (%) was outside the comfort range, occupied hours, 17/1-12/2.*

Relative humidity (%)	Class1	Class2	Class3	Hall
% of time RH(%) was below 40%	11%	30%	22%	0%
% of time RH(%) was above 70%	0%	0%	4.6%	0%

Indoor air quality: winter 2013-14

Overall, collected data showed that the CO_2 levels were more than satisfying in all spaces, as IAQ conditions evidently complied with the Building Bulletin 101 (BB101) requirements based on all 3 criteria for the average, peak and immediate recovery (Tables 5.3.5-6 and Figure 7.6.6). More details on this can be found in the report in the Appendices. On average, and also based on Table 5.3.6 percentages, Class 3 was the best performing space in terms of IAQ. However, the highest CO_2 concentration peak was also recorded in Class 3. Finally, based on Table 7.6.5 and Figure 7.6.6, Class 2 was likely to perform better than Class 1 in terms of IAQ. This fact in combination with higher IAT peaks in Class 1, indicate low ventilation rates when occupied. In addition, Class 2 maintains adequate ventilation rates and IAQ while maintaining relatively high IAT. This, however, is not the case with Class 3.

Table 7.6.5 *CO_2 concentration summary, occupied hours, 17/1-12/2/2014*

CO_2 concentration (ppm)	Class1	Class2	Class3	Hall
Mean	879	805	697	789
Max	1516	1505	1734	1691
Standard deviation	205	256	231	260
1st quartile	730	597	504	570
Median	882	764	625	754
3rd quartile	1017	989	854	948
5th percentile	542	467	428	464

Table 7.6.6 *Percentage of occupied time, CO_2 concentration (ppm) exceeded thresholds, 17/1-12/2/2014.*

	Class1	Class2	Class3	Hall
% CO_2 loggings >1000 ppm	28.9%	24.3%	12.6%	20.7%
% CO_2 loggings >1200 ppm	5.6%	8.9%	2.8%	8.2%
% CO_2 loggings >1400 ppm	0.5%	1.3%	0.1%	2.7%
% CO_2 loggings >1500 ppm	0.1%	0.1%	0.1%	1.5%

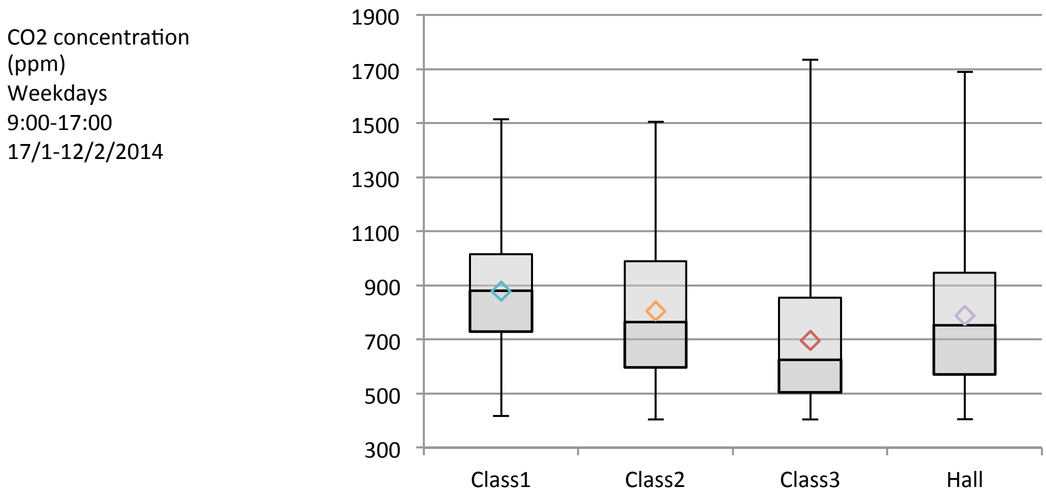


Figure 7.6.6 CO_2 concentration (ppm) box plot showing the averages, quartiles and ranges, for the logging period 17 January-12 February 2014, in Staunton-on-Wye Primary School.

7.6.2 Summer monitoring

Summer monitoring of the IEQ (1st May to 5th July 2013) took place in Class 2 and Class 3, using EXTECH CO210 loggers. For the monitoring of IAT and RH in the Office, the main Hall, the Library and the ceiling void above it in summer 2013, a different type of data logger was used.

None of the spaces were likely to overheat in summer occupied hours according to CIBSE static criteria, as IAT did not exceed 28°C (Table 7.6.7). However, the upper threshold of CIBSE comfort range of 21-23°C for primary schools was exceeded in approximately 6% and 8% in the classrooms, 13% in the Library and 10% in the ceiling void above, 22% in the Office and 27% in the Hall. The highest percentage of loggings above the upper comfort threshold was recorded in the Hall, which could be attributed to the high occupancy numbers/metabolic rate activities (e.g. during lunchtime). Higher was the percentage of loggings below the lower comfort limit 21°C for all spaces. The difference is more evident for the classrooms where almost half the loggings in both classrooms were 21°C.

The upper threshold of RH comfort range (70%) was exceeded for a negligible amount of time, whereas, a considerable percentage of the loggings recorded RH below 40%, the lower threshold. This indicated a high risk of static shock risk (according to CIBSE Guide A) for one third of the occupied hours in both classrooms. Class 2 could be considered to perform marginally better than Class 3, in summer, with more loggings inside the comfort range. Additionally, as shown in Figure 7.6.8, RH distribution range was evidently narrower than the ranges of all occupied spaces, potentially due to absence of human activity or thanks to the ceiling tile material.

***Table 7.6.7** IAT and RH summary, May -July 2013, School days 9:00-17:00.*

Air temperature (°C)	**Class 2**	**Class 3**	**Ceiling void**	**Library**	**Hall**	**Office**
Mean	20.9	21.0	21.3	21.4	21.7	21.9
Min	16.4	16.6	17.4	17.5	16.2	17.8
Max	24.7	25.3	24.2	25.6	25.2	25.1
Percentage above 28°C	0%	0%	0%	0%	0%	0%
Percentage above 23°C	5.7%	8.1%	10.4%	13%	27.2%	22%
Percentage below 21°C	47%	50%	34.5%	37.6%	29.8%	25.6%
Relative Humidity (%)						
Mean	45	45	46	47	47	45
Min	20	19	40	32	29	35
Max	63	70	57	66	68	59
Percentage above 70%	0%	0%	0%	0%	0%	0%
Percentage above 60%	0.7%	3%	0%	2.3%	2.1%	0%
Percentage below 40%	25.7%	30%	0%	5.9%	8.8%	9.3%

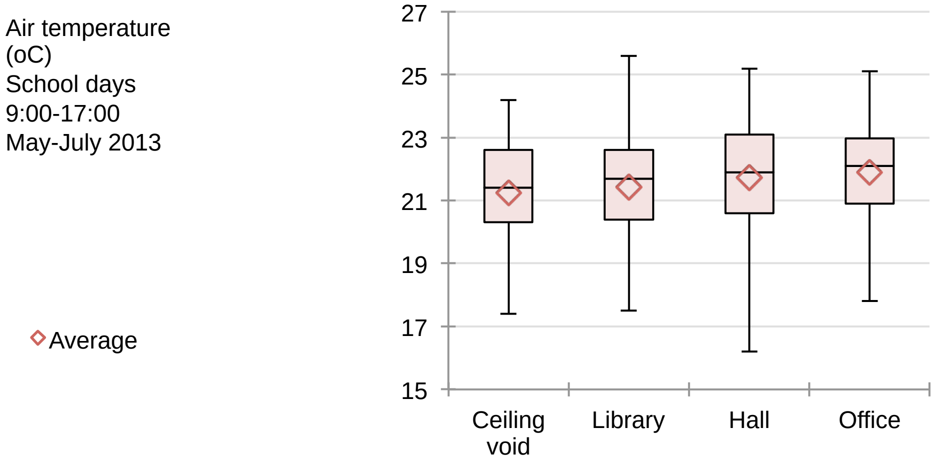


Figure 7.6.7 Air temperature (°C) box & whiskers plot, occupied time, May-July 2013.

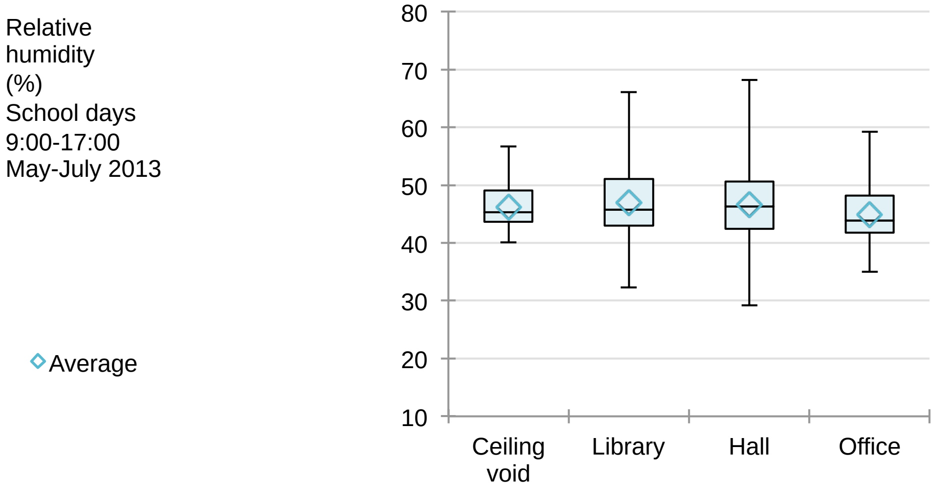


Figure 7.6.8 Relative humidity (%) box & whiskers plot, occupied time, May-July 2013.

Loggings during occupied hours showed that peak CO_2 concentrations in each classroom were within the acceptable levels and averaged considerably low (Figure 7.6.9). Table 7.6.9 shows high peaks but low averages of CO_2 concentration levels. Surprisingly, CO_2 peaks in summer were higher than CO_2 peaks in winter, but there is no evidence that the overall IAQ was worse in summer than in winter, in any of the classrooms. This could be attributed to higher metabolic rates of pupils in summer after breaks combined with higher ventilation rates. A typical week is plotted in Figure 7.6.10 and Figure 7.6.11 shows carbon dioxide concentration during a typical day, in June 2013. During this week higher spikes are observed in Class 2.

***Table 7.6.8** CO_2 levels (ppm) summary, May - July 2013, occupied hours.*

CO_2 concentration (ppm)	Class 2	Class 3
Mean	674	735
Max	2573	3507
Percentage above 2000	**0.8%**	**3.6%**
Percentage above 1500	3.2%	8.8%
Percentage above 1000	13.1%	18%

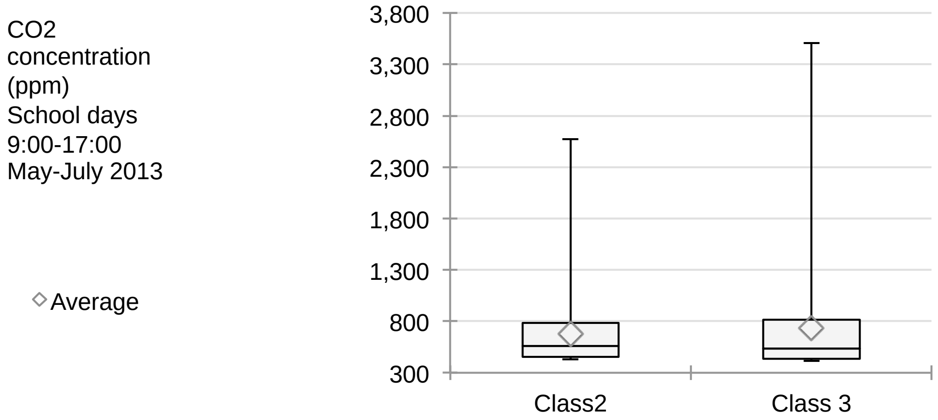


Figure 7.6.9 CO_2 concentration (ppm) box & whiskers plot, occupied time, May-July 2013, Class 2 and Class 3.

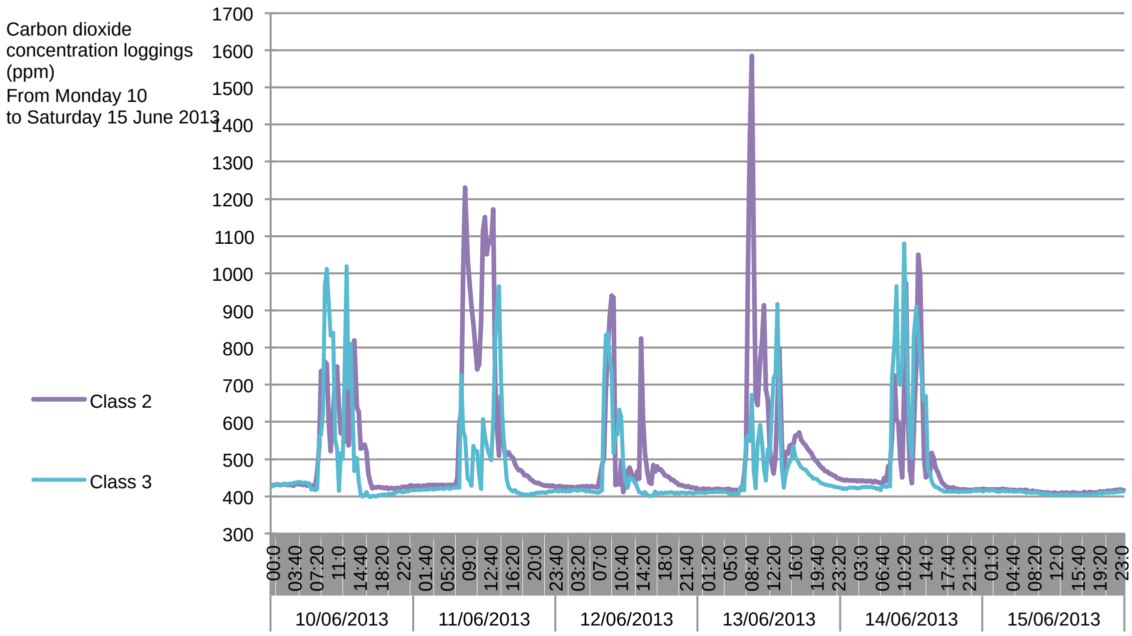


Figure 7.6.10 Carbon dioxide concentration (ppm) during a typical week in summer 2013 in class2 and class 3 (loggings at 20' intervals).

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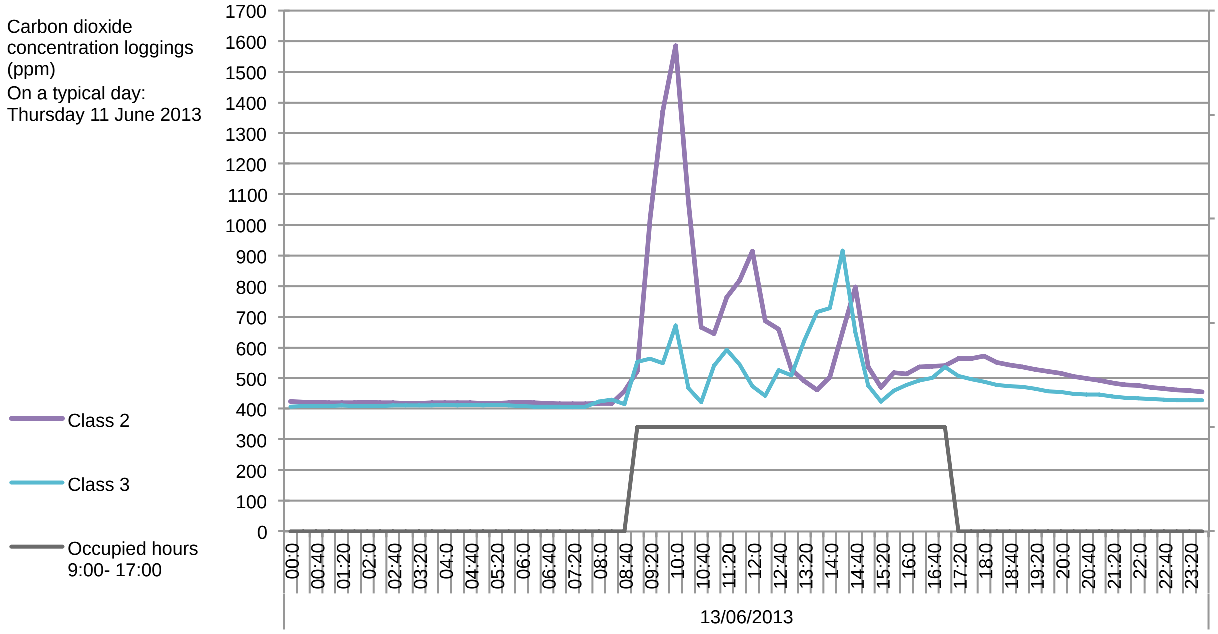

Figure 7.6.11 Carbon dioxide concentration on a typical summer school day, Class 2 and Class 3.

7.6.3 A note on materials and Relative Humidity levels

The original choice of internal materials and building construction were informed in part by the belief that they would contribute to a healthy indoor environment. In particular:

- the breathable construction of the external walls and roof (a build-up which allows vapour to pass from one side to the other), and
- the use of wood wool ceiling tiles in the main spaces.

The ceiling tiles are promoted by their manufacturer's (Troldekt & Heraklith) as having hygroscopic properties, being able to absorb and release atmospheric vapour on a cycle to help maintain healthy RH levels. It was intended that this study would attempt to empirically prove the benefit brought by these elements to the indoor environment, however it became evident that this level of specific data was beyond the possible scope of this project team from an expertise, and budgetary point of view. In the first year of data logging, an RH monitor was placed in the library area, and another within the ceiling void above, in order to monitor the difference either side of the wood wool. The results of this monitoring can be seen in the reports from 2013 in the appendices. There was a significant drop on the figures being recorded in the ceiling void which suggests that the ceiling tiles were contributing to the RH levels in the library. This is the only evidence which the team was able to gather which does suggest that there is a link between the excellent RH levels being recorded around the school, and the choice of materials used in the original design.

Conclusions and key findings from Indoor Air Quality monitoring

The main conclusions for winter IEQ in the primary school based on monitoring, were:

- In terms of IAT, none of the classrooms satisfied the CIBSE requirements for thermal comfort, with 80% or more of the air temperature loggings below 19^{o}C during winter 2013-14 because of user control. This meant that occupants were likely to feel thermally uncomfortable most of the time.

- In terms of IAQ, on the other hand, all monitored spaces showed excellent performance, based on monitored CO_2 concentration levels. Because all classrooms outperformed the (CIBSE Guide A, Building Bulletin 101) requirements in terms of CO_2 concentration during occupied hours, it is reasonable to consider reducing intended or unintended air exchange rates in the spaces in winter.

- RH levels in winter remained within the CIBSE limits most of the time, scarcely or never exceeding the upper threshold of 70%.

- The middle classroom (Class 2) performed better than Class 1 both in terms of thermal comfort and IAQ in winter. In addition, IAT range recorded in Class 2 was significantly narrower than the one observed in the other classrooms, where IAT dropped considerably. The middle classroom could be most appropriate classroom for the Foundation class, which has a higher IAT requirement.

- At night, IAT in Class 1 typically dropped below Class 2 IAT while it peaked higher than Class 2 during occupied hours. This indicated higher nighttime heat loss in Class 1 and better thermal performance in Class 2 (which could be attributed to the different exposed wall and glazing areas and window/door frame length).

- In Class 3, the air temperature patterns did not match the ones in the other two classrooms, indicating irregularly increasing ventilation rates. These could be attributed to the classroom door being near a school exit door, possibly increasing draught.

The main conclusions for summer IEQ, based on data collected in May-July 2013, were:

- IAT did not exceed 28^{o}C (BB87 & BB101 threshold) in any of the monitored spaces. There is minimal summertime overheating risk in Class 2 and Class 3. Class 3 is more likely to be perceived as “too warm” by the occupants in summer, compared to Class 2. Additionally, occupants are likely to feel “too cold”, for approximately half the time in both classrooms, during summer, based on the CIBSE comfort range of 21-23^{o}C. Class 2 had a higher percentage of loggings within the comfort range and could therefore be considered to perform marginally better than Class 3.

- Minimal summer overheating risk was also observed for the library, the hall and the office. These spaces averaged between 21-22^{o}C. The occupants in these spaces were more likely to feel too cold than too hot, based on the CIBSE comfort range of 21-23^{o}C.

- RH did not exceed 70% in any of the monitored spaces, including: Class 2 and Class 3 , the Office, the Hall and the library. RH loggings below 40% indicated a high static shock and dry-eyes-effect risk, according to CIBSE Guide A, for 1/4 and 1/3 of the occupied hours in Class 2 and Class 3 respectively.

- IAQ in summer was acceptable with the CO_2 concentration averaging considerably low, and with peaks in each classroom within the acceptable levels. Class 2 performed better than Class 3 in terms of summer IAQ as in Class 3, 9% of the recordings were above 1500 ppm, almost 3 times the percentage in Class 2 (3.2%).

Overall, the IAQ levels are satisfying and outperform current BB requirements. Most spaces are likely to feel towards "too cold" in winter and there is minimal overheating risk in summer. Also, Class 2 performed better than Class 3 both in terms of thermal comfort and IAQ both in summer and winter.

7.7 Lighting

The external lighting was designed on a daylight sensor and 7 day time clock in the hall cupboard. This allowed the lights to come on in the morning / evening at a time set on the time clock and turns on / off according how bright it was outside. However, the school had difficulty using the 7 day timer and found the lights being left on overnight. The school then opted for a manual push button with overrun timer on exit for the car park lighting during the initial TM22 period.

The external lighting was correctly designed for the purpose and could have benefitted from an exit switch in the reception to override the time clock.

The time clock was the main issue for the failure of the system as the user found it difficult to operate. The time clock was the same one as installed for the water heaters. A simple 7 days digital timeclock may have proven a better solution.

The training hall lighting was adequate for the purpose of lighting the hall however it would have been beneficial to have installed dimmable lighting and control to set different levels for different uses in the hall e.g. school plays.

7.8 Fabric performance (thermal imaging findings)

Background:

Thermographic imaging has been used in previous studies to identify weak points called "thermal anomalies" in buildings. The images show false-colour temperature variations of the surfaces photographed, based on the level of infrared radiation they emit. The images can help to identify vulnerabilities in the envelope detailing (thermal bridging), flaws in construction (infiltration and missing insulation), maintenance issues (water penetration) and poor operation (open windows in winter).

The images give a relative indication of thermal performance, however they are subject to certain conditions, and even if conducted and analysed rigorously, are unlikely to give readings of building facades to less than 1.5 ^oC accuracy.

Internal thermal effects such as rooms being heated unequally could influence the images, making some windows appear warmer than others. This does not necessarily indicate that the windows are underperforming, but could simply indicate the room is being heated to a higher temperature.

Thermography is also sensitive to the ambient air temperature, emissivity of the target material, distance between the camera and the subject, and the relative humidity of the air. These factors will affect the actual numerical surface temperature perceived by the camera when conducting a detailed quantitative analysis. Surface colours can also affect the superficial surface temperatures, as research has documented that thermographic images can detect the difference in thermal absorption and emissivity due to surfaces having different colours. A comparative, visual-spectrum image, will help to account for this, when documenting building envelopes.

Analysis

Nick Grant of Elemental Solutions and Tom McEwen of Architype Architects conducted a walk round and through Staunton on Wye Primary school on the morning of 16/01/13 at 06:30am. The extent and scope of the survey was for the purpose of detecting any areas where the thermal performance of the envelope might be compromised and resulting in a performance worse than designed.

The full report is available in the appendices and consists of a series of relevant thermal images highlighted and analysed with the FLIR reporting software, each with relevant normal photograph, and explanation / description of the images.

The following points summarise the main findings from the survey:

1. Overall the building appears to be largely free of problematic thermal bridges other than doorframes and to a lesser extent windows. However only the doors appear to be at risk of causing condensation issues. Note; this issue was discussed with the head-teacher, who reported that there was not a problem being caused by condensation forming on the aluminium doors and felt there was no intervention necessary.

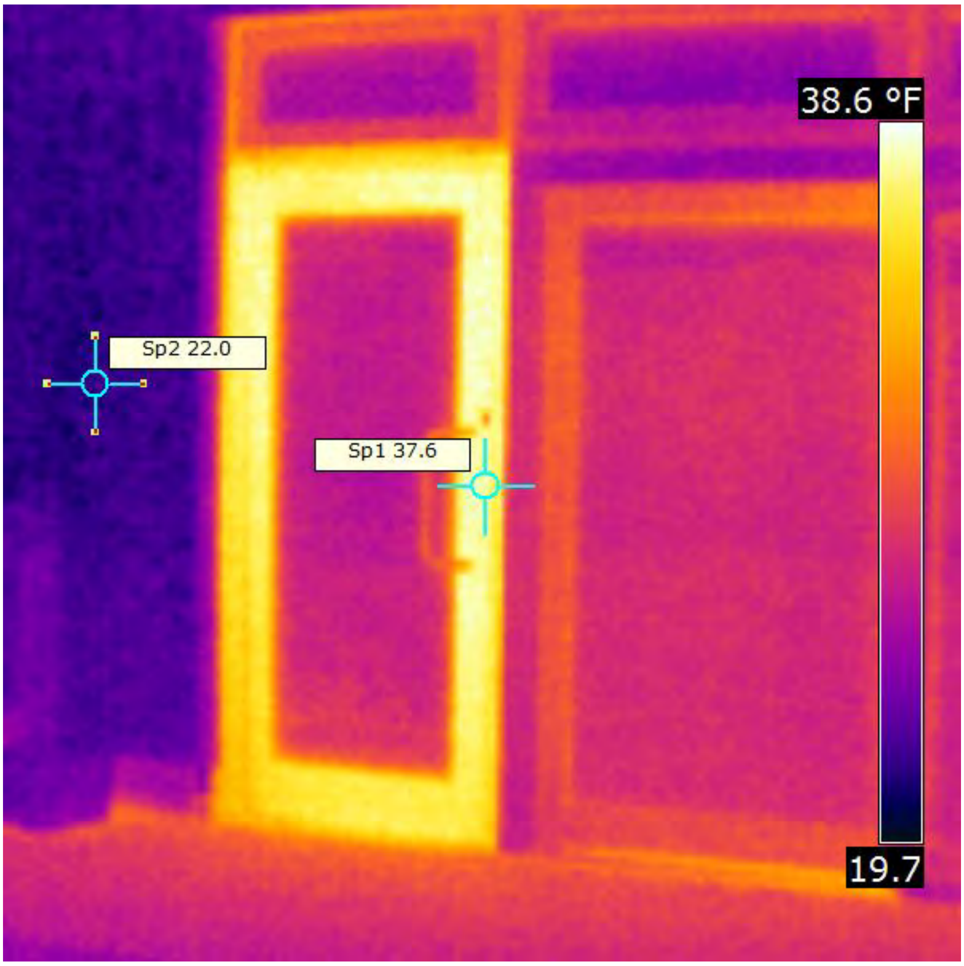

Figure 7.8.1 Poor thermal performance of aluminium door frames highlighted during thermal imaging survey

2. Some general weaknesses were found at junctions and these may be due to structural thermal bridges or simply less than perfect insulation installation. Some heat loss due to air movement is also suggested by the images although detailed diagnosis would require further investigation. Other images taken during windy weather (previous visit) showed more exaggerated effect suggesting that wind tightness could be less than perfect in some places.

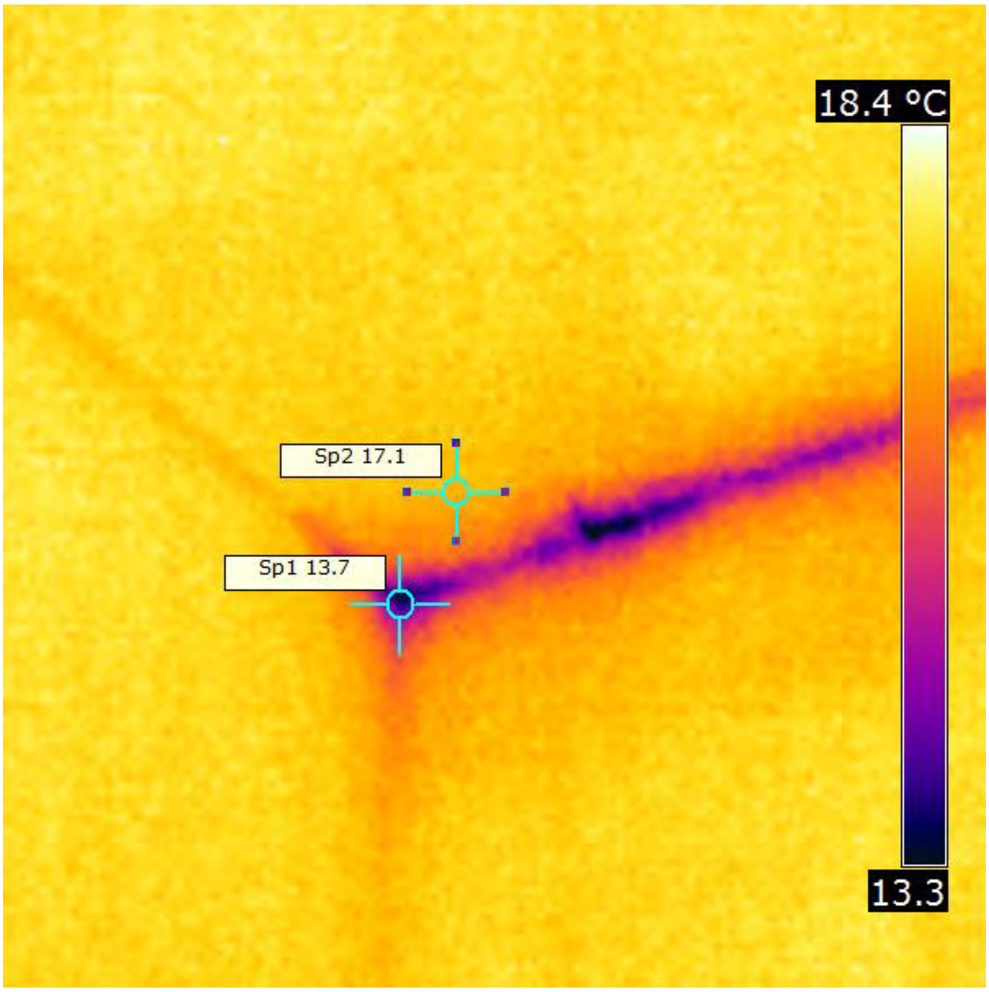

Figure 7.8.2 Thermal image showing probable air leakage at Ceiling/wall junction

3. Depressurisation to check specifically for air leakage was not undertaken and the lack of wind meant that the stack effect was dominant. Air leaks at high level would either not show or would appear as warm due to escaping warmer air as seen at the trickle vents.

Full details and further analysis from the Thermal Imaging survey can be found in the Appendixes.

7.9 Conclusions and key findings for this chapter

The key findings and recommendations for this chapter can be summarised as follows:

- An effective commissioning period is required to thoroughly test and refine all the systems to perform ‘as designed’ before the occupiers move in.
- Some staff did not have a good understanding of how to control their environment and systems effectively leading to reduced indoor air quality and unnecessary energy use. A period of demonstrations to all the building users would have greatly benefitted the staff and overall building performance.
- A balance has to be met between energy use and a comfortable environment and should be discussed with key members of staff during demonstrations / soft landings.
- Care should be taken in value engineering a project not to lose sight of the original design intent as this can compromise the building performance and environment.
- The original brief must identify all of the different uses of the buildings e.g. different uses of buildings and out of hours use.

8 Key messages for the client, owner and occupier

8.1 Key messages for the occupier

8.1.1 Heating control.

It is recommended to run the biomass boiler under the control of the BMS. This will benefit the school for the following reasons:

- BMS control will allow the pre-school to have heating when they need it most and it will then not be dependent on the main schools heating routine.

- Opening windows in the heating season increases heat demand on the boiler but improves the indoor air quality. The boiler time set points should be configured to reflect when the windows may be opened e.g. between 9am and 3:30pm.

- BMS control will allow frost protection for the building and for the boiler in adverse weather conditions i.e. a cold snap in September.

The pre-school now has some control of the buildings heating set points and times. However, the main school has overriding control of these to check the building is not being heated when not needed. However, the main school must consider the needs of the pre-school, especially as the heating is now metered separately and it is possible to account for the actual energy use.

8.1.2 Equipment out of hours energy use

Turning off equipment over holidays. The user can create an “equipment turn off” checklist for which equipment is to be turned off and when i.e. summer holidays. Labelling the switches will assist people in turning off the correct equipment.

8.1.3 User guides

Print, laminate and display the new ‘User Guide’ documents, produced during this BPE study, these should be kept in a visible location in each occupied room. When new or temporary staff are inducted, these documents should be pointed out as a quick guide to the correct usage of the building.

8.2 Further work for consideration by the occupier

8.2.1 Classroom environment – natural ventilation

Consider investing in permanent CO_2 sensors for the classrooms, for instance ‘traffic light’ type sensors which display a red light when the levels get above a set point. Whilst the findings from this study could be used to inform a ventilation regime for the winter months, this would be dependent on outside air temperatures and the teachers sticking to the regime. The traffic light alert would provide a visual reminder to the teacher whenever required, and would provide a reliable prompt in enforcing the guidelines shown on the classroom user guide. These alerts are fairly common place in a number of newer schools now so are widely available and easy to install. The alarms on the data loggers were popular with the teachers in alerting them to the CO_2 levels, and proved to be a positive tool in establishing a 'better' air quality (or lower CO_2 levels). The data loggers are still in place in the classrooms, at the request of the head teacher, however, they are intended to be temporary and the alarms are not as appropriate for a classroom as a light system would be.

8.2.2 Classroom environment – mechanical ventilation

Mechanical ventilation heat recovery (MVHR) could be considered as an alternative to the natural ventilation traffic light system as this can reduce classroom CO2 levels and minimise heat losses through open windows. The system operates by recovering heat in the exhaust air to temper the fresh air and can be up to 90% efficient. There are several units on the market that offer compact and affordable solutions that could be installed in the classroom bulkheads. A cost-benefit analysis should be carried out if this is to be seriously considered, however it is unlikely to prove financially viable and the school internal environment is presently performing well.

8.2.3 Storage

Extra storage capacity could be gained by building fixed furniture in the classrooms. The lack of storage space was raised as being an issue in the BUS (though not rasied before this), and it is felt by the research team that there are a number of corners which could be better utilised with fixed cabinetry to provide additional storage capacity.

8.2.4 Engagement of end user in energy use and internal environment

Continue to engage the staff and pupils with the energy use, and indoor air quality of the school, as they have been through the period of this BPE study. For instance, data loggers could be retained in the classrooms to enable the children to record the trends of air quality and remain aware of the need for ventilation and heating.

8.3 Key messages for the design team

8.3.1 Estimating operational energy performance at design stage

It is recommended that an estimate of the total building operational energy use at the design stage, such as a TM54: Evaluating operational energy performance, or TM22: Energy assessment and reporting methodology. This offers a better prediction of operational energy use compared to the typical building regulation Part L calculations. This also engages the client and the design team to consider in detail, how the design, operation and small power equipment will influence the running costs and building emissions of the building at an early stage.

8.3.2 Evaluating in-use operational energy performance

The TM54 and / or the TM22 can also be used to evaluate the in-use energy use by reviewing energy meter readings, provided these are available. The in-use data can be compared to the design prediction to understand how accurate this was, and also to see if the building use and controls deviate significantly from the predictions. Any items of unexpectedly high energy use can be identified and investigated, with possible interventions offering improved performance and energy savings.

The in-use energy assessment methodology can be performed periodically e.g. annually or every other year, to establish the performance of the building and make interventions where necessary. It is also a good tool to understand if the interventions were effective.

8.3.3 Commissioning

It is recommended that a specific period is set aside specifically for the commissioning of the building and the mechanical and electrical systems. This should be before practical completion and the building should be free of the other trades to allow the building to be commissioned most effectively. Often, the commissioning period is a rushed process as all the trades are trying to complete work for handover and this can result in a number of teething problems when the occupants move in.

The process of seasonal commissioning is also recommended as it allows the building systems e.g. heating, air conditioning, ventilation, lighting, and controls in general to be tuned according to the season.

8.3.4 Soft landings

The soft landings process is recommended following building handover to the client. This process helps the building to be fine tuned and de-bugged, and ensures the occupiers understand how to control, maintain and best use the building . This involves the design and construction team remaining involved in the project for the first few months of operation and beyond (typically 18 months).

8.3.5 Boiler selection

The boiler selection was driven by the client who wanted a low carbon building that was off the natural gas grid. Biomass was an attractive option as it met the criteria and grants were made available to make it a financially viable option. However, this may not have been the best solution for the school based on the information that is known now i.e. independent buildings with different control regimes. A renewable feasibility study was completed in the design stage and this assisted the design team and client in making an informed decision based on payback period and carbon savings. However, an alternative selection such as LPG boilers or heat pumps may have been more suitable.

8.3.6 Heat emitter selection

The school uses underfloor heating in many areas of the school however this was not ideal for all space. In the pre-school a faster response system would have been more beneficial due to how the space is used i.e. doors regularly open to outside to allow the children to run between spaces.

8.3.7 Hot water

Hot water can use a large proportion of the total amount of energy and the system should be carefully selected to provide a lowest energy solution while minimising risk of legionella.

8.3.8 Lighting control

Lighting control needs to be carefully considered by the client and design team while also meeting the requirements of Part L. Part L is continually driving down the overall energy targets and lighting is typically the largest consumer depending on building type. Daylight control and energy efficient fixtures have a big impact on reducing the overall building emission rate and is now the notional classroom for which the TER is determined, and for which the BER compared against .This conflicts with the school's feedback for simpler controls as it believed this would help educate the children to be more energy conscious in learning to turn light switches off when they are not needed. This manual control of the lighting would be penalised in Part L calculation with a worse BER, and may lead to the requirement for additional measures to reduce the BER, such as photovoltaics.

8.3.9 Storage

Storage has proved to be a contentious point at the school. Although there was a clear brief being followed in the areas allowed for in design, it could be prudent to make stand-by provision for this common 'sticking point'.

8.3.10 Metering

The schools metering strategy could have been more robust and it would have been beneficial if items such as external lighting, the hot water generators, servers and WCs fans were metered individually from the outset. The school would then have had the ability to interrogate energy use should they find they are using more energy than expected.

9 Wider lessons

9.1 Internal environment

A building with good airtightness and natural ventilation will have a build-up of CO_2 unless fresh air is introduced into occupied spaces i.e. opening windows. This has to be balanced with the heating to ensure that the occupants are not uncomfortable. Staunton has flagged up slight issues around using underfloor heating alongside natural ventilation. The indoor air quality data logging undertaken for this study identified that in order for CO_2 levels in classrooms to be kept at an acceptable level, 'purge' ventilation was required during winter months when the windows were generally kept closed or nearly closed. This has the effect of quickly lowering classroom temperatures, sometimes to below the minimum temperature recommended by CIBSE. Although the temperatures do come back up, the slow response of underfloor heating is slow compared to what a conventional wall mounted radiator would be. The school boiler operating times also had a large influence on this.

9.2 Risks associated with Value Engineering

Secondary to the point made above is the consideration which must be given to the impact of decisions made during the VE (Value Engineering) process. The issue discussed above would have been avoided if the original intention of using mechanical ventilation heat recovery for winter ventilation had not been VE'd out at around RIBA Stage E. It is difficult to speculate at this stage, so long after the event, as to whether full design consideration was given to the knock on effects of this VE decision (we must presume it was), but in retrospect, it is worth noting that the original ventilation intent would have been better suited to the heating system installed.

9.3 Soft landings and post occupancy evaluation

Soft landings and post occupancy evaluation can be a valuable tool in the smooth running of a new school building. Many of the issues raised through this study were being ignored for the year before the study started, and only drawn attention to once an informal 'soft landings' begun. These could have been dealt with straight away if a Soft Landings programme had been included in the contract.

More time should have been put aside for systems commissioning and explaining how the systems work to the end user to ensure effective usage in the first instance. Simple things like the clear labelling of switches and levers have improved the overall user experience of the building.

A post occupancy evaluation is also valuable to the designer to see first hand if their design is working as intended, how the building occupants react to the design and if there are lessons that can be taken for future projects.

9.4 TM22 energy assessment methodology

The TM22 is a good methodology for assessing the in-use energy performance of a building and in particular investigation any unusual energy loads. This can lead to significant energy savings in replacing inefficient equipment or rectifying bad operational practice. The TM22 methodology is dependent on good metering data and/or accurate assumption for equipment loads and usage profiles and these can honed with greater experience and understanding of the process. TM22 training is essential in setting up an accurate TM22 for a building.

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10 Transcript from Close Down Meeting with the Head Teacher

On the 7th October a concluding interview was held with Pippa Lloyd, the head teacher at Staunton, with an aim of summarising the outcomes of the TSB study from the school's perspective. The following is a verbatim transcript from this meeting which include some valuable lessons from the study and provide a fitting conclusion to this report.

Do you think that this kind of BPE should be included in new school building contracts?
Yes, it's amazing that it isn't always. It should be in every building, otherwise, you are not going to learn any lessons, are you? I can't understand why it isn't always.

And to the extent of this one?
I do not think it needs to be that long, but I think if it was built-in right at the beginning it would tighten up all processes and it might help avoid some problems before they even happen in the first place. What I mean is, silly things, like the reasoning behind using high-tech things. I know that is not quite what this project was about, but we are using high-tech mechanisms, which do not educate children how to use less energy. We do not want automatic switches: we want to teach children to switch the light off, to switch water off, and having all this high-tech gadgetry is not necessarily what we want in a school, if you are going to educate the children to be socially responsible. That might be a message that architects got, if they got feedback for every building they built. I appreciate not every school has as much input as we did, cause usually school buildings are not built by schools, they are built by local authorities. And so, I ask myself, would it be as meaningful, if a school building was built by the local authorities.

This type of BPE study, would have to be engaged with the teachers.
Yes, exactly. They are paying for the business, but they are not involved. If they are not involved in the feedback, then they are going to make the same mistakes over and over again, when commissioning other buildings, because they would not be aware of the mistakes that they made. They ought to be involved. Otherwise, the architects make the same mistakes, and so do the local authorities.
But, yes, I am surprised this is not always the case.

In your opinion, what have been the standout benefits of this study?
Dealing with problems that we had was obviously a really important thing, like the heating issues we had. Making staff more aware of the building and engaging staff has also been very useful. CO2 stuff has been great in teaching the children about indoor air quality.
Will the school keep this element of awareness?
Yes, I hope so. The User Guides are going to help with that. Even though we are actually quite a stable staff here, a teacher and I am about to leave, so the user guides are a useful thing to have to remind people how to do things.
Even though these building user guides are quite simple, a quick glance?
Yes, because this is all you need, really, just a reminder, like this.

What advice would you give to other head teachers involved in a new school building project?
If you have the opportunity, be involved, from day one, through to completion. Because most head teachers do not have a say in building of their school, they are given a completed building and for that building to be "the school" they have to be involved in the design and in every element really. So, push away into the design. It can be done, it probably is hard work, but it should be done. Because the school, is for children and teachers, not for the local authorities. I mean, that is why this worked so well, really, because it is for us. So, yes, my advice is get involved.

Are there any changes you would make to the brief of the new school if you did that again?
More storage, way more storage. No matter how many times you tell an architect, that this is a school and it needs more storage, they don't believe you. And less high-tech stuff. For instance, you don't need dimmer switches, there is not a time ever, that you will want atmospheric lighting in a primary school, never. Not in the classroom and not in a cupboard, or in an office. Perhaps only in the PE Hall, when we are doing a performance, but there are no dimmer switches there.
Also, the taps, these are beautiful but they are expensive to replace, 60 quid. What we did with the taps, is replace those we had to replace with cheap ones, which do the same job. So, some of this beautiful high-tech equipment does not work very well and can be quite expensive to replace. So, less complex, more simple, that teaches the children to turn taps and lights off.
Another thing is that, these light bulbs, are really expensive to replace, do not last as long, and it is difficult to tell when they are on, so they get left on. You actually have to stand directly underneath them to see if they are on.
I would insist on keeping it simple.

Would you say this TSB study has added value to the curriculum?
Yes, definitely. Because we made the children part of it: they have been taking readings, they designed their own user guides. It was really good for the curriculum.
So that's particularly the classroom environment aspect more that the monitoring or metering part or the BMS.
They have done a bit of that, not a huge amount, and lots of monitoring on the solar panels, which a separate thing. It was mainly the classroom staff that we involved them in. It meant something to them.

Which elements of the study have been most beneficial?
Heat metering would be quite useful, because it will be nice to be able tell pre-school how much they are using, they can control their air heating, so they don't have to ask me, how much they are spending. So that has made it much easier.
So, that was basically addressing shortfalls in the original energy metering system.
Yes.
Making it perform as much as you need it really.
It should always have been like that and it never worked quite right.
Also, I think the classrooms CO2 monitoring was also beneficial, because it highlighted various issues for the staff, to try and make the school healthier.

Do you think that putting those user guides in the classrooms, do you think that will have a beneficial outcome?
Yes, it will. This should have happened at the beginning, when the school opened. It has been 4 years now.

Bearing in mind the final report has not been handed to you yet, how did you find the dissemination of the results of the study, so far?
I haven't seen the final report yet, but I have been involved as much as I wanted to be involved. I am not desperate to find out all the technical details.

In what ways has the study improved the user experience of the school?
To be fair, we were pretty good anyway. We were using the building quite effectively. It was just about a trickling thing really, but this makes quite a difference. Because that is how you resolve the irritating things that spoil one's enjoyment of the building. The term fine-tuning is quite accurate. In other TSB studies, there may have been fundamental problems were discovered and had to be dealt with. Here, it was just about fine tuning.