Rogiet Primary School

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Innovate UK project number	40042
Project lead and author	Piers Sadler Consulting (via White Design Associates)
Report date	2014
InnovateUK Evaluator	Roderic Bunn (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
School	Monmouthshire	Design & build	2008

Floor area	**Storeys**	**EPC / DEC (2015)**	**BREEAM rating**
1853 m^2 (TFA)*	1	B (32) / C (65)	Excellent

BRUKL quotes 1454 m^2, EPC quotes 1439 m^2. Researchers should check actual usable floor area used in calculations.

Purpose of evaluation

The BPE at Rogiet school aimed to study discrepancies between design intent and realisation and predicted and actual energy usage, taking into account the contexts of design, procurement, construction, handover and building management. The study identified how discrepancies could be avoided in future.

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

Electrricity consumption at 48.2 kWh/m^2 per annum, thermal (gas) at 54.1 kWh/m^2 per annum. At the beginning of 2014, the energy performance of the school was reviewed using 2013 gas and electricity data. The TM22 simple assessment was revised to reflect the later energy consumption. Data was available covering a period of 347 days from 7 February 2013 to 20 January 2014. Electrically, there was a significant increase in wind turbine energy usage compared to 2012 when the turbine was out of commission for a long period. Most of the discrepancy between the as-built EPC and the DEC results from actual gas usage of 153,799 kWh per annum compared with a design estimation of 41,002 kWh per annum.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	28	100%

The summary overall comfort scores for Rogiet School were statistically above both scale midpoint and the benchmark references for all comfort variables other than temperature in winter, which was above scale midpoint but typical against benchmark. The detailed variables for 10 air quality, noise, control and temperature variables were statistically worse than midpoint and benchmark, while 11 control, lighting and temperature sub-variables were classified as ‘typical’.

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About this document:

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

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

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

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Contents

1 Introduction and overview

Monmouthshire County Council commissioned Rogiet Primary School in 2008, as part of its primary school framework. It provides 210 primary places, community and playgroup facilities. The school is a single storey building of area 1,660m^2, laid out in a U shape, which forms a central courtyard aligned approximately E-W and open to the east. The construction is from a pre-fabricated timber panel system with cellulose insulation. The building comprises kitchen/catering facilities, hall, administration area and community room on the south wing; and 6 classrooms on the north wing. The reception classroom is at the base of the U (western end of building) and opens into the central courtyard. The school has 186 pupils and 28 staff.

Rogiet school Building Performance Evaluation (BPE)has provided an excellent opportunity to study discrepancies between design intent and realisation and predicted and actual energy usage, even where considerable effort has been put in to ensure the design, procurement, construction, handover and operation meet expectations. The study identifies how such discrepancies could be avoided in future. The building has been very well received and this has been reflected by the Building Users Survey(BUS). However the detail of the BUS, the audit of the design, construction and handover processes, as well as the detailed energy analysis has indicated that there are improvements that can be made for both the school and future design and construction processes of similar buildings.

1.1 Key Facts

Project	Rogiet Primary School BPE	
Address	Station Road, Rogiet, Monmouthshire	
Post code	NP26 3SD	
Procurement	Monmouthshire Framework	
Occupation	October 2009	
Project team	Architecture & Landscape	White Design
	Services Eng.	McCann & Partners
	Structural Eng.	Jubb Consulting
	Acoustician	Mach Acoustics
	Contractor	Willmott Dixon Construction Ltd.
Floor areas	Gross Internal	
	Circulation	
Fabric performance	Wall 0.19 $W/m^2/K$	
	Roof 0.19 $W/m^2/K$	
	Windows 1.5 $W/m^2/K$	
	Roof-lights 1.3 $W/m^2/K$	
	Floor 0.22 $W/m^2/K$	
Airtightness	$3.62m^3/(h.m^2)$@50pa	
Occupancy	240 (students approx 300staff)	
Energy calculations	EPC B Rating (32)	
	DEC C Rating (65)	
BUS survey	01/02/2012,100% response	
	28 returned questionnaires.	
BREEAM	‘Excellent’ rating (78.18%)	
Renewables	Wind turbine Quite Revolution 5 kkW	
	Solar Hot Water	

1.2 Rogiet School BPE Outcomes and Benefits

The study has provided the following summary of outcomes, benefits and recommendations for the school itself. These are summarised below and discussed in detail throughout the body of this report.

BPE Outcomes and Benefits for Rogiet School

- Change to start time of morning heating.
- Reduced energy wastage from frost protection system for the external sprinkler system housing.
- Increased temperature set point for IT cooling unit.
- Reduced domestic hot water system temperature and hours of operation in holidays;
- Reduced natural ventilation system CO_2 set point;
- In-class static displays describing Natural Ventilation process and opportunities for users to effect changes.
- Improved signposting to encourage use of roof blinds.
- The use of QR codes on building control systems to help users interpret what systems are for and how to use them.
- Change to the cost of the maintenance contract for the natural ventilation system.

BPE Recommendations

- The recommendation to use the night cooling feature as part of natural ventilation system.
- Install point of use electric hot water system to community room and caretakers room to allow specific provision when needed outside of school hours.
- Reduce lighting run-on times;
- Investigate un-metered base load, particularly in relation to sprinkler system trace heating and immersion heater;
- Investigate IT cooling unit controls to limit operation to cooling only;
- Investigate options for continued operation of the wind turbine;
- Investigate fiscal and plant room gas metering discrepancy;
- Consider using group room lobby spaces in winter to reduce loss of heat through classroom doors.
- Consider additional Window-master room controls for teachers in individual classrooms.
- Consider changing colour of internal face of external wall in classrooms and swapping dark coloured polycarbonate canopies with clear coloured sheets.

1.3 BPE Wider Industry Conclusions

As well as the above specific changes that have been identified for the school through the study the following conclusions have also been highlighted which provide wider recommendations to client, design and contractor teams regarding future design Strategies; Design, Construction and Handover Processes; and Design Specification. These are listed below and discussed in detail throughout the body of this report and appendices

Design Strategy and Brief

- More rigorous interrogation of the relevance of Building Bulletin (BB), Education Funding Agency (EFA) and other education guidance to tailor the most beneficial design with regards to site context, education brief and building performance.

Design Process

- More informed Lifecycle cost information, and client information provided when considering automated natural ventilation systems.

- Adoption of the 'Soft Landings' process and dedicated champion, from the outset of a project to ensure building performance is considered through all stages of design and construction as well as helping to guide the handover and first few years of occupancy.
- Use of the Soft Landings process to interrogate design changes and Value Engineering changes to ensure any implications on performance are considered alongside use and capital cost implications.
- Develop user guidance during the first year and develop it as an interactive tool to include better and clearer information as users' needs emerge.
- Client procurement processes should include the requirement for 2 years POE carried out collaboratively between designers, contractors and users.

Design Specification

- Understand the user requirements of group spaces when they are anticipated to double in use as lobby spaces to the outside to help prevent heat loss.
- Consider use of high level vertical clerestory glazing instead of roof-lights for summer ventilation to avoid risks of closing due to rainfall and consequentially temporary loss of ventilation, and to help prevent summer glare.
- Ensure canopies and similar architectural features on north-facing elevations do not critically reduce internal daylighting levels in classrooms.
- Ensure lighting is daylight controlled. Rogiet has a 27% increase in energy use from lighting in comparison to the SBEM design model for lighting usage.
- Ensure provision of zoning and sub-metering for non-school based activities. Community space at Rogiet requires whole school hot water system to be on to provide to one small kitchen even when school is not in use.
- Consider in detail the energy implications of domestic hot water provision to widely spread outlets and consider point of use electric water heaters as an alternative.
- Careful attention to design detail e.g. domestic hot water systems can save much more energy than renewable energy systems, such as solar thermal, will generate.
- Be aware of and avoid the cold bridge and airtightness issue generated by the use of steel and timber composite beams with an undulating web when the design incorporates a roof overhang.

1.4 Project Management

White Design with Piers Sadler Consulting carried out this BPE research study. The project took longer than expected and the project period was extended by 6 months. This allowed for the handover of recommendations from the study to the Head-teacher who returned from maternity leave in January 2014. It also allowed the study to include an additional winter season to test some of the changes suggested and made through 2013. The project tasks were completed within the contract period ending February 2014.

1.5 Structured Review

A structured review was carried out on the 30/11/2012. In attendance were the following:

- Rob O'Dwyer (RO) - Property Services Manager at Monmouthshire County Council (MCC)
- Kath Evans (KE) - Headteacher Rogiet School
- Frank Ainscow (FA) – TSB Monitoring Officer
- Matt Harrison (MH) – White Design
- Piers Sadler (PS) – Piers Sadler Consulting

The structured review presented the findings from the first year's data gathering and analysis activities of the BPE and allowed for comment from those present. The review took the form of a 2-3 hour presentation, followed by a walk round to visibly demonstrate some of the findings. Some of the findings led to recommendations that were carried out in the second year of the study and these are included in the lists of recommendations above.

1.6 Dissemination

Dissemination has occurred consistently throughout the study, alongside a focussed set of dissemination activities to conclude the study. White Design have used the information to inform future Natural Ventilation designs on new buildings at Thornwell School for Monmouthshire, St. Greg's Sixth Form Centre for BANES and the merging design of a "Zero Carbon' School at Bicester. The outputs from the BPE study have been used to inform early design discussions of these projects.

White Design have also spoken at two LCRI events in September 2013 reporting on the findings and recommendations to date found from the two TSB BPE studies that they have been working on since 2012.
The conclusion Dissemination events have involved the following activities carried out in March 2014;

- Presentation to all teaching staff and caretakers
- Presentation to MCC energy team and procurement team
- Presentation/CPD event to wider MCC staff across the education and capital projects teams

There are further events planned with Rethinking the consultancy /sustainability arm of Willmott Dixon.

There are also several static documents that have been produced to aid dissemination of the learning from this BPE study and these include engaged in class Building Users Guidance, this is shown and discussed in more detail later in this report and a project case study which can be downloaded from the TSB Carbon Buzz website.

2 Details of the building, its design, and its delivery

2.1 Summary of design brief and design intent

Rogiet Primary School was commissioned by Monmouthshire County Council in 2008, as part of its primary school framework. It provides 210 primary places, community and playgroup facilities. Monmouthshire County Council's brief for Rogiet Primary School asked for a sustainable, robust and accessible building that promotes a safe and healthy learning and working environment in a cost effective way.

Site Layout

Rogiet school is a single storey building of area 1660m^2, laid out in a U shape, which forms a central courtyard aligned approximately E-W and open to the east (see Figure 2.1). The building comprises kitchen/catering facilities, hall, administration area and community room on the south wing and 6 classrooms on the north wing. The layout of the school site is divided into distinct zones, with the more public areas at the front and the more private, secure spaces towards the rear of the site. This layout reflects the inclusion of additional facilities to allow the school to strengthen its roots in the community. A number of meetings with staff, parents and members of the public have ensured that the needs and wishes of the wider community have been included within the designs. The building is therefore easily accessible and welcoming but designed in such a way that allows security to be carefully and discretely managed.

At the front of the site (South side) is the main public access, car park and deliveries area. Footpath access to the site extends from the North side of the junction on Station Road and skirts around the edge of the road and parking area to the main entrance and secure cycle parking area. There are also raised footpath routes through and across the car park area for safe pedestrian access from vehicles. The school building is set back from this area and partially screened behind a line of trees. The layout of the building in two parallel wings enables all the publicly accessible spaces to be located in the South wing overlooking the site entrance, while the teaching spaces are located in the more private zone behind this wing to the North. The main entrance is clearly marked on the South-facing facade by a large overhanging roof canopy and is positioned centrally along the facade.

Figure 2.1: Site plan showing north facing arrangement of class-bases to grassed play areas

A secure line across the site, level with the main entrance façade, enables the courtyard spaces between the two wings to be secure educational play spaces. Activities in this area are closely supervised due to the inclusion of a pond and a 15m high wind turbine; hence a further division from the informal hard and soft play spaces beyond.

The landscape design was an important element of the Rogiet school design. The building and landscape were designed together to give aspects such as the productive garden and outdoor performance - a 'centre-stage' within the school, and to provide a range of interactions between the buildings and the diverse external spaces.

The school building is set around a courtyard, allowing the landscape to enter into the heart of the school. Teaching spaces are able to interact with the external spaces and the boundaries between inside and outside learning are broken down. The school uses food growing within an allotment garden, placed at the heart of the school, and an orchard. All these natural and land-based elements are intended to invite interaction with the children either in the form of play or as an educational and creative resource.

An acoustic and natural ventilation driven design

The layout of the school on the site was also fundamentally driven by the acoustic constraints generated by the nearby motorways and national rail-line in order to achieve a naturally ventilated solution. The school site is sandwiched between the M4 and M48 motorways and the main line from London to Cardiff. Despite the location, the whole building is naturally ventilated (except for toilet and kitchen areas). An automated window system, which responds to changes in temperature and CO_2 levels opens windows in very small increments to provide ventilation whilst managing draughts and noise.

All rooms and corridors have roof lights, which provide natural lighting and combine with high-level windows to provide automated natural ventilation. The 6 classrooms on the north wing have north facing glazing to maximise natural lighting whilst avoiding glare and over-heating potential. These classrooms all open directly into the outdoor teaching/play areas as well as having external access via buffer spaces. Brise soleil provide shading to prevent excessive heat gain on key south facing windows.

Figure 2.2 : Recommended maximum ambient noise levels(db) in spaces throughout the building.

The adoption of a natural ventilation approach, combined with the acoustic constraints generated by the site context demanded a more involved design process to ensure appropriate internal comfort levels could be met for both ventilation, natural light and prevention of excessive noise ingress. This has led to considerable investigation through the study and more detail can be found in Section 7 technical issues.

In summary the building design was developed to provide a Building Bulletin 93 (BB93) compliant school providing an internal environment that achieved the required internal ambient noise levels. Through design development and interrogation of the acoustic design following observations that the noise level drops after 09:30, a derogation was sought in order to simplify aspects of the acoustically attenuated natural ventilation design. The resulting design, however, through on site spot measurements, still appears to achieve the required BB93 ambient noise levels. The school however uses the classrooms in a way that was unknown at design stage, adopting an open doors policy to the classrooms, which in turn raises the ambient background noise level over and above that of the external noise sources. The conclusions of the acoustic study raised the need to question the negative impact of a consistent and regular background noise in the design of regulatory compliant spaces, which could in turn save capital expenditure on possibly over engineered solutions in order to achieve compliance.

The natural ventilation design defines the building and has been the subject of many aspects of this study and it is discussed in detail within Section 7 of this report. Issues with its effectiveness were implied though the Building Users Survey, (see Section 4) anecdotal evidence through the interviews with key staff and through the design and construction audit . The focus of the building users guidance and some of the BPE outcomes and recommendation have provided an improved use of this system through assistance from WindowMaster, the system manufacturers. In summary some of these issues and improvements have been,

- Identification that night cooling facility was not being used due to initial security concerns,
- over compensation of the CO_2 set point to reduce winter opening resulting in stillness and stuffiness,
- better access and training for school staff on the use of the WindowMaster control panel

Figure 2.3: Environmental schematic model and diagram prepared by the architects

Class access arrangements and heat loss

The school layout has evolved from previous class-group layouts that the architect's White Design have worked upon. These have to varying degrees implemented the use of a buffer space to prevent heat loss direct from the classroom to the outside. A review of the design development of 'buffer spaces' with White Design schools was carried out through the TSB BPE Oakham study. This highlighted that the resulting arrangement at Rogiet was unfortunately undermined by the incorporation of an additional door from the classroom direct to the outside, therefore negating the use of the intended group room/ buffer space to reduce heat loss. Through the BUS study the instability of the internal temperature was highlighted as "being outside the BUS benchmarks'. The study concluded that the combination of a slow response under floor heating system coupled with the negative effect of heat loss during the arrival of pupils on a winter morning is probably responsible in part to the perception of variable internal temperature. This is analysed in detail through the Section 7 study into the buffer spaces at Rogiet.

Lighting

The BUS follow up section in Section 4 and the lighting study carried out in Section 7 reviews some of the anecdotal issues concerning internal lighting levels where there is a noted perception by some that the classrooms are a little gloomy. The study concluded that a number of design decisions and methods of use were combining to produce this perception despite the classrooms still providing lux levels within recommended limits.

Figure 2.4 shows the central group space between two class-bases intended for use as a buffer zone as well as the direct door to the outside. It also shows, indicated in blue, the centrally located roof-light installed which was changed from two smaller roof-lights, as well as the area marked red which was added to the classrooms when its previous use as a cloak space was omitted. The green strip also shows the extent of the external canopy in front of the north facing windows.

Figure 2.4: Classroom layout: roof light location (blue) and area opened up to the class-bases (pink)

2.2 Structure and materials

This is a pre-fabricated timber frame building with recycled newspaper insulation. The intention was to select materials to support the sustainability agenda providing natural self-finished, low maintenance finishes. Externally, this is evident for example in the untreated cedar (sourced locally) timber boarding and the rendered walls and brick plinth.

The windows use low emissivity clear glass and the cavity is argon filled. The windows are wood and aluminium composite. The roof is lined with a single layer of roofing EPDM membrane, which is a non-PVC plastic membrane. Finishes – there is some negative feedback on the colour strategy at the school. Whilst this does not explicitly appear through the BUS, both the dark yellow/mustard colour on the inside face of the outside wall of some classrooms, and the dark red and blue used in the polycarbonate external canopy have been subject to informal feedback from teachers. This may have had a negative effect on natural light levels in those classrooms concerned, whether real or perceived.

Where possible the building has used materials and construction techniques to minimise embodied energy. The timber frame however was amended to incorporate a timber steel composite joist in contrast to the originally specified solid timber flange, this had an impact on thermal performance through the roof to wall junction and is discussed in detail below through its identification during the thermographic imaging report (see Section 2.6).

2.3 Documentation

This section includes a review of the documentation, which was provided with the building including:

- O&M Manual
- Building User Guide
- Log Book

These documents were delivered many months after the school was opened, in three boxes and two and half years after the school was first occupied. The head teacher was not aware of the information in the boxes having been used, what the documentation was for or how it should be used.

O&M Manual

- This review considers the overall content of the O&M manual with more detailed review of those sections of the manual which address the school's energy systems – mechanical, electrical and controls. It is not the intention to summarise the content, but review the quality and usability of these documents. It is acknowledged that the O&M manuals are intended for the use of skilled engineers in operating and maintaining the installations at the school, and this review has been undertaken with this in mind.

Overall

O&M manual exhibit typical features of such documentation. The O&M manual contains 11 main volumes. The contents page is a little vague and uses headings which do not make it clear what is included in each section. It appears to be a repository for all information related to the project whether it is relevant to the running of the school or not. Much of the information should be held by the client, for example, archaeological, demolition and ground investigation reports, but does not need to be held in the O&M manual. The bias is towards design and planning information rather than as built. Design reports may present features that were not actually built.

- Supplier information is generic – usually with multiple products or systems described without any information on what was actually used and where (in most cases).
- Some of the volumes are sub-divided into sections whilst others are not.
- It appears that the overall content of these manuals, the organisation of the materials present and the specific detail provided have not been developed with the building user in mind.

- Whilst there is a section on Testing and Commissioning Certificates, these certificates are 'buried' throughout the volumes.

These would benefit from considerable thinning; restructuring and ordering with logical section headings and Table of Contents; details of what is included in each volume on the front cover; an introduction explaining what has been included and why; and a description of the building stating exactly what products were used where and referring to the manufacturers literature.

Mechanical iInstallation

This section of the manual is well organised and there is effective cross-referencing within the section (i.e. the mechanical installation), but reference to drawings is generally to the drawings section rather than a specific drawing. Description of controls for the heating and ventilation are included in this section. The document does not generally acknowledge or cross-reference other parts of the manual, which are related such as the natural ventilation system (WindowMaster) or wind turbine.

The description of the mechanical systems is very brief with no detailed description of any of the plant, for example, the model and capacity of the boilers is not given, nor is there reference to their relative roles (e.g. duty/assist) or their features, for example, modulation. The description of the solar hot water and twin coil cylinder, does not explain how the solar hot water and constant temperature circuit from the boilers work together.

Generally, the make and model of plant items are not given making it difficult to identify which items of plant were actually installed from the manufacturers' literature. The description of the controls is fairly comprehensive, although there is no reference to the Building Management System (BMS) interfaces in the plant room or through the web portal. A site specific description of the WindowMaster natural ventilation system is 'buried' in the manufacturers' literature section. There is no cross-referencing between the section on heating and that on natural ventilation to explain how the controls of these two systems operate together. The WindowMaster section includes a detailed account of system operation through the user interface.

Sprinkler system drawings are included in this section but there is no written description. The drawings do not show energy consuming items such as frost protection fan, immersion heater and trace heating. Manufacturer's information provides some further information but as with other manufacturers data shows multiple items without any reference to what was installed.

Electrical installation

The table of contents for the electrical installation section is as follows:

- Introduction
- Emergency Conditions, Health and Safety
- Operating and Test Procedures
- Routine Test Procedures
- Drawings & Schedules
- Test and Commissioning Documentation
- Manufacturers Directory
- Manufacturers Documents
- Log Books

There is no clear description of the electrical systems installed at the school in part of the manual. Much of this section is generic, for example, the Health and Safety section appears to be entirely generic, apparently covering every possible hazard involved in electrical installations without drawing the reader's attention to specific aspects of the installation at the school which might be unusually hazardous. Information specific to the Rogiet installation is mainly available in the schedules and drawings section. The ‘Luminaire Schedule’ is just a heading with no text, although the schedule can be found later in the document after the drawings. There is no mention of metering and the drawings are too small and of insufficient quality to see the detail. The test certificates are also included after the drawings with no section dividers or headings to indicate what these are. After these are the section dividers and headings for the test certificates.

There is no section header for the manufacturers’ documents and the ‘Log Books’ section appears to be missing.

Wind turbine

The wind turbine section has a detailed description and maintenance information together with user instructions for accessing the ‘microsite’, which provides information on the energy generated. The commissioning information is also in this section. There is no information on the peak output of the turbine or predicted energy generation.

O&M manual conclusion

The O & M manual has been developed as a repository for all information, which might be relevant for the future operation and maintenance of the building. Much of the information is not relevant and the inclusion of the irrelevant information makes identifying the relevant information much more difficult. Furthermore, the quality of the relevant information is often variable with poor cross-referencing, incomplete sections and an overall lack of clarity. It is telling that more than two years after occupation the O&M manual had hardly been looked at and the head teacher was not aware that it contained information relevant to building users. The reason that the quality of these documents is so poor is that neither the delivery team nor the client has any interest in their contents until things start to go wrong. Each of the individual contributors provides information on their parts of the building but there is little review or overview. Information is often omitted because no one knows who needs to provide it or because no one notices it is missing.

O&M manual wider recommendations

The best way to rectify this is for an individual from within the delivery team to take responsibility for the documentation and the explanation of the documentation to the client. This individual needs to understand the interactions between systems and to have the authority to ensure the quality of information supplied is adequate.

User Guide

The first section of the O&M manuals is entitled ‘User Guide’. This section is not a building user guide (BUG) as we would normally understand it, but an introduction to the O&M manuals explaining the intended purpose and use of the manuals. It appears to explain how the manuals should be rather than how they are. There is limited value in the current format of the building user guide and critically the role of this document can often been seen as a route to achieving a simple BREEAM credit. The intentions behind a building user guide are worthwhile and should be developed in collaboration with the end users. This may mean it cannot be completed in time to achieve the required BREEAM credit. This BPE study has used the opportunity to review the use of the building with its occupants to develop some further information and relevant users guidance responding to the questions and needs that have arisen. This is appended to the end of the BUS follow up in Section 4.

Building Regulations, Log Books and TM31

The Log Book is contained in Volume 2 of the O&M Manual under Section 02, it was produced by FP Hurley and Sons Ltd. Under Regulation L1c of Part L of the Building Regulations there is a requirement for provision of sufficient information about the building, building services and maintenance requirements to enable the building to be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances. The Log Book is identified in Approved Document L2A as a way of demonstrating compliance with Regulation L1c. Building regulations recommend that the Log Book follows the guidance in CIBSE TM31: Building Logbook ToolKit.

The CIBSE TM31 guidance suggests the following headings for a building Log Book:

1. Building history
2. Purpose and responsibilities
3. Links to other key documents
4. Main contacts
5. Commissioning handover and compliance
6. Overall building design
7. Summary of areas and occupancy
8. Summary of main building services plant
9. Overview of controls/BMS
10. Occupant information
11. Metering/monitoring and targeting strategy
12. Building energy performance records
13. Maintenance review
14. Results of in-use investigations

Appendices – relevant compliance and test certificates.

The Log Book should be a dynamic document, which is updated to reflect changes to the building, energy use/performance and maintenance. The Log Book should be updated at least annually. The school's Log Book contains all the sections recommended in TM31 except 'Occupant information' and it has an additional section entitled 'Major Alterations'. 'Occupant information' is supposed to contain useful information for occupants. It has presumably been omitted because this information should be included in the Building User Guide.

The school were not aware of the existence of this document, which is buried in the 11 volumes of O&M manuals. It has now been moved to a separate folder and the head teacher will manage the document dynamically as intended. A summary of the content of the Log Book and recommended improvements are included in the following Figure 2.5 below.

Figure. 2.5 Table showing summary of the content of the Log Book

Title page	Building Owner, Organisation and manager not filled in
1. Annual Review & updates to Log Book	Refers to page number of the Log Book, but the pages are not numbered. Never been updated.
2. Purposes and Responsibilities	Standard text – building manager not entered, no signature
3. Links to other key documents	There are 6 key documents listed, each of which is identified as being located in the O&M manual. The list appears to be generic. The following listed key documents are not listed in the contents page of the O&M Manual – Emergency Procedures, Hazard Register, Asset register, BMS Manual. Health and Safety and Drawings are listed. It would be useful to be more specific about the locations of the key documents as well as which documents are key and should be referred to in the Log Book.
4. Main contacts	This list includes only those involved in mechanical and electrical installations. It would also sensibly include other companies eg architect, principal contractor and other contractors involved in design and maintenance of the wind turbine, solar, kitchen, landscaping.
5. Commissioning Handover and Compliance	This only covers mechanical systems. The commissioning documents are not included and there is no reference to where these can be found.
6. Overall building design	Only covers mechanical installation. Much of the required information will be available from the current study design and construction audit.
7. Summary of Areas/occupancy	Generic page, not completed.
8. Summary of main building services plant	List provided in table. Table has a heading 'Ref', but it is not clear what this provides a reference to.

9. Overview of Controls/BEMS	Overview provided, but no information about the controller software (Trend 963 Supervisor) or how to operate the system.
10. Metering, monitoring and targeting strategy	List of meters excluding electrical. Nothing on monitoring and targeting strategy.
11. Building performance records	Indicates what should be included, but not used.
12. Summary of Maintenance	Form – currently blank
13. Major Alterations	Form – currently blank
14. Results of In-use Investigations	No content. Should include summary of findings of the current study.

Log Book wider recommendations

To help improve the quality of the Log Book for future projects, it is recommended that a mandatory part of the handover is the initial completion of the Log Book with the person responsible for facilities management and the client. It is expected that the client and facilities manager would not be satisfied with generic sections or those that are clearly incomplete. An annual review at the end of the first year of operation when the DEC is produced would also be a useful milestone to see whether the Log Book was being used as intended. It appears that the Log Book also highlights the 'tick box' approach of BREEAM, whereby points are awarded because ostensibly the Log Book has been produced, but the Log Book is not a useful document and is not used as intended.

2.4 Energy strategy

The school is on mains gas and electricity. A 5kW (peak) vertical axis wind turbine supplements electricity supply and a solar thermal system contributes to hot water. Underfloor heating and hot water are provided by 3 No. 115kW condensing gas boilers. Natural ventilation is provided using an automated system with coupled high-level windows and roof lights responding to CO_2 and temperature in each room (and manual over-ride).

As mentioned above, natural day lighting is maximised through use of roof lights and large north facing windows in classrooms. Lighting is controlled by PIR movement sensors and manual over-ride. Children and staff discussed and agreed optimal time delay for light operation. The head teacher pro-actively operates the BMS.

To reduce the regulated and unregulated electrical usage, classrooms and the whole school have single switches for shutdown at the end of the day. Switches are labelled to clarify their purpose. Graphical and written interpretations around the school intend to foster an awareness of energy issues and encourage energy saving behaviour. Children have been appointed 'Eco-monitors' to ensure equipment is switched off when not in use.

It has been noted that despite the implementation of graphics and displays, through the interviews with teaching staff it was stated there is limited understanding of the information that is on display. It was commented ‘whilst the energy display looks great what does it mean and what does it tell us”. In quarters 5 -7 of the BPE project, one of the curriculum engagement activities that have been developed with the teachers includes an energy audit with the children, which translates the energy usage of equipment and systems within the building into a tangible unit of reference for teachers and pupils.

The design building energy performance designed for an emissions rate of 15.661kg/CO_2/annum with an EPC rating of B (32). It also achieved BREEAM Excellent (78.18%); the highest for an educational project in the UK when the scheme was completed. Despite this, performance falls short of expectations with the DEC of 65. Most of the discrepancy results from actual gas usage 153,799kWhr/yr compared with 41,002 kWh/yr predicted.

2.5 Construction management processes

The following provides a summary of the findings relative to the construction and construction management processes. It summarises the contract, Soft Landings and handover processes and effects of changes made through the value engineering processes during the contract. More information can be found within appendix B

The project was procured under a design and build contract and constructed by Monmouthshire County Council's (MCC) framework contractor, Willmott Dixon. White Design was novated to Willmott Dixon. The team has worked on several schools together in Monmouthshire, subsequent projects procured through the framework include Dewstow and Thornwell primary schools. Due to this on-going relationship, continuous improvement has been achieved relative to improved energy performance of subsequent buildings completed on the framework as well as increasing achieved of BREEAM standards.

Interviews with the contracting team were carried out in November 2012 and January 2013. Issues that were identified at this stage relating to the Design and Build contract can be identified as follows;

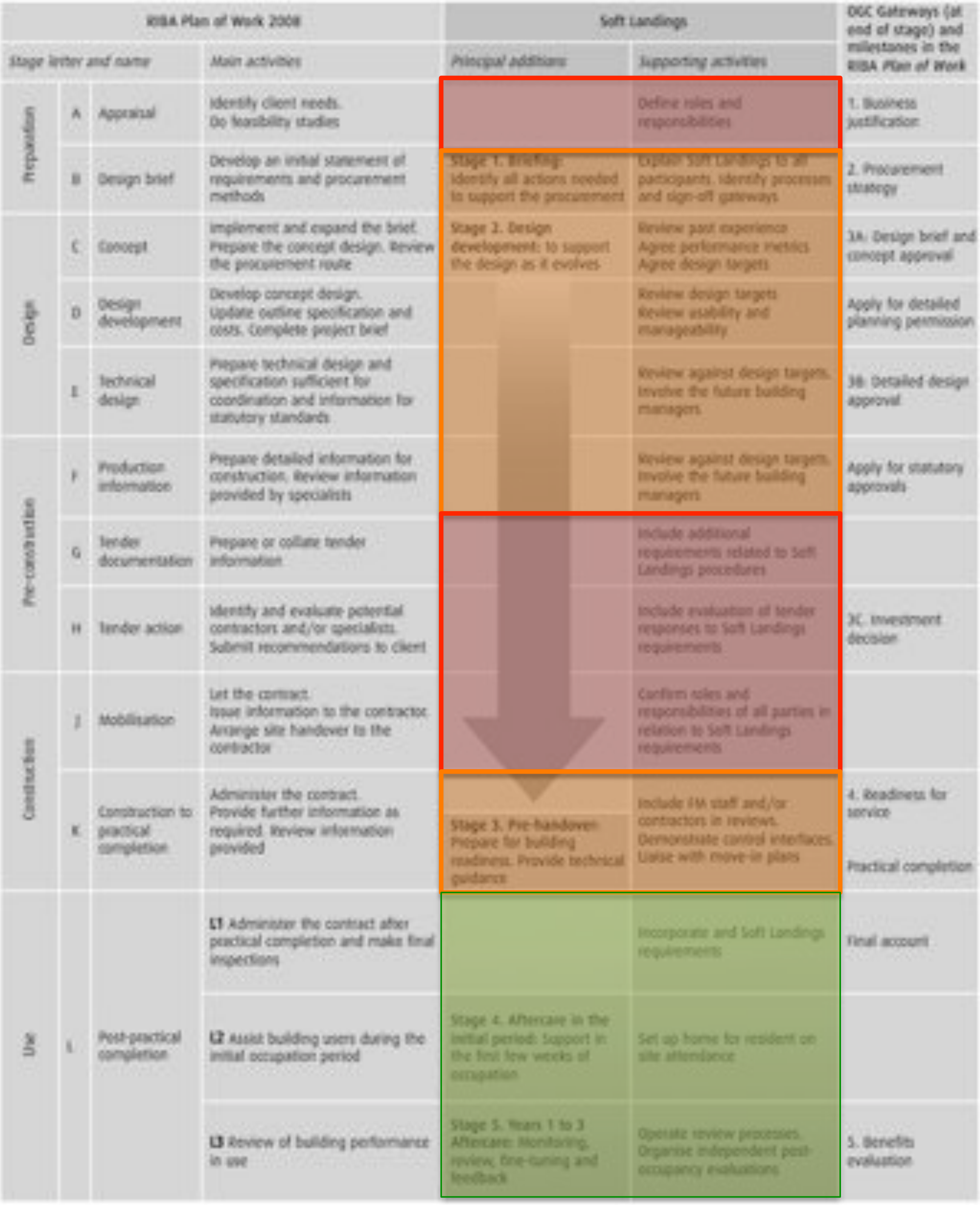
- Rogiet primary school was procured through a Framework procurement process and was the third school of six to be completed through the framework. The process of passing on best practice and learning from issues has been facilitated by this process and this was stated by both Willmott Dixon and Monmouthshire representatives.
- It was however stated that maybe more could have been made of this repeat relationship. Monmouthshire County Council did state during the structured review that this BPE study has highlighted a perceived void in the roles within the team and a clarity over who takes overall ownership for ensuring the performance of the school. This was stated by Rob O'Dwyer Head of Capital projects MCC at the structured review and similarly by Paul Phillips during the telephone interview as part of this audit.
- The commissioning client (MCC) have responsibility for the spending of the capital budget so are not explicitly focussed on the ongoing performance of the facility although have some roles associated with considering lifecycle performance.
- The contractor is involved throughout but may not have the detailed knowledge of the engineer regarding the systems installed and are only contracted to one year post completion
- The school pays for the maintenance and operation of the building but has limited resource and skills to ensure ultimate performance.

Soft Landings

Willmot Dixon operate a process called Soft Landings which is informed by the BSRIA Soft Landings guidance but which cannot be defined as a the BSRIA Soft Landings process. The commentary from MCC regarding the perceived need for a defined champion to be questioning and interrogating decision throughout to ensure best performance signifies an absence of a clear definition of roles and responsibilities as suggested at the outset of the project by the BSRIA soft landing guidance. However a bespoke best practice learning and handover process was established by Willmott Dixon and Monmouthshire County Council for all the Monmouthshire school projects including Rogiet.

The Soft Landings process was established formally as a process 12 weeks prior to handover. From our experience this is comparative to the introduction of the process on many other construction processes where the delivery and management of the Soft Landings process is the ownership of the contractor and is associated with the handover process. The following table is taken from the BSRIA Soft Landings guidance. The red, amber, green overlay summaries where, following the interviews with key team members, our observations indicate we believe the BSRIA process has been followed or not(activities highlighted in red were not completed, orange were intended as Soft Landings, but were not seen through or completed in full, and green were completed).For more detailed interpretation of the RAG (red amber green) analysis shown below please see appendix A Soft Landing Report.

Figure. 2.6 below shows RAG analysis of the BSRIA soft landings table.



RIBA Plan of Work 2008				Soft Landings		OGC Gateways (at end of stage) and milestones in the RIBA *Plan of Work*
Stage letter and name			*Main activities*	*Principal additions*	*Supporting activities*	
Preparation	A	Appraisal	Identify client needs. Do feasibility studies		Define roles and responsibilities	1. Business justification
	B	Design brief	Develop an initial statement of requirements and procurement methods	Stage 1. Briefing: Identify all actions needed to support the procurement	Explain Soft Landings to all participants. Identify processes and sign-off gateways	2. Procurement strategy
Design	C	Concept	Implement and expand the brief. Prepare the concept design. Review the procurement route	Stage 2. Design development: to support the design as it evolves	Review past experience Agree performance metrics Agree design targets	3A. Design brief and concept approval
	D	Design development	Develop concept design. Update outline specification and costs. Complete project brief		Review design targets Review usability and manageability	Apply for detailed planning permission
	E	Technical design	Prepare technical design and specification sufficient for coordination and information for statutory standards		Review against design targets. Involve the future building managers	3B. Detailed design approval
Pre-construction	F	Production information	Prepare detailed information for construction. Review information provided by specialists		Review against design targets. Involve the future building managers	Apply for statutory approvals
	G	Tender documentation	Prepare or collate tender information		Include additional requirements related to Soft Landings procedures	
	H	Tender action	Identify and evaluate potential contractors and/or specialists. Submit recommendations to client		Include evaluation of tender responses to Soft Landings requirements	3C. Investment decision
Construction	J	Mobilisation	Let the contract. Issue information to the contractor. Arrange site handover to the contractor		Confirm roles and responsibilities of all parties in relation to Soft Landings requirements	
	K	Construction to practical completion	Administer the contract. Provide further information as required. Review information provided	Stage 3. Pre-handover: Prepare for building readiness. Provide technical guidance	Include FM staff and/or contractors in reviews. Demonstrate control interfaces. Liaise with move-in plans	4. Readiness for service Practical completion
Use	L	Post-practical completion	**L1** Administer the contract after practical completion and make final inspections		Incorporate and Soft Landings requirements	Final account
			L2 Assist building users during the initial occupation period	Stage 4. Aftercare in the initial period: Support in the first few weeks of occupation	Set up home for resident on site attendance	
			L3 Review of building performance in use	Stage 5. Years 1 to 3 Aftercare: Monitoring, review, fine-tuning and feedback	Operate review processes. Organise independent post-occupancy evaluations	5. Benefits evaluation

Design vs as-built review – summary of changes made during design and construction

The design and construction audit interrogated all of the changes made during the construction process of the building and the summary of the main changes can be concluded as follows, (the full design and construction audit can be found in appendix B);

- the change in procurement of the timber frame and subsequent change to the soffit junction detail has had a negative effect on the thermal performance of the building. This is explored in more detail through Section 3.8 in the review of the thermal imaging report .
- alternative specification of insulation is unlikely to have had a negative impact on the overall performance of the building given the U value was matched. However embodied energy performance and WUFI calculations may have been negatively effected due to the use of a non-hygroscopic insulation manufactured with blown glass fibres.
- the change in size and amount of roof-lights will have some negative effect on daylight distribution, light levels and ventilation. This is explored in more detail through the identification and investigation of issues arising form the BUS, concerning lighting levels in the classrooms.
- trickle vents omitted in lieu of incremental opening facility of window system.
- timber cladding omitted in lieu of brick and render may have changed the wall U value
- changes of internal use of spaces and the daylight and ventilation impacts
- proposed vs occupied use of a space and the daylight and ventilation impacts
- reduction in overhangs to the canopies, may have increased the risk of overheating to the south facing rooms, however in review the length of the original overhang which was too short originally and then shortened further was not sufficient to provide an adequate means of shading.
- alterations to the ventilation strategy, due to the acoustic strategy.

The change in procurement of the timber frame, the change in size and amount of roof-lights, the change to the trickle ventilation requirement, the change in use of spaces and alteration to the acoustic strategy have led to further investigation and reports carried out through this study. The detailed considerations of these changes are discussed further in Section 2.6, Section 4 (BUS follow up) and Section 7 (Technical issues).

2.6 Thermal imaging

A thermographic survey was carried out by BSRIA at the school on 14 March 2012 between 19:00 and 21:00. The objectives were to show the effectiveness of thermal insulation and identify areas of air leakage, thermal bridging and less than adequate insulation. The heating was operational before and during the test providing an internal temperature of 9.5 °C -20.5°C and the external temperature was between 4°C and 6°C during the test.

The survey found that the insulation was generally effective, but that high heat loss was occurring in the following areas:

- at the wall/roof junction especially where the soffit is timber clad;
- at junctions between walls;
- occasional cold spots on the walls; and
- around and on window and door frames.

Most of these were interpreted by BSRIA as air leakage with some anomalies being interpreted as disturbance of insulation.

A full report on the survey is presented in Appendix C and some examples of the anomalies identified are shown in Figures 2.7 to 2.11 (full details of the locations of these anomalies and the thermal data are also presented in the report in Appendix C). The TSB checklist for thermal imaging is also included in Appendix C.

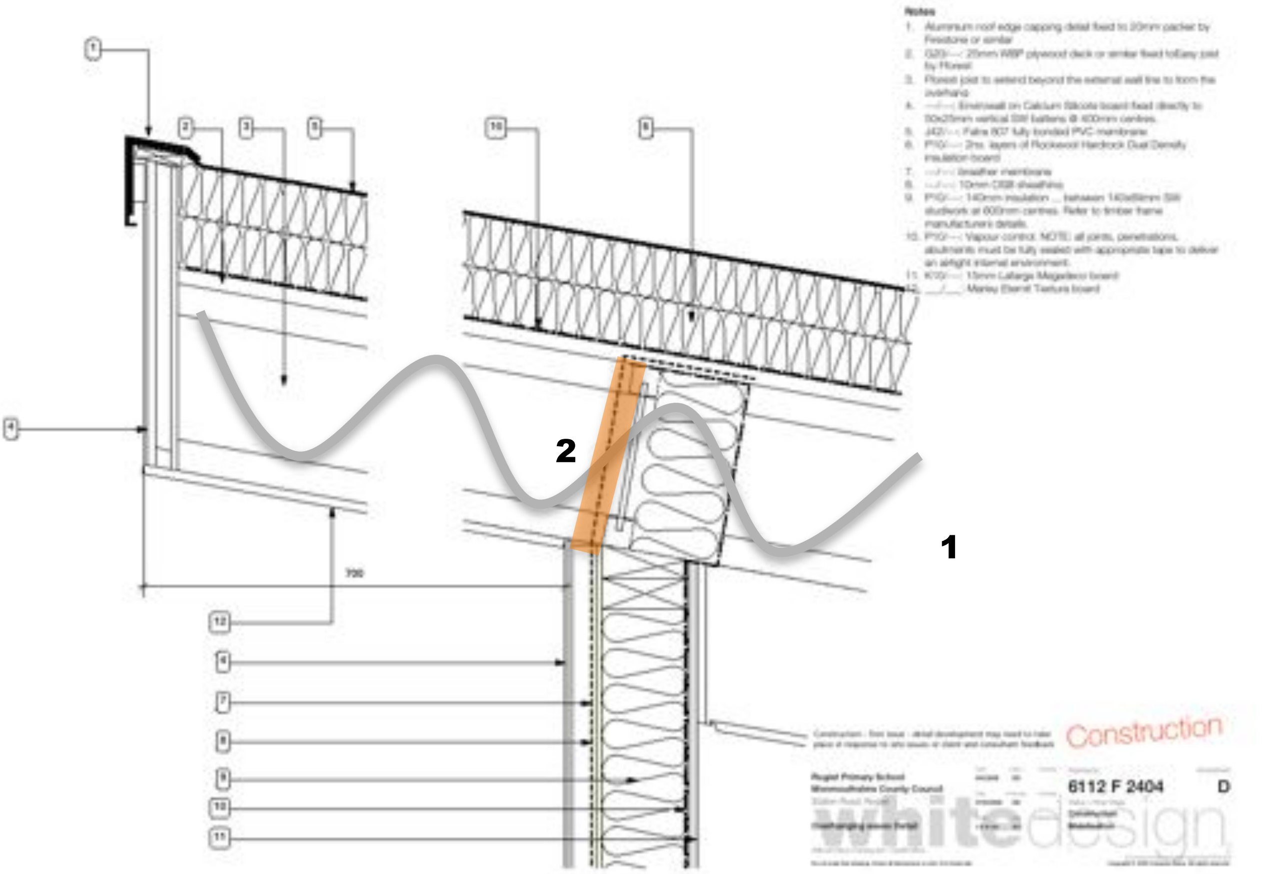
Whether the anomaly is caused by air leakage or conduction of heat through the building fabric, the ultimate cause for those anomalies along junctions is inadequate attention to the detail either in design or construction. Anomalies in the windows are probably a result of air leakage combined with thermal bridging through the frames and probably reflect the quality of the doors and windows selected.

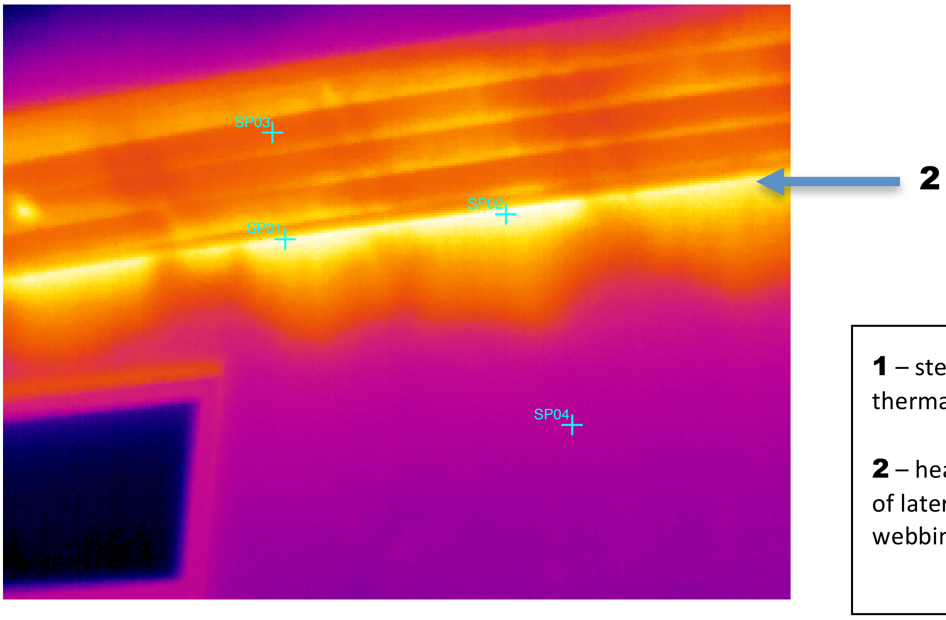
These issues are also considered in the construction audit and the following commentary is made here concerning the soffit junction. The prefabricated timber roof construction as part of the Framewise (the timber frame manufacturers) procured system produced a design change to the connection details between wall and roof. The structural proposal designed by architect and engineer used a timber I-beam with a solid and continuous web that cantilevered through the external wall to produce the soffit overhang. Whilst the beam effectively punctures the thermal envelope as it continues outside, the straight edges of the I-beam web enabled a simple to construct and potentially effective airtightness detail. The procurement of Framewise saw their system introduce a timber and steel composite beam with an open web. Whilst concerns were raised at the time over the ability to provide the required airtightness integrity it was concluded that the cost saving provided by the Framewise solution could pay for builders work in connection with addressing the closure of the roof system at the head of the wall. Whilst considerable effort was made in improving the airtightness at this junction, the thermal images show that there is still significant heat loss at this junction.

Figure 2.7; Originally proposed solid timber web I beam

Figure 2.8; Installed open web composite beam

Figure 2.9: Thermal anomaly at wall roof junction and soffit





1 – steel webbing punctures thermal envelope

2 – heat lost through poor closure of lateral connection to undulating webbing

Figure 2.10: Thermal Anomaly at wall junction

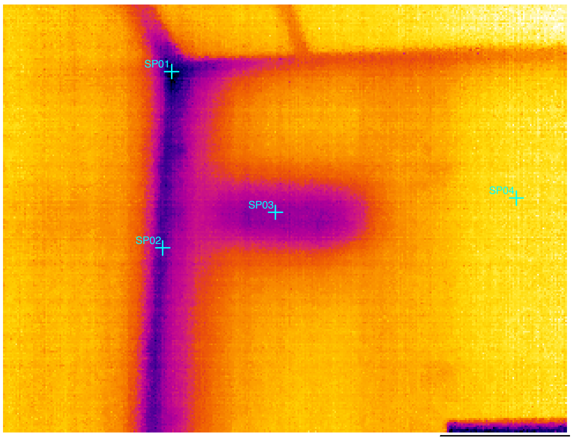
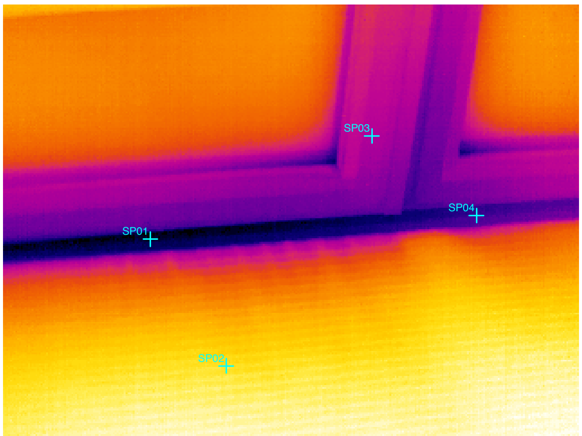


Figure 2.11: Thermal Anomaly at window/door



2.7 Equipment Inventory

An equipment inventory has been collated for a dual purpose, firstly to have an accurate listing of all equipment that has an energy demand to understand and incorporate into the energy analysis. Secondly, for the school to have an understanding of their assets. Rogiet Primary School has been open since October 2009. When they moved into the building much of the older equipment was removed from the school, with only new and necessary equipment remaining. Since this time they have added 15 laptops, a 'notebus' and some stage lighting in the main hall. For a full listing of all equipment, please refer to Appendix D

A follow up of the main inventory was undertaken to pick up items missed in the initial inventory. The main items addressed were lighting, fans and pumps and the sprinkler system.

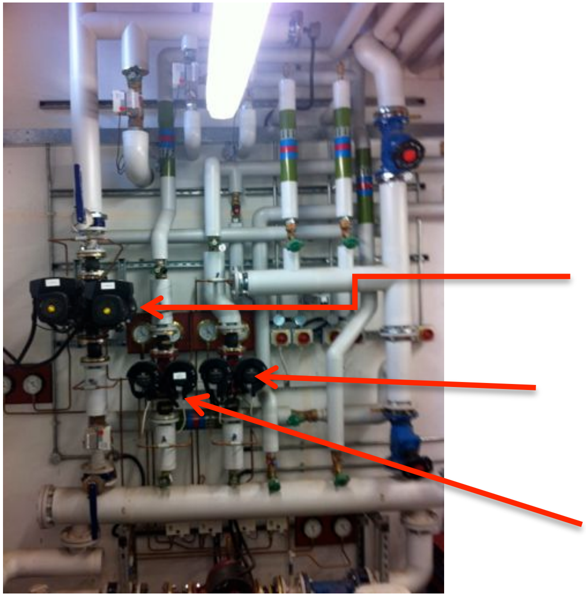
A full inventory of all luminaires in the school by room and electrical zone giving the wattage of each is presented in Appendix D. The main pumps and pumps are listed in Figure 2.11 below.

Figure 2.11: Main pumps and fans

Pump Function	Wattage	Comment
Main boiler flow and return pumps (duty & standby)	900W	Grundfos variable speed pumps
Variable temp pumps for underfloor heating (duty & standby)	750W	Grundfos variable speed pumps
Constant temperature pumps calorifier hot water supply from boilers (duty & standby)	180W	Grundfos variable speed pumps running at 70% load
Constant temperature pumps air handling unit supply from boilers (duty & standby)	180W	Grundfos variable speed pump
Calorifier solar destratification pump	110W	Nuaire Ecosmart System
Hot water system return pump	110W	Nuaire
AHU system supply fan	2.2kW	Nuaire
AHU extract fan	660W	Nuaire
Toilet Extract fans (7 No)	150W	Nuaire
Changing extract fans (2 No.)	170W	Nuaire
Cupboard extract fans (5 No.)	75W	Nuaire
Sprinkler cupboard frost protection	3.5kW	Dimplex

The pairs of variable speed pumps for the constant and variable temperature hot water circuits are shown in Figure 2.12 below.

Figure 2.12: Hot water circuit pumps



The sprinkler system is housed in a fibreglass shed at the east end of the car park in a compound which also includes the sprinkler tank. The pipework in the shed is protected against frost by the 3kW Dimplex fan listed in Figure 3.4. The water storage tank is protected against frost by two 1.5kW immersion heaters. The sprinkler pipework is protected against frost by a trace heating system by Raychem, details of which we have not been able to establish.

2.8 Conclusions and key findings for this section

The following conclusions and key findings can be summarised for this section:

- More rigorous interrogation of the relevance of Building Bulletin (BB), Education Funding Agency (EFA) and other education guidance to tailor the most beneficial design with regards to site context, education brief and building performance.
- Adoption of the Soft Landings process and dedicated champion, from the outset of a project to ensure building performance is considered through all stages of design and construction as well as helping to guide the handover and first few years of occupancy.
- Use of the Soft Landings process to interrogate design changes and value engineering changes to ensure any implications on performance are considered alongside use and capital cost implications.
- Develop user guidance during the first year and develop it as an interactive tool to include better and clearer information as users' needs emerge.
- Client procurement processes should include the requirement for 2 years POE carried out collaboratively between designers, contractors and users.
- A mandatory part of the handover should be the initial completion of the Log Book with the person responsible for facilities management and the client.
- An annual review of the Log Book at the end of the first year of operation when the DEC is produced would be a useful milestone to understand whether the log book was being used as intended.

3 Review of building services and energy systems

3.1 Energy systems

Description of energy systems

Controls

Heating and hot water systems, air handling units, ventilation and windows are controlled by a Trend IQ3 BMS. The BMS is controlled via a web based interface or directly from the BMS panel in the plant room, operated by the building manager. The operation of each element is described together with the description of that element in the sections below. Sub-metering is also linked into the BMS (see Section 3.2on metering).

Space heating

The space heating is provided by three Broag 115 kW condensing gas boilers from which run three low pressure hot water circuits:

- variable temperature circuit runs the underfloor heating in the three heating zones - hall area, community area and school area;
- constant temperature circuit to serve the kitchen air handling unit (AHU);
- constant temperature circuit to run the domestic hot water (DHW) system calorifiers (see below).

The heat generated by the boilers is circulated to a low loss header from which it is pumped around the building on demand. The water is circulated in the under floor heating circuit at 50/42°C flow and return temperatures and in the constant temperature circuit at 80/70°C flow and return.

The boilers modulate from 18-100% of their 115kW rating.

The heating circuits are controlled by means of zone heating time schedules and room thermostats which are set within the BMS. The flow to the under floor heating within a room is controlled by a valve which will open/close to maintain the temperature at the set point. The set point is set within the BMS – default 20°C, but varies with the zone heating time schedule.

There are three stages of frost/condensation protection as follows:

1. When the external temperature falls below the set point (set at 1°C). Heating pumps operate.
2. When plant temperature falls below its set point (set at 8°C). Boiler and pumps operate.
3. If the inside temperature falls below 10°C (out of hours set back temperature). Boiler, pumps and valves operate.

Frost protection will only circulate water within the low loss header unless condition 3 triggers a demand for heat in any part of the building. When the external temperature reaches 17°C the heating system is disabled (high ambient temperature shut down).

The underfloor heating system is weather compensated. The circulation temperature varies with the outside temperature according to the following relationship: at an external temperature of 0°C or less the circulation temperature is 50°C; whilst at an external temperature of 20°C the circulation temperature (theoretically only) would be 20°C. The system also incorporates an optimum start feature. The optimum start enables the BMS to start the heating system to get spaces up to temperature by the set time at different times depending on the external temperature. The BMS learns the heating response of the building to ensure that the start time is correct. This feature was not in use until 19 September 2012. During a BPE project site visit by Piers Sadler and BMS review meeting with the head teacher and the controls company engineer, it was discovered that the feature was not in use. The head teacher who sets the controls through the BMS was not aware of this feature and was starting the heating early each day to allow for a heat up time. The optimum start is now in use with a maximum start time of 300 minutes before the required set time. This long start time allows the building to be warm on a Monday morning after weekends or after holidays.

On 14 February 2014 the heating start time was changed from 06:00 to 07:30, recognising that the school is rarely occupied at 06:00. If cleaners are present at that time, on a cold morning, the heating would have already started (due to optimisation) and the cleaners will be active. Therefore the building does not need to be up to temperature at 06:00.

Domestic hot water

DHW is provided from the constant temperature hot water circuit from the boilers and from 12 flat plate solar collectors to a 1500 l twin coil calorifier. The solar coil is at low level and a secondary coil from the boilers raises the temperature in the calorifiers to 60^{o}C as required.

The DHW is circulated around the building via a secondary return circuit. Hot water outlets in student and visitor areas are limited to 43^{o}C by adjustable mixing valves below the taps. The DHW is set to operate according to the time schedule within the BMS. All temperature controls are set on the solar control system in the plant room.

Heat loss from the secondary circulation system and potential improvements are discussed further in Sections 6.5, 6.6, 8.1 and 8.2.

Ventilation

The building is ventilated by natural ventilation high level windows and rooflights in classrooms, louvres connecting classrooms to the adjacent corridors and roof lights in corridors, halls and other rooms. The natural ventilation operates automatically using a WindowMaster system controlled by a dedicated PC in the caretakers room. Smaller rooms are ventilated through manual window operation. Full details of the natural ventilation system are provided in Section 7.5.

Mechanical ventilation is via extract fans to toilets, changing rooms, cleaners/caretakers rooms, reception class, community and staff kitchens and shower. The toilets, changing rooms and stores are ventilated by individual duct mounted extract fans located in the ceiling void and controlled by PIR sensors linked to the lighting circuit. The reception class, community kitchen, staff room/kitchen are similar but controlled manually by wall mounted speed controllers.

The kitchen is ventilated by supply and extract AHU, located in the plant room, which runs off the constant temperature hot water circuit from the boilers. The system operates according to the time schedule set within the BMS. The kitchen AHU, also has local over-ride. The air supply set-point is 21^{o}C. There is a central island four sided supply and extract canopy and a four sided extract only canopy for the dishwasher.

Air Conditioning

Cooling of the server room is achieved with a 3.5kW split packaged cooling system utilising refrigerant R410A. The system comprises Daikin FAQ100BUV1B indoor unit mounted on the wall of the server room at high level, and FAQ100BVV1B floor mounted condensing unit on the external wall of the room (ie outside). The system is controlled by a wall mounted thermosat which was set at 20^{o}C when the project started. The refrigerant has a global warming potential 2088 times that of CO_2 and therefore any indication of leakage should be investigated and resolved immediately. No such leakage has been reported at the school.

Cold water system

The cold water supply feeds:

- potable outlets;
- sprinkler tank;
- heating and hot water systems;
- roof mounted tank for toilet flushing.

Low flow taps (<6l/min) are installed throughout the building. Toilets are dual flush 6 and 3 l. Showers are <8 l/min. Urinals are fitted with water saving SmartFlush system.

There is a rainwater harvesting system which captures roof run-off an filters it before storing it in an underground tank. The stored water is pumped to a header tank on the roof of the building and used for toilet flushing.

Lighting

The building is lit by low energy fluorescent lamps. A full lighting schedule is presented in Appendix D. The following spaces have automatic PIR motion sensors:

- classrooms;
- community room;
- corridors;
- library;
- WCs;
- some cupboards and stores;
- staff room.

In each case the manual switching is via a key switch which can only be operated with a key. The lights are generally left on and come on in the morning when the space is first used. Typically lights switch off after 20 minutes if no movement is detected in the space. This means in the automated areas the lights are almost always on during the school day. In the classrooms there are three rows of independently switchable T5s. The middle row is often switched off by teaching staff when teaching screens are in use.

External lighting

The roads and car parks are lit by column mounted lamps, 2 at 300W and 9 at 150W. Nineteen lamps are also mounted on the building for external lighting – these are 70W each.

There is also a Multi-use Games Area (MUGA) which has external lamps operated by a token meter. Tokens can be bought from the school office. The MUGA lights are rarely used.

The external lighting is controlled by a timer set manually in the switch room.

Power and equipment

A separate equipment inventory has been produced and has details of all the equipment in the school. Some key features are:

- all kitchen equipment except the ovens and hobs are electrically powered;
- all classrooms have 60 inch LCD teaching screens;
- all classrooms and the community room have 4 PCs;
- 15 laptops are available for teaching and are moved from classroom to classroom according to a booking system.

Other small power includes water heaters, fridges, cleaning equipment, audio equipment and lighting in the hall.

Other electrical

The following additional electrical systems are in place:

- Sprinkler system
- Security panel
- Fire alarm
- Surge protector.

The sprinkler system is protected against frost by the fan, immersion heaters and trace heating system listed in the equipment inventory (Section 2.7). The following information has been established about their control:

- the Dimplex fan operates from its own thermostat which can be set at between 5 and 35°C;
- it is understood (Tyco engineer) that the immersion heaters are set to come on when the external temperature falls to 5°C, but the location of the thermostat and how it is controlled are not known;
- there is no information on the trace heating system except that its energy use can be between 10 and 31W/m at 5°C depending on the system installed. The literature in the O&M manual is generic, but the suggestion is that this also operates on a 5°C set point.

The following items are maintained under services contracts:

- Rainwater harvesting;
- WindowMaster natural ventilation;
- Wind Turbine (expired);
- Sprinkler system;
- Emergency lighting;
- Boiler servicing.

Some of the contracts are administered by Monmouthshire County Council, whilst others are administered by the school. The school pays directly for all the servicing contracts. The kitchen is not run by the school, but run directly by the council. Other systems are all paid for as and when required.

3.2 Metering

The school gas, electricity and water supplies are all sub-metered. There is also heat sub-metering of the heat supply to the community area. Part L2A of the Building Regulations requires the following of new non-domestic buildings:

- sub-metering allows at least 90% of the annual energy consumption of each fuel type to be assigned to the various end uses (e.g. heating and lighting);
- sub-metering allows performance of low and zero carbon technologies to be monitored; and
- for buildings of over 1000m^2 total useful floor area - automatic meter reading and data collection facilities should be provided.

The sub-meters installed at the school are listed in Figure 4.1. The table simply lists the meter and does not show the relationships between the meters and sub-meters.

The water metering does not directly effect the energy usage of the school and therefore is not considered further in this report. The DHW system water is the cold water supply to the DHW system which represents the amount of DHW flowing from the taps and as such has been used to assess the energy in the DHW delivered.

The description of the metering below is based on inspection at the school and a site meeting with the electrical designer from McCann and Partners to answer questions regarding uncertainties.

Figure. 3.1: List of sub-meters

Gas	Electricity	Heat	Water
Main external supply	Main incoming	Community heat	Main incoming water
Main gas plant room	DB01	Solar collector	Kitchen water
Kitchen gas	DB01 lights		Community water
	DB02		DHW system water
	DB02 lights		Rainwater inlet
	DB03		Main water feed to rainwater harvesting
	DB03 lights		Rainwater harvesting tank (usage)
	DB04		
	DB04 lights		
	DB05		
	DB05 lights		
	DB hall (including lights)		
	DB kitchen (including lights)		
	DB externals		
	DB plant room		
	Mechanical Panel (MCC1)		
	Wind		
	DB IT		
	Fiscal		

Meters shaded are also monitored by the BMS

There is limited information in the O&M manual on metering.

The areas covered by the different distribution boards or zones are shown in Figure 3.2. Most are self explanatory with DB01-05 representing Zones 1-5. The plant room meter has always read zero and does not appear to be connected. DB mechanical panel is the electrical supply to the mechanical control panel incorporating the pumps, fans and controls in the plant room. DB IT is the power for the IT server.

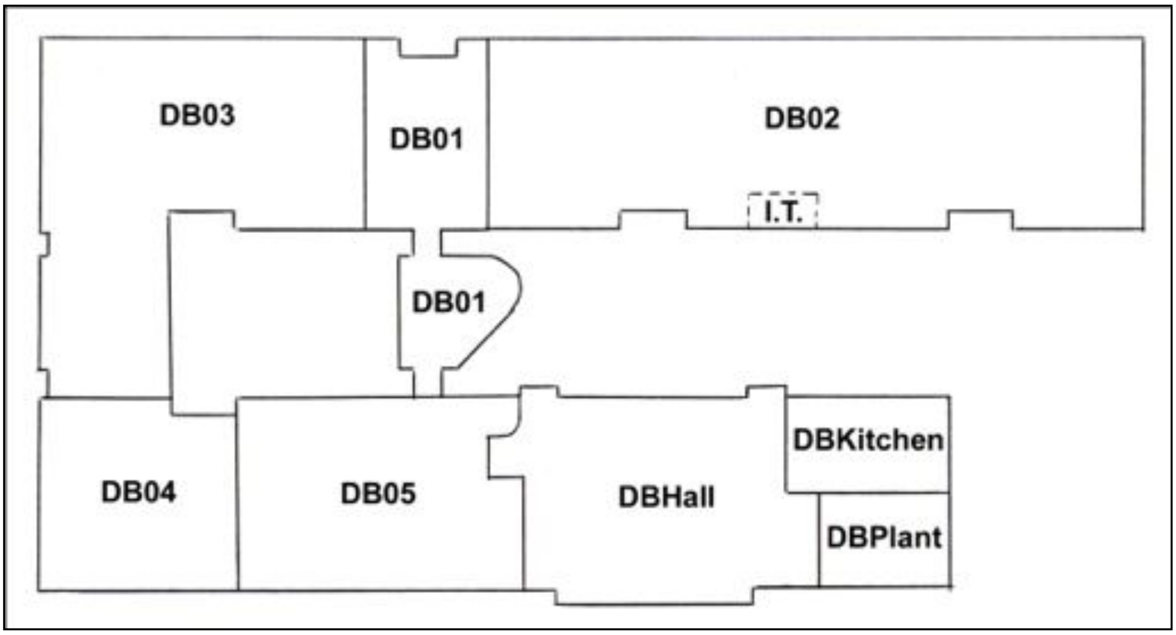
The distribution boards for Zone 1-5 also have a lighting sub-meter. The lighting sub-meters read very low total energy used (kWh) and instantaneous reading (kW), and it is likely that the initial set up of the meters was incorrect. It was attempted to reconcile the meters with the lighting usage by multiplying the meter readings by a factor of 10, but the meter readings are still well below the anticipated energy usage. These lighting sub-meters have therefore been disregarded in the study.

The wind turbine and solar thermal meters are connected to the Ecowall display in the library and are not connected to the BMS. The wind turbine is also connected to a generation and export meter in the plant room, although this does not appear to be working most of the time. The wind turbine electrical energy feeds into the electrical system via the un-metered panel in the switch room, so the interpretation is that the wind energy generated and used in the building must be added to the imported electrical energy to obtain the total electrical usage of the building.
The following are not metered:

- DB tank room
- DB sprinkler room
- Security panel
- Fire alarm

- MUGA
- Surge protector

Fig. 3.2: Electricity Zones



3.3 TM39 Compliance

The gas sub-metering covers 100% of the supply and covers all the gas appliances separately: the three boilers considered as one and the gas cooker. Since the heating and hot water are both produced by the same boiler plant, strictly, separate metering is not required under CIBSE TM39 or Building Regulations Part L2A.
The solar thermal system is also separately metered in compliance with CIBSE TM39 guidance. The heat metering to the community room is not a requirement under TM39, because this separately tenanted area is less than 500m^2, but this has been done to facilitate cross charging.

The electrical sub-metering was thought to cover almost 100% of the load and therefore be compliant with CIBSE TM39. In this case there would be no loads exceeding the sizes in Table 1 of TM39 and no uses, which need to be separated out to enable benchmarking. However, through the evolution of the project it has been uncovered that there are substantial un-metered loads, mostly thought to be associated with the sprinkler system. Had TM 39 been followed correctly, the energy usage of the sprinkler system could have been identified and mitigated to some extent.
The water metering is compliant with TM39, with the water used in the school calculated by difference.
There is no evidence that TM39 was used to develop the sub-metering strategy which was driven more by the need to gain BREEAM points than by Building Regulations Compliance.

3.4 Conclusions and key findings for this section

The sub-metering of gas/heat and water is comprehensive and compliant with TM39. The electricity sub-metering is not compliant with TM39 because the sprinkler room energy is un-metered. The lighting and plant room electrical sub-meter, whilst existing do not work. The majority of the sub-meters are also connected to the BMS to enable recording of data, with the exceptions being lighting, renewables and some of the water meters.
There is no evidence that TM39 (or the metering requirements of Part L2A) were taken into account in a detailed manner in defining the metering strategy for the building.

4 Key findings from occupant survey

4.1 How the study was undertaken

The BUS was undertaken in accordance with the guidance document ‘How to carry out a BUS occupant survey’. Approval for the use and distribution of the questionnaire was sought and gained from Kathryn Evans, Headteacher at Rogiet Primary School. White Design delivered a quick introduction to the process through presentation at the staff meeting on 30 January 2012 a week before the survey was to be conducted. The presentation explained the reasons for the survey, as well as an introduction to the wider project. All staff were asked to fill the form in on their own and the reasons for this explained.

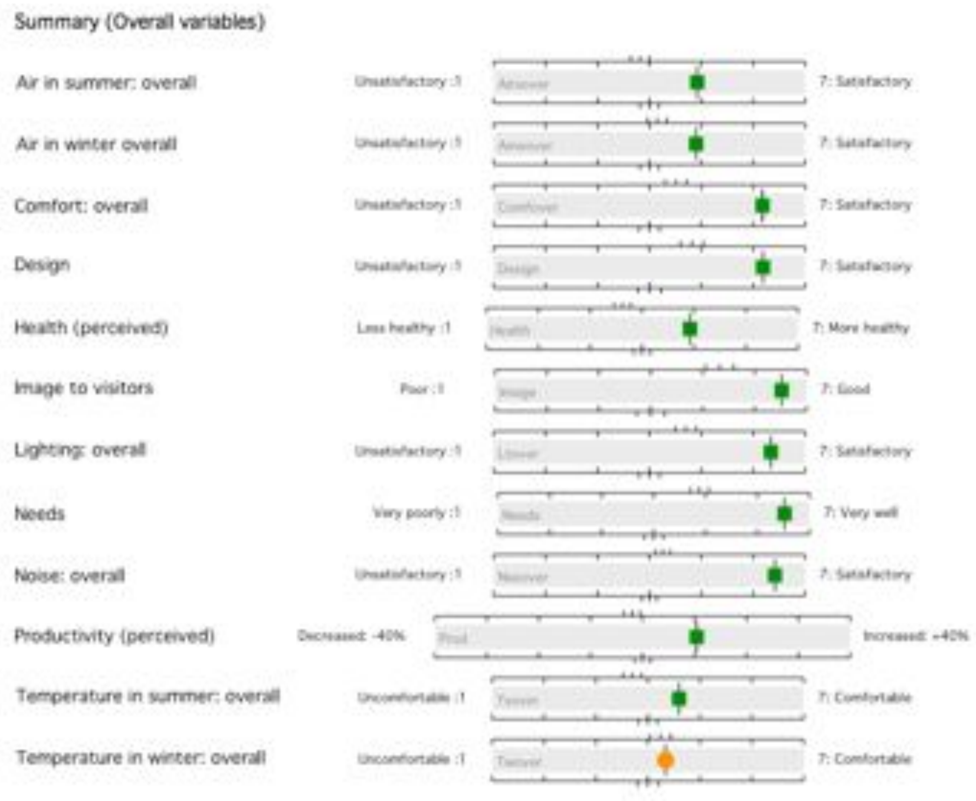
The following week on 6 February 2012 the surveys were distributed to all the staff members and the staff a time frame in which to complete the surveys. 28 surveys were distributed and on the day 23 were returned, the other 5 were subsequently sent through about a week later due to staff illness.

The data was entered into the dedicated spreadsheet and sent off to Arup on 5 March 2012. The results of the survey were returned on 2 April 2012 with the following comment from Arup’s Engineer “These are extremely good results, with the BUS summary index coming in at the top of the data set, and some fantastic comments. You should be very pleased with these.” See figure 4.1 below. The full BUS survey can be found in Appendix E.

4.2 Main findings of the BUS

The summary below depicts a very rosy picture of the building however, there are some areas that did not score particularly well which are lost in the summary. The areas that scored the lowest marks are further discussed in the Section 4.3.

Figure. 4.1: Overall summary of the BUS



The purpose of this section is to follow up on the issues identified through the BUS and identify aspects of this BPE study, which warrant further investigation.

The following list Figure 4.2 is taken directly form the ARUP BUS summary indicating the green amber and red sub-categories within the overall BUS survey.

Figure. 4.2 detailed summary of issues from the BUS

Green	Amber	Red
Air In Summer: Odourless/Smelly!	Air In Summer: Fresh/Stuffy	Air In Summer: Dry/Humid
Air In Summer: Overall	Air In Winter: Dry/Humid	Air In Summer: Still/Draughty
Air In Winter Overall	Control Over Cooling	Air In Winter: Still/Draughty
Air In Winter: Fresh/Stuffy	Control Over Noise	Control Over Heating
Air In Winter: Odourless/Smelly	Control Over Ventilation	Noise: Noise From Colleagues
Cleaning	Lighting: Artificial Light	Noise: Noise From Other People
Comfort: Overall!	Lighting: Natural Light	Noise: Noise From Outside
Control Over Lighting	Space At Desk	Noise: Other Noise From Inside
Design	Temperature In Summer: Hot/Cold	Temperature In Winter: Hot/Cold
Do Facilities Meet Needs?	Temperature In Summer: Stable/Varies	Temperature In Winter: Stable/Varies
Furniture	Temperature In Winter: Overall	
Health (Perceived		
Image To Visitors		
Lighting: Glare From Lights		
Lighting: Glare From Sun And Sky		
Lighting: Overall		
Meeting Rooms: Overall		
Needs		
Noise: Overall		
Noise: Unwanted Interruptions		
Personal Safety In Building /Vicinity		
Productivity (Perceived)		
Space In The Building		
Storage Space: Overall		
Temperature In Summer: Overall		

Temperature

The results of the temperature responses indicate that in summer the building is slightly too hot, but comfortable with little variability during the day. In winter the overall opinion is that the building is too cold, although again comfortable and variable during the day. Comments about temperature occur throughout the questionnaire, with the library and pods (winter gardens) being described as too hot and too cold. These rooms have large external envelopes and are vulnerable to outdoor temperature for this reason. The issues around temperature are also associated with control (see below). In the latter part of the study it was discovered that the temperature sensor in the year 3 & 4 pod was not working, reading a continuous temperature of over 30°C, causing the valve controlling the under floor heating to this space to be closed – hence the feeling of cold in this area.

Air

The responses for summer and winter were consistent in that they were good overall and odourless. In summer the air was considered too still and humid, whilst in winter too still and perhaps a bit dry. Few comments relate directly to air, with one comment saying some rooms are stuffy. Follow up was required to assess whether sufficient natural ventilation can be achieved in summer, and/or whether the problem is essentially one of overheating or of air quality.

Noise

Many of the staff noted that this question was unclear to them. Given this building is a school, the noise levels are understandably higher than in an office or apartment building, particularly if the 'pod' doors are open into two classrooms (the pod doors can easily be closed if required). The teachers clarified that they answered the question in terms of noise levels in their work environment, rather than noise nuisance levels. This is supported by the results of 'noise: unwanted interruptions' and is also partially backed up by the comments given by the occupants:

- "Acoustics very sound. Work with pupil sensitive to noise and the building definitely helps her with this."
- "Can hear loud sounds through walls. Unwanted interruptions during music lessons."
- "Noise does not disturb us."
- "Noise does not affect my job."
- "The building is well sound proofed! When teaching in class, noise can be heard through the pod sometimes - this happens when the doors are open. PPA Room - very little sound is heard when the door is shut."
- "Unwanted interruptions are nothing to do with the building! A good balance with acoustics has been achieved, still nice to hear children in the building."
- "Very little noise comes through from either class."
- "Within the building, noise from other areas does not pose a problem."

Control

The responses on controls are each addressed separately as the issues are different for each category.

Cooling

The cooling in the school is in the IT server room and the AHU in the kitchen. Generally staff would not be expected to have control over these. Generally the response was that there was little or no control over cooling, which is consistent with the specific cooling requirements of the building. Some respondents indicated that they did have control over cooling – there may have been some acknowledgement of cooling by natural ventilation.

Heating

All staff are affected by the heating, but the general response was that they had no control over heating. Since there are no programmable room thermostats, only the head teacher controls heating through the BMS. A system of feedback to the head and responding to the needs of staff would address this to some extent, but this is difficult because unless there is a consistent problem the heating needs are likely to vary from day to day. Several of the comments reflect lack of control and the effects of weather changes on temperature.

Lighting

Opinions on control over-lighting were split, with most respondents considering their level of control to be moderate to high, although several staff considered they had no control over lighting – perhaps reflecting different locations in the school and/or different roles. For classrooms the level of control is generally good and it is expected that the responses from teachers based in the classrooms were positive. Whilst for other staff such as office based and kitchen staff responses were less positive.

Noise

As expected in a school the control over noise is generally low.

Ventilation

The responses on ventilation control were weighted towards no control and low control. This may reflect different roles and locations of staff, but may also reflect a feeling by classroom teachers that the windows don't open far enough (this was one of the comments) or that the automated natural ventilation cannot or should not be over-ridden.

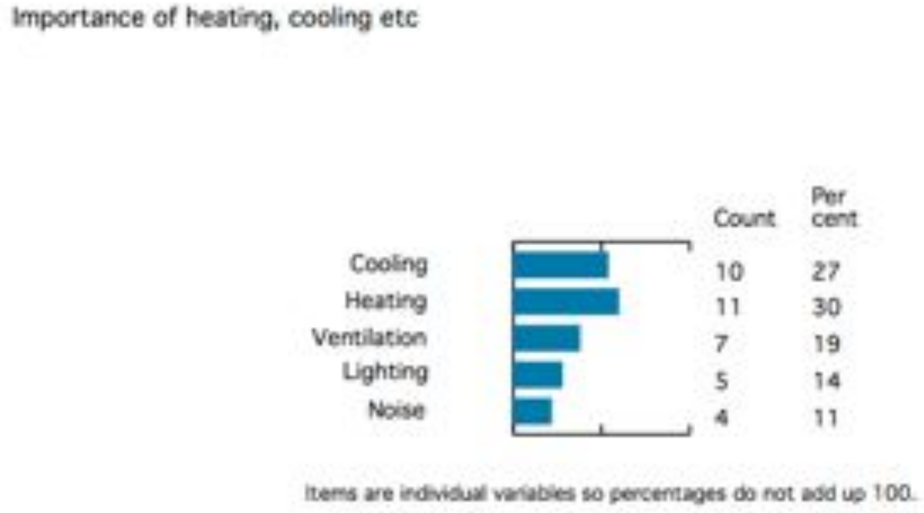
Overall

Despite the lack of control over most individual items, the response on overall control was very positive with the responses heavily weight towards satisfactory. This perhaps reflects that the systems work and provide a comfortable environment without staff being able to control individual features and systems.

4.3 Follow up on BUS issues

Figure 4.3 is a graph from the BUS data tables that indicates the relative importance of the various aspects of the building and helps to frame where the emphasis of further investigation needs to concentrate.

Figure. 4.3 Summary table indicating relative importance of issues from the BUS



This can be combined with the red amber green table which clearly identifies those area with a red indicator which fall outside comparable BUS data benchmarks   Alongside the quantitative data the anecdotal commentary that is collated through the BUS process can be married against scores outside the comparable benchmarks and this can point towards an issue.

This is definitely the case with cooling, heating and ventilation and these three aspects are looked at in more detail in the following pages. Lighting did not score significantly outside the BUS benchmarks however anecdotal evidence suggest some perceived feelings of gloominess and this has been investigated further in Section 7 .

Air, temperature and heating (cooling)

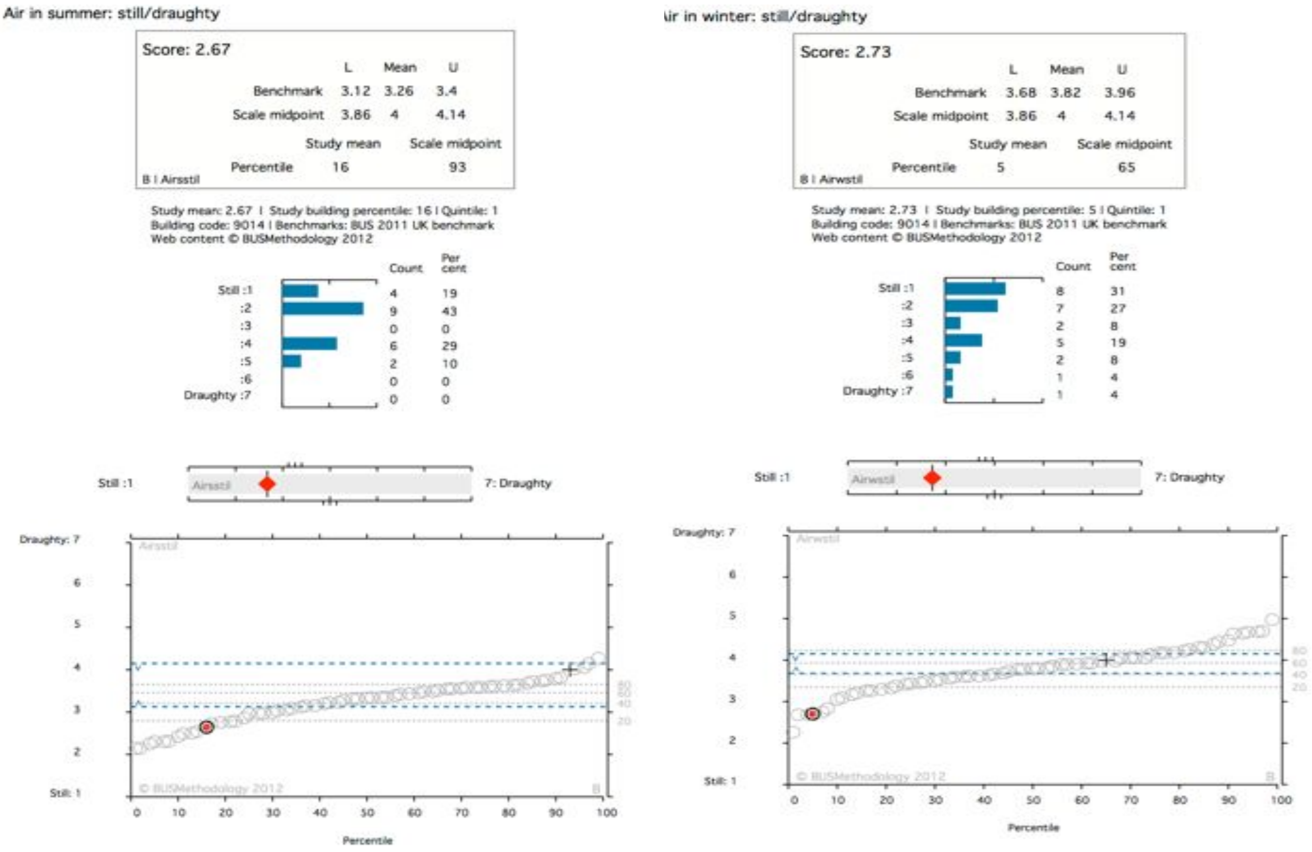
The BUS comments below and data summary above have established the absolute need for the BPE study to assess the heating and ventilation strategy. The following comments were listed through the BUS relating to these aspects;

Air (summary of BUS comments)

- Humidity and stillness of the air in summer;
- Rain sensors closing the roof-lights (having an effect on the summer temperatures);
- In summer the air was considered too still and humid; and
- In winter too still and perhaps a bit dry.

The data tables in figure 4.4 below show the red scores for air in winter and air in summer implied as still. This suggests a perceived lack of air movement on the occupied zone, which could be a result of the performance of the natural ventilation approach. As reported in the As-Built vs Design drawing review, the value engineering process saw the omission of the low level incoming air vents to the classroom, as a result there could be a short circuiting of air movement between the higher level openings. However it has also been discovered in the latter part of this study that the CO_2 set point was in fact too high resulting in more limited window opening in winter and that night cooling was not enabled.

Figure. 4.4 Air in Summer; Air in Winter



Air in summer: still/draughty

Score: 2.67

	L	Mean	U
Benchmark	3.12	3.26	3.4
Scale midpoint	3.86	4	4.14

	Study mean	Scale midpoint
Percentile	16	93

B I Airsstil

Study mean: 2.67 I Study building percentile: 16 I Quintile: 1
Building code: 9014 I Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012

	Count	Per cent
Still :1	4	19
:2	9	43
:3	0	0
:4	6	29
:5	2	10
:6	0	0
Draughty :7	0	0

Air in winter: still/draughty

Score: 2.73

	L	Mean	U
Benchmark	3.68	3.82	3.96
Scale midpoint	3.86	4	4.14

	Study mean	Scale midpoint
Percentile	5	65

B I Airwstil

Study mean: 2.73 I Study building percentile: 5 I Quintile: 1
Building code: 9014 I Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012

	Count	Per cent
Still :1	8	31
:2	7	27
:3	2	8
:4	5	19
:5	2	8
:6	1	4
Draughty :7	1	4

Heating (summary of BUS comments)

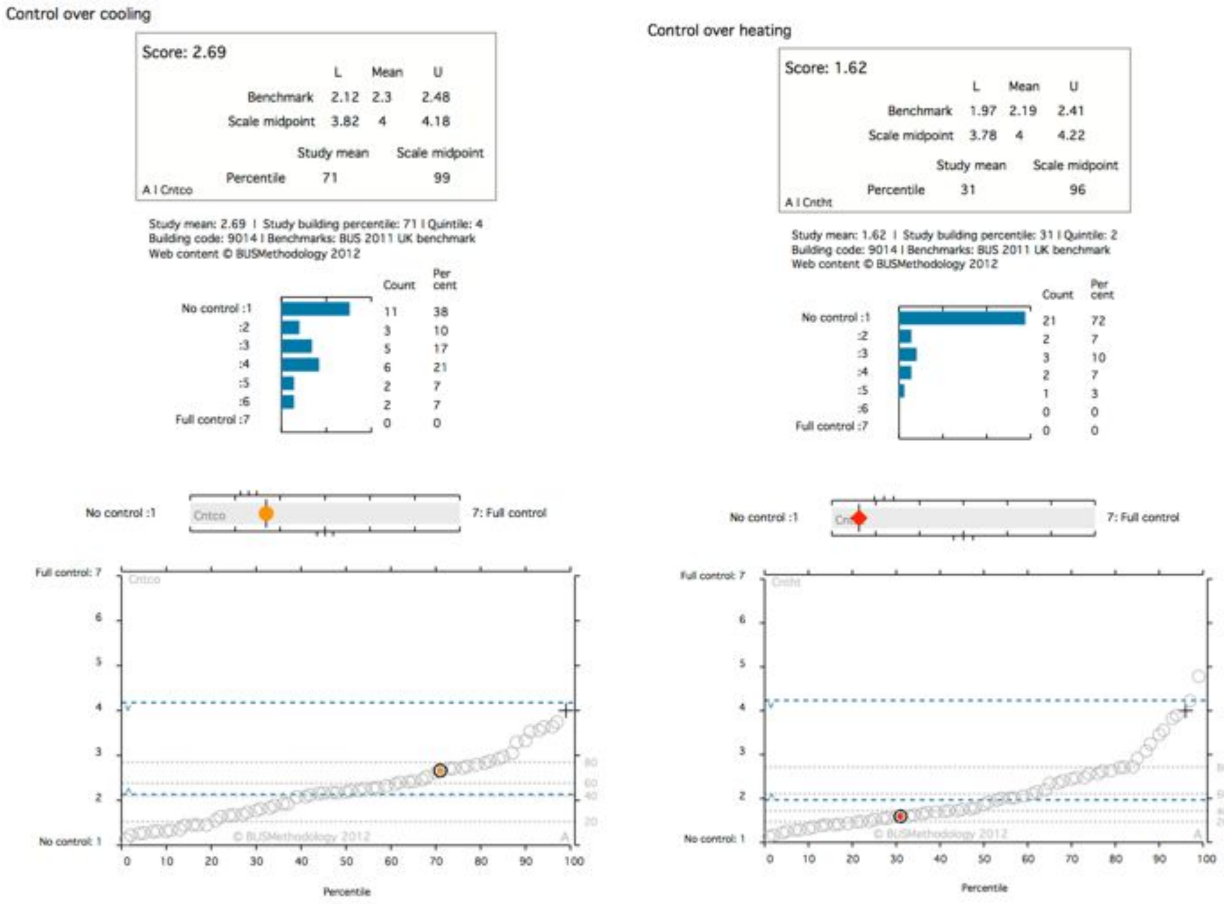
- Users do not have control over the heating, controlled through a central system;
- Lack of control, when the weather changes through the day; and
- A system of feedback to the controller and responding to the needs of staff would try to address this, though could be problematic.

Cooling (summary of BUS comments)

- Only in limited rooms IT server room and kitchen;
- Through the opening of windows/roof-lights additional ventilation has been seen as a way of passively cooling a space; and
- Linked to comments on temperature additional coolth would be ideal in the summer months.

Whilst cooling is indicated orange and not significantly different to the BUS benchmarks, the issues raised by the data could also be linked to the perception of air being still in the summer. There is perceived by many to be no or little control over cooling. This is further exacerbated by the feedback highlighting the feeling of 'no control' over heating. (It is also worth noting that the confidence limits identified by the blue dotted lines are broader than those shown on other comfort variables).

Figure. 4.5 Control over cooling; Control over heating

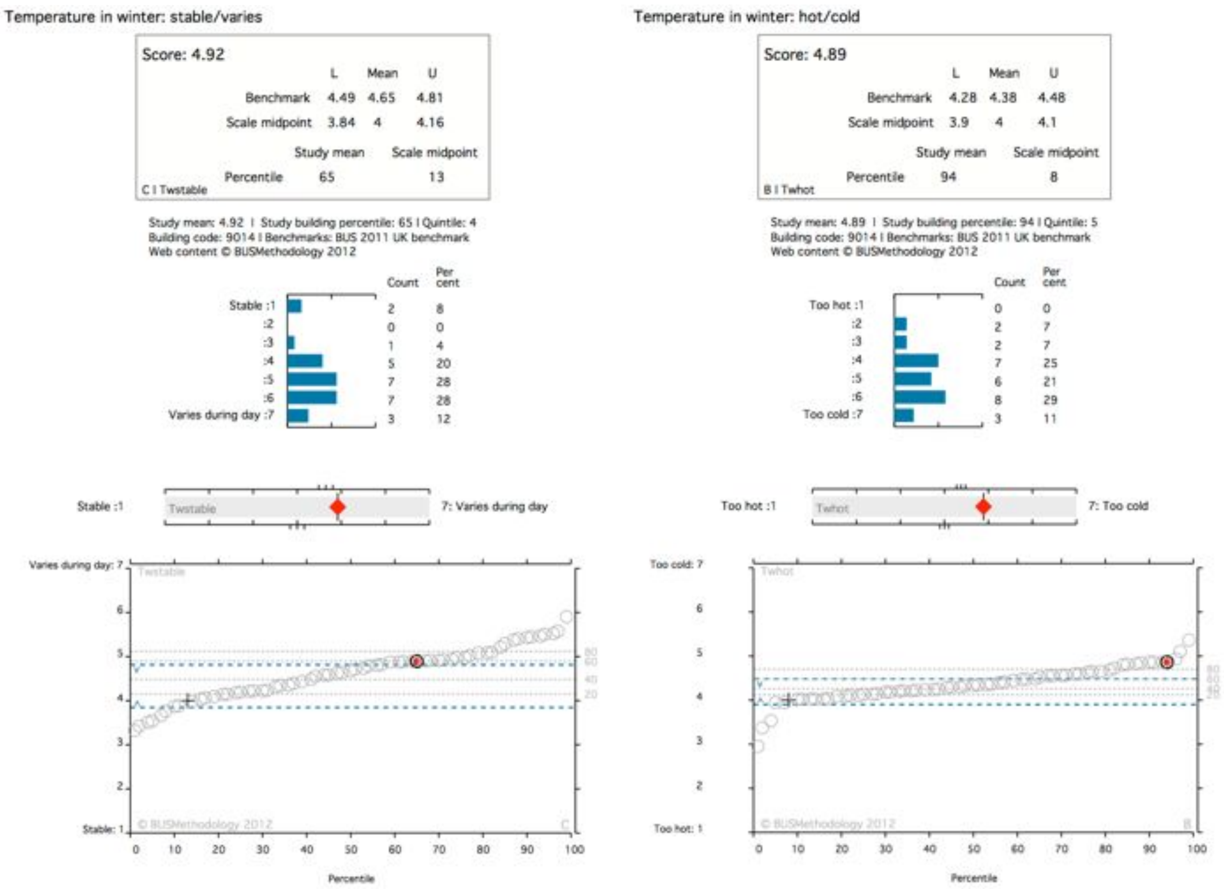


Temperature (summary of BUS comments)

- Temperature and stability of temperature in winter;
- In summer, the building is perceived to be slightly too hot, comfortable with little variability during the day;
- In winter, the building is perceived to be slightly too cold, although again comfortable and variable during the day; and
- Comments about temperature occur throughout the questionnaire, with the library and pods (winter gardens) being described as too hot and too cold.

The BUS data and comments do corroborate the lack of feeling of control over the heating. In contrast to the note above it is also worth highlighting the narrow confidence limits relating to the temperature in winter benchmark data.

Figure. 4.6 Temperature in winter(stable varies) ; Temperature in winter (hot/cold)



4.4 Conclusions and key findings for this section

The follow-up to these issues has been carried out through three specific investigations, each of these were also identified through the initial brief for this BPE project. These are, specific temperature and control investigations reported within the summer and winter monitoring and the TM22,(CIBSE Technical Manual 22) the Lobby Group Room design review, and the Natural Ventilation Effectiveness review.

Section 7 Technical Issues Review of the Lobby spaces and design - explores the issues created by the lack of adherence to an exit and egress strategy through the lobby/group space alongside the added issue of a door direct from the classroom to the outside. This has compounded issues relating to the unnecessary purging of classroom heat as students enter and leave the classroom throughout the day alongside an unresponsive under-floor heating specification which cannot boost heat locally when needed in contrast to radiant heating.

Section 7 Technical Issues - Natural Ventilation effectiveness review, has reviewed the value engineering changes that were made to the acoustic and ventilation strategy and tested whether these may have had a negative effect on the performance of the ventilation strategy. This in particular challenges the omission of the low level ventilation on the window wall of the classrooms, which was omitted.

The studies identified above provide some answers to the following questions.

- Is the natural ventilation system effective enough?
- How could users gain better control of the ventilation system to prevent heating and cooling issues?
- What can be learnt from these issues that could change future designs?
- The follow up interviews and further interrogation of the anecdotal feedback suggest that noise may not warrant further investigation given the range of positive and negative feedback. However, reinforcement of the natural ventilation strategy to improve internal air quality could have a detrimental effect on noise ingress from outside, this is discussed in Section 7 Technical Issues – Noise Profile anlaysis

5 Curriculum Integration

White Design have tried through the design of schools to integrate opportunities for using completed school buildings as a teaching and learning tool in their own right to help teachers and students understand the effects of their own actions in terms of energy use and sustainable lifestyles. The initial proposal for this TSB study proposed using the opportunity of the BPE to further this engagement and understanding with the school users.

It is however difficult to quantify the improvement in building performance through the advocacy of more sustainable behaviours. Making information more available and relevant to a person's knowledge can only be beneficial as well as translating it and comparing it to other more common place activities. The outcome from these activities will not demonstrate tangible results for the purposes of this TSB study but may help to reinforce the legacy intention of the building as a curriculum tool that may not have been fully delivered through the original execution.
This section provides a summary of the activities that have been undertaken over the two year period relating to activities that have engaged staff and students.

A curriculum workshop was held with 9 members of staff and completed in Quarter 2 and assessed legitimate and helpful links between the BPE project and the school curriculum over the two years and where the most benefit could be made. Various suggestions were discussed, particularly appropriateness of the topics for each of the year groups.

The following activities were then undertaken throughout this study relating aspects of the BPE study to curriculum integration opportunities and link to some of the activities identified above;

- Quarter 2 curriculum workshop with staff to discuss ideas and projects linked to BPE study as stated above
- Quarter 4 - Workshop 1 around energy - how it is used in the school where it comes from. Workshop 2 around CO_2
- Quarter 5 - formatting projects into data sheets for use by school for future curriculum activities
- Quarter 7 - creative labelling exercise workshop with students and IT curriculum leader embedding building related information into QR codes and applied around the school.
- Quarter 8 - Buffer Zone Experiment
- Quarter 10 - Presentation of Building Users guidance information into an in class static display.

5.1 Curriculum workshops and data sheets

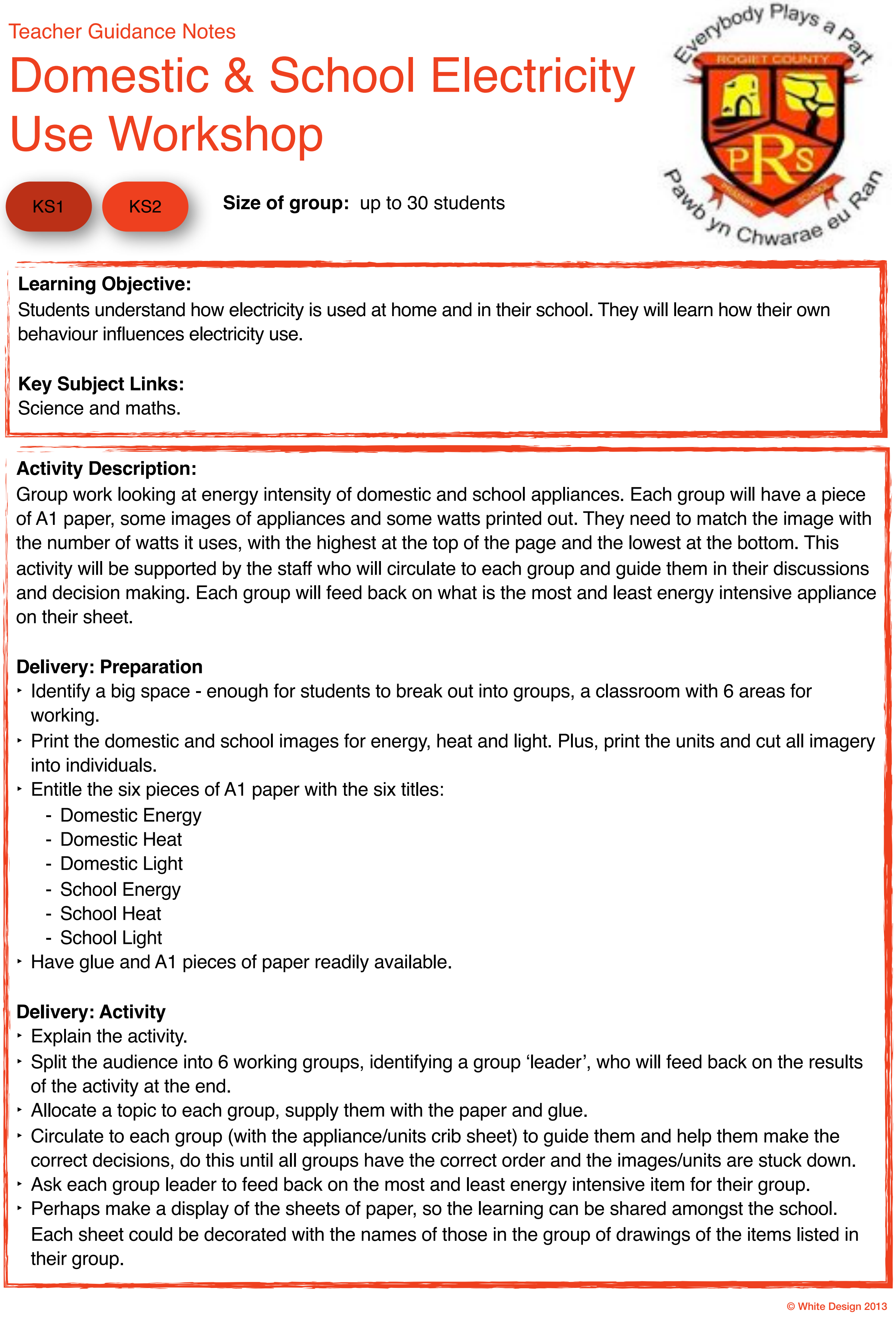
Student Workshop 1 - Q4a and b – Energy

In discussion with the school White Design designed a workshop for Year 5 pupils to be introduced to the concepts of electrical grids and networks, plus where energy comes from and how this relates to the things used on a daily basis.

After a 20 minute presentation on energy sources, production, distribution and use, the students were required to categorise domestic and school energy use, this was followed by a quiz and prize giving. After a break, the students were then asked to split into four groups and rank a series of items on their electricity demand, based on what they have learnt earlier in the morning.

The feedback from the day was very positive and the staff and students responded to the connections between their actions and the influence on their home and school lives. See figure 5.1 and 5. 2 below

Figure 5.1 Student Workshop 1 - Q5 c Extract from Data sheet compilation



Teacher Guidance Notes

Domestic & School Electricity Use Workshop

KS1 KS2 **Size of group:** up to 30 students

Learning Objective:
Students understand how electricity is used at home and in their school. They will learn how their own behaviour influences electricity use.

Key Subject Links:
Science and maths.

Activity Description:
Group work looking at energy intensity of domestic and school appliances. Each group will have a piece of A1 paper, some images of appliances and some watts printed out. They need to match the image with the number of watts it uses, with the highest at the top of the page and the lowest at the bottom. This activity will be supported by the staff who will circulate to each group and guide them in their discussions and decision making. Each group will feed back on what is the most and least energy intensive appliance on their sheet.

Delivery: Preparation

- Identify a big space - enough for students to break out into groups, a classroom with 6 areas for working.
- Print the domestic and school images for energy, heat and light. Plus, print the units and cut all imagery into individuals.
- Entitle the six pieces of A1 paper with the six titles:
    - Domestic Energy
    - Domestic Heat
    - Domestic Light
    - School Energy
    - School Heat
    - School Light
- Have glue and A1 pieces of paper readily available.

Delivery: Activity

- Explain the activity.
- Split the audience into 6 working groups, identifying a group ‘leader’, who will feed back on the results of the activity at the end.
- Allocate a topic to each group, supply them with the paper and glue.
- Circulate to each group (with the appliance/units crib sheet) to guide them and help them make the correct decisions, do this until all groups have the correct order and the images/units are stuck down.
- Ask each group leader to feed back on the most and least energy intensive item for their group.
- Perhaps make a display of the sheets of paper, so the learning can be shared amongst the school. Each sheet could be decorated with the names of those in the group of drawings of the items listed in their group.

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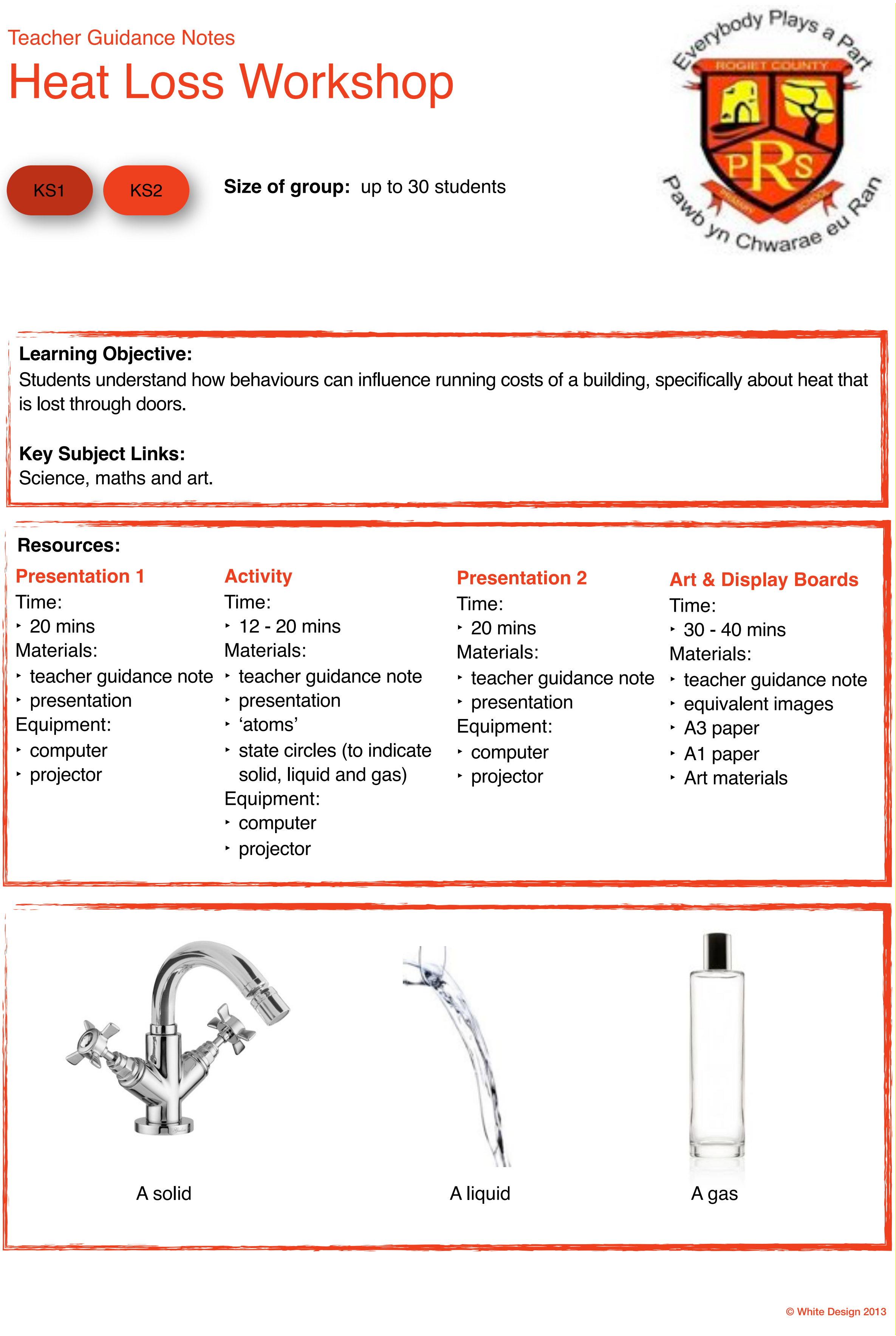
Figure 5.2 Student Workshop 2 - Q5 c Extract from Data sheet compilation



Teacher Guidance Notes

Heat Loss Workshop

KS1 KS2

Size of group: up to 30 students

Learning Objective:
Students understand how behaviours can influence running costs of a building, specifically about heat that is lost through doors.

Key Subject Links:
Science, maths and art.

Resources:

Presentation 1

Time:
- 20 mins

Materials:
- teacher guidance note
- presentation

Equipment:
- computer
- projector

Activity

Time:
- 12 - 20 mins

Materials:
- teacher guidance note
- presentation
- ‘atoms’
- state circles (to indicate solid, liquid and gas)

Equipment:
- computer
- projector

Presentation 2

Time:
- 20 mins

Materials:
- teacher guidance note
- presentation

Equipment:
- computer
- projector

Art & Display Boards

Time:
- 30 - 40 mins

Materials:
- teacher guidance note
- equivalent images
- A3 paper
- A1 paper
- Art materials

A solid

A liquid

A gas

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5.2 Creative Labelling task

The creative labelling task completed by Year 6 at Rogiet Primary School took the form of a workshop with 28 students. The workshop was designed to introduce the class to the control systems that are used to monitor and support the school in its everyday activities. The workshop went on to explain about how the controls/sensors situated periodically around the school contribute to and deliver information about its environment to regulate the systems.
The systems included were cooking, lighting, heating, electricity, sanitary, fire alarms, security, fresh water and drainage.

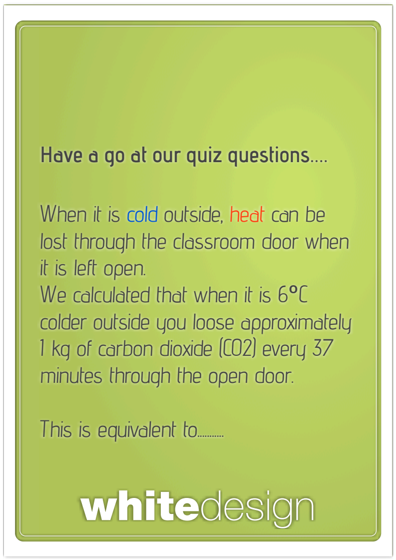
The students were very knowledgeable about their school and had a good working knowledge of many of the control systems. A majority of the class had been taught in the old school and could report on what the improvements to the new school were.

In the second half of the workshop, the students went on to create Quick Response (QR) codes, linked to a website, which detailed the information about each of the 13 controls/sensors identified to them. Some also created a video to introduce their control. The school now has a newly formed 'Sensor Trail'. This information is designed to not only provide information to the rest of the school and the general public, but also reinforces their abilities in IT, writing and media skills. See Figures 5.3 below.

Figures 5.3 Photos of installed QR code information

5.3 Buffer Zone Experiment

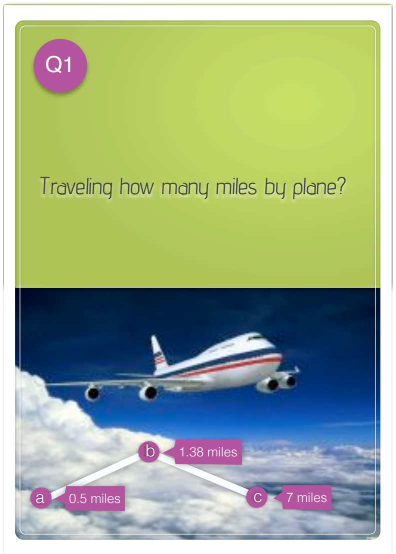
The technical issues considering the design of the Buffer zone spaces is discussed in Chapter 7. Alongside the investigation of this part of the building, an experiment was carried out to determine if the group rooms could be used as lobby spaces as original intended and what would be the effects of this on the use of the space. The experiment involved the teaching staff and students using the lobby space as an airlock to minimise heat lost from the class-base. This was followed by a short presentation to each class. (Years 1 and 2 and Years 5 and 6) regarding the potential effect of heat lost from the classroom by using the direct door to the outside.



Have a go at our quiz questions....

When it is cold outside, heat can be lost through the classroom door when it is left open.
We calculated that when it is 6°C colder outside you loose approximately 1 kg of carbon dioxide (CO2) every 37 minutes through the open door.

This is equivalent to........



Q1

Traveling how many miles by plane?

a 0.5 miles
b 1.38 miles
c 7 miles

Q2

Driving how many miles by car?

(Assuming 7.3 litres of petrol per 100km or 39 mpg)

a 3.75 miles
b 5 miles
c 30 miles

5.4 Enhanced Building Users Guidance

The technical issues identified through the BUS and followed up through the investigations throughout this study have identified the need for better simple guidance for the users to understand how they can effect changes in the classroom environment and provide clear information on what additionally the building could do for them if trends appear over time. e.g. too hot in late spring. Through the tasks which investigated the relevance of the existing Building Users Guide, it was identified that some in class static displays would be useful, that better described the opportunities for users to alter the internal environment of the classroom. These were developed in collaboration with the teachers and also made reference to stats and facts generated from the Buffer Zone experiment above.

Please see the sheets developed below.

Rogiet Primary School - Room Control Guidance

whitedesign

There are some simple things that can be done within the classroom environment to make changes.

Over and above the simple changes the system settings can be changed.

If it is regularly too hot or too cold the heating settings should be changed.

If the classrooms regularly feel stuffy or draughty the ventilation system should be adjusted.

too gloomy?

What can i do?

- Ensure roof window blind is open
- Remove artworks from windows to maximise incoming light.
- Slide back fully the window blinds rather than leave in the open position.

too hot?

What can i do?

- **In summer** open manual windows and doors to allow more fresh air in.
- Use remote control to open the roof light wider if it is not raining.

What can the building do?

- Reduce the length of time the heating is on.
- Reduce the window-master temperature set point.
- Enable Night Cooling

too stuffy?

What can i do?

- **In summer and winter** open manual windows and doors to allow more fresh air in provided this does not make the classroom too cold.

What can the building do?

- Increase opening time or opening width of windows using the Window-master control.

too bright?

What can i do?

- Use Roof blind as required to minimise glare. Possibly assign "**student lighting monitor**" to assist with control of roof blind.
- Consider repositioning tables to avoid potential glare from single roof-light.

too cold?

What can i do?

- **In winter** reduce use of the classroom door to the playground to prevent unwanted heat loss.
- Close the classroom to corridor door and close any manually openable windows.

What can the building do?

- Increase the length of time the heating is on and/or the morning start time.

too draughty?

What can i do?

- Close the classroom/corridor door.
- Ensure manually openable windows are closed.

What can the building do?

- Reduce opening time or opening width of windows using the Window-master control.

Technology Strategy Board
Driving Innovation

Building Performance Evaluation Programme

Rogiet Primary School - Room Control Guidance

whitedesign

too gloomy?
Ensure roof blinds and window blinds are open .

too bright?
Use blind as required to minimise glare.

too stuffy?
open manual windows doors and rooflight

too hot?
open manual windows doors and rooflight

remember!
In winter if the classroom door is open for 37mins this loses the same amount as Carbon Dioxide as used to make one third of a hamburger!

too draughty?
Close the classroom/corridor door and ensure manually openable windows are closed.

too cold?
reduce use of the door classroom to playground and close door to corridor.

Technology Strategy Board
Driving Innovation

Building Performance Evaluation Programme

5.5 Conclusions and key findings for this section

Ensuring the on-going success of the building is partly the responsibility of the users. To this end, supporting the teachers and school management in educating the building occupants, particularly students, to use the building efficiently and to maximum benefit has been a part of this project.

This study has concluded that the use of the buffer zones, in particular, was not intuitive to the occupants. This has been considered further in task Q6e but it should be noted here as a cross-reference to the engagement activities.

There were comments made by the teachers through the initial curriculum workshop that “the kWh display is nice but what does it mean”. The creative labelling exercise and curriculum workshops were aimed at leaving a legacy of more easily interpretative data for use by the teachers and pupils. We are aware that some contractors are using this approach as a means of making O+M /Building users information more readily available to building users.

6 Energy use by source

6.1 Data collection and the BMS

When the school was commissioned the BMS was collecting weekly and daily cumulative data from the meters shown shaded in Figure 4.1. Data were stored on the BMS controller for each point and overwritten after 1000 readings. Daily cumulative readings were at quarter hourly intervals giving a total each day and only about 10 days of data were stored on the BMS before the data were overwritten. The weekly cumulative data were at daily intervals with 1000 days of data stored on the BMS controller before being overwritten.

This was the situation with the meter readings and the BMS when the project began in November 2011. Data could be obtained from the BMS but the process was laborious and to obtain detailed data, downloads had to be undertaken every 10 days. The initial approach taken was to focus on the daily data (in the weekly cumulative record) until changes to the BMS could be made. The data are wiped occasionally if work is carried out on the BMS and consequently daily data are only available from about February 2011.

The controls sub-contractor for the installation (BBM Control Systems Ltd) was commissioned to make changes to the BMS and metering and the following changes were made in August 2012:

- DB02 (Zone 2), DB05 (Zone 5) and DB mechanical sub-meters were all add to the BMS;
- the BMS meter readings were reset to be the same as the physical meter readings;
- the BMS was set up to record and store 30 minutes, daily, monthly and total cumulative data and back these data up onto a database at the local authority's offices;
- temperature sensors recording 1000 hourly readings on the BMS controller in the plant room; and
- access to the BMS including graphical meter reading data for the project team available via a web portal from the main BMS PC in the council's offices.

The contract was set up following a site meeting with BBM Control Systems Ltd and a meeting with Monmouthshire County Council's energy officer. The work was funded jointly between the project and the council, in acknowledgement by MCC that this could have been included in the original contract. This work was completed on 23 August 2012. The BMS was then reviewed with the controls contractor and head teacher on 19 September 2012 to check that the BMS readings were all correct. For each meter the new BMS reading was checked against the actual meter and all were found to read the same number (allowing for minor variances), indicating that there had been no significant drift of BMS readings relative to the meters in almost a month. The data storage on the BMS PC in the council offices was also checked and confirmed to be working. The first data was downloaded from the BMS PC in the council offices on 8 October 2012, but there were some teething problems with the data and these were followed up by the controls contractor who rectified the problem on 25 November 2012.

The BMS data collection and access are now working reasonably, but the following issues remain:

- the half hourly data can only be downloaded 1000 points at a time for each record, meaning that only 23 days of data can be downloaded in a single file and that to download a continue period of one year requires 16 files, which would then all have to be 'stitched' together to produce a continuous record. This issue could not be easily rectified by the BMS supplier and as such will remain an issue;
- the data resolution is poor at 1kWh, so some of the records, especially out of hours when energy usage is low cannot accurately reflect the actual energy usage e.g. a continuous usage of 0.1kW would show as 1kWh every ten hours.

The controls sub-contractor reviewed the potential to fix the DB plant room and lighting circuit sub-metering, but was not able to since these meters are built into the panels supplied by the electrical contractor. The project does not have the resources to reset, repair or replace these meters. The plant room electrical sub-meter measures power supplied for lighting and sockets in the plant room. This is expected to be a very small load. The problem with the lighting meters has not been resolved, but does not cause significant problems for the energy assessment as the lighting is also covered by the main sub-meters for each zone.

6.2 Data collation and reconciliation

The following sources of data were collected early in the project and reconciled as far as possible:

- quarter hourly data from the BMS for selected sub-meters;
- daily data from the BMS for selected sub-meters;
- automatic meter reading (AMR) from the fiscal gas meter;
- manual meter readings taken during this project; and
- billing data.

6.2.1 Gas data

There are two main sources of data for total gas usage:

- the main fiscal meter at the entrance to the car park; and
- the main incoming gas meter in the plant room.

In each case there are automatic and manual readings. The reconciliation involves comparison of the automatic and manual readings for each meter and comparison between the meters.

Half hourly AMR data from the main fiscal meter were compiled from 20 September 2010 to 11 December 2012. Daily gas energy usage data were also derived from the AMR data and are plotted in Figure 6.1, which shows cumulative and daily total data for the period. The plot also shows the cumulative data from the bills. The data suggest reasonable correlation between the bill and AMR data. The main discrepancy is early in the period, with the bill data typically reflecting the AMR data within 5% after December 2010. The discrepancy is not a consistent ratio and its cause is not known, however for the purposes of this study the level of agreement is sufficient to make engineering judgements about the energy use of the building.

The main gas data from the BMS have been converted from m^3 to kWh using a conversion factor of 39.2MJ/m^3 and a correction factor of 1.022 (taken from bills). A plot of the data from February 2011 to May 2012 is presented in Figure 6.2, which also shows manual readings taken for the project in this period. The agreement between manual and automatic (BMS) readings is generally reasonably good, within 3%, but the reading on 27 March 2012 shows a 13% difference between the manual and BMS readings. The period between measurements was short and some of the discrepancy could be associated with the time of day the readings were taken and resolution of the BMS. The overall effect on the cumulative data is negligible. Again there appears to be a reasonable degree of agreement, sufficient for making engineering judgements about the building energy usage between the BMS and manual readings.

Figure 6.1: Fiscal meter gas AMR and billing data

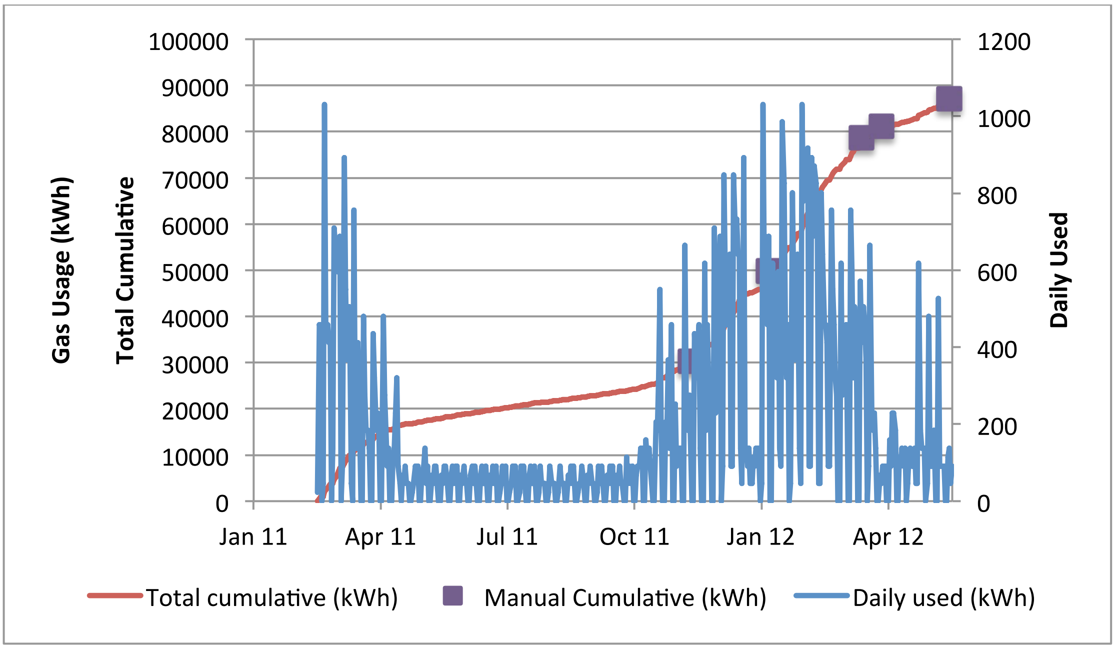


Figure 6.2: Main incoming gas (plant room) and manual readings

Comparison of the gas used according to the Fiscal meter (AMR data) and plant room meter (BMS data) are presented in Figure 6.3.

Figure 6.3: Gas meter comparison

Date	Fiscal meter AMR reading cumulative (kWh)	BMS main incoming gas meter usage (kWh)
1 March 2011	72,467	5248
30 November 2011	127,076	35,368
Gas used in period	**54,609**	**30,120**

The data indicate that there is a significant discrepancy between the two meters. Further review of the data indicates that the correlation between the AMR data and the main incoming meter is very inconsistent with the ratio for single days between the AMR data and the BMS readings ranging from about 14 to 0.2 and with the AMR readings averaging 1.8 times the BMS readings. Both data sets seem to show reasonable patterns of usage, with zero gas usage at weekends in many cases, but even this agreement becomes offset when the AMR data only has one zero gas usage day in July 2011 and from this point onwards the AMR and BMS weekends are offset by a day. A plot of daily gas usage from the fiscal meter (AMR) and main meter in the plant room (BMS) is presented in Figure 6.4.

The plot shows that both meters follow very similar patterns, but that the pattern is inconsistent between the two meters ie there is not a consistent error. Possible causes are:

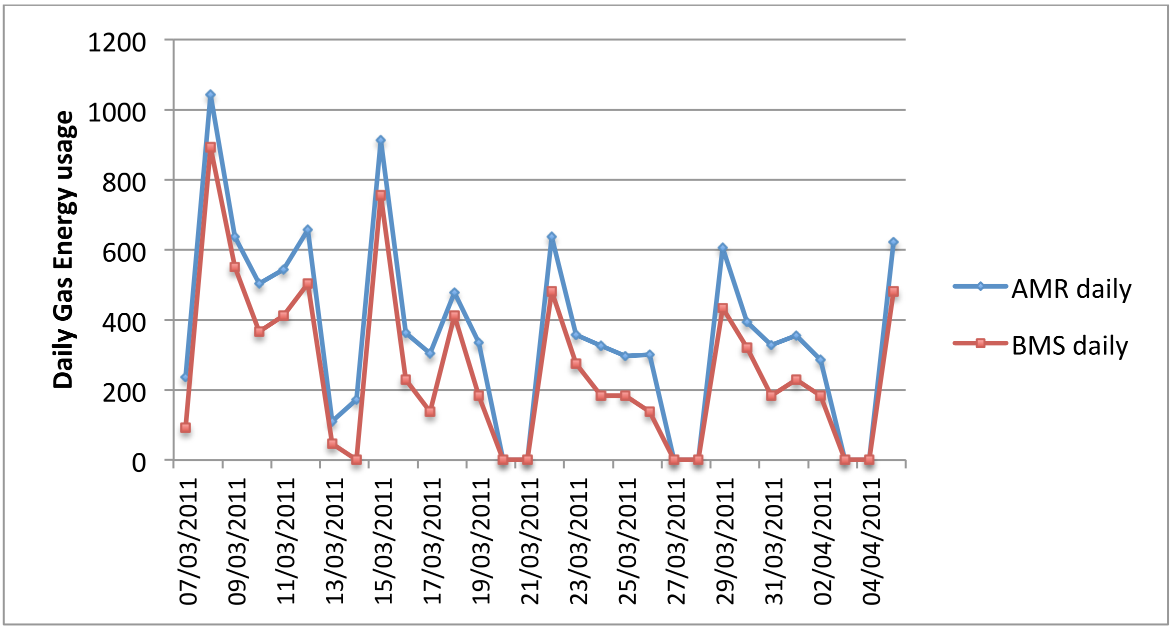
- meter calibration;
- meter installation issues e.g. meter installed on a bend in pipework;
- other gas use between the fiscal and main incoming meter;
- gas leakage; and/or
- meter pulsing and resolution issues.

The cause of the discrepancy has not been established and the problem has been reported to Monmouthshire County Council's Property Services. The last three of these have been eliminated because:

- the gas pipework in the plant room has been followed and traced to al the gas usages in the building;
- the gas usage would have to be very significant and would have been detected by now (and probably have caused an explosion);
- the discrepancy is detected from manual as well as automated readings.

Given that billing is based on the fiscal meter and this meter is more likely to have been installed by gas meter specialists, the fiscal meter has been used for the remainder of the analysis in this report.

Figure 6.4: AMR vs BMS gas usage data



6.2.2 Electricity data

There are two main sources of data for total gas usage:

- the main fiscal electricity meter; and
- the main incoming electricity meter in the room adjacent to the plant room.

The fiscal meter only has manual readings, whilst the main incoming meter has both automatic (BMS) and manual readings. The reconciliation involves comparison of the automatic and manual readings for each meter and comparison between the meters. The data are plotted on Figure 6.5. The agreement is reasonable, both between the manual and BMS readings and between the meters.

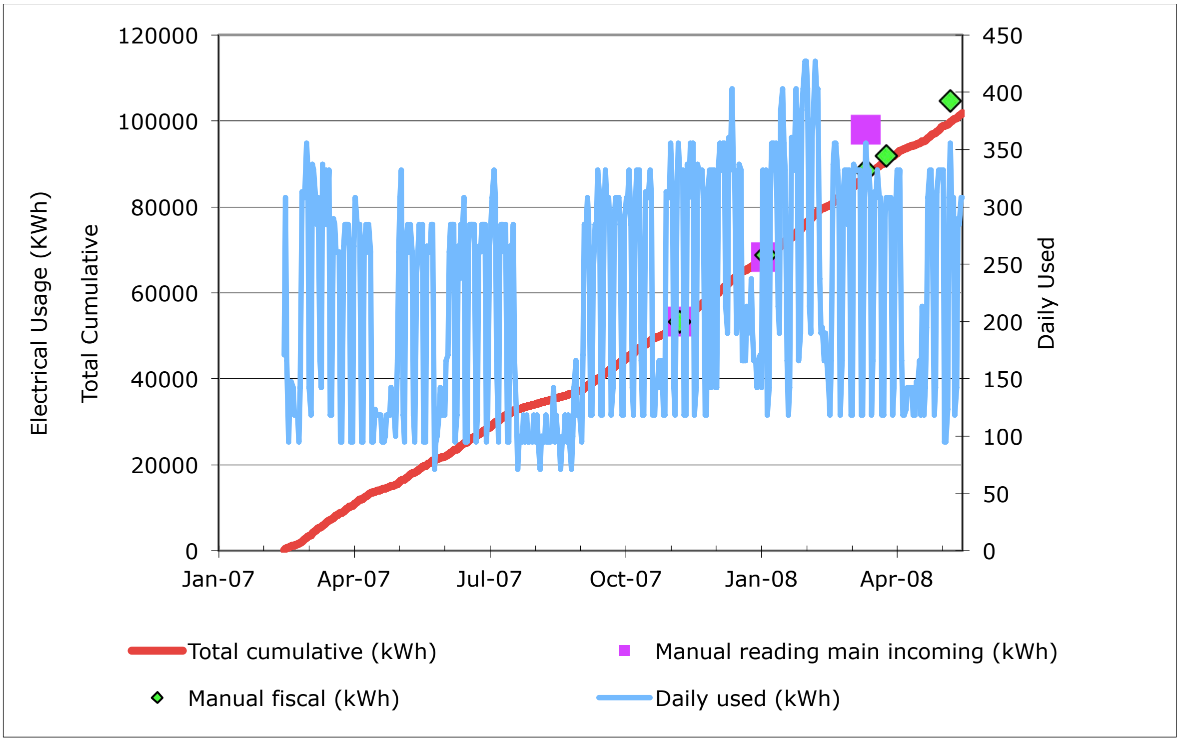


Figure 6.5: Electricity meter readings comparison

Wind energy generated and used in the building is connected into the un-metered part of the mains electricity panel and therefore the actual electricity used by the building is equal to metered import plus wind energy used in the building.

A comparison between the total metered energy from the electrical sub-meters and the total electrical energy used in the building (main meter plus wind used in building) is presented in Figure 6.6. There were some missing sub-meter data on the early monitoring visits due to initial confusion about sub-meter labelling. The missing data have been estimated by linear interpolation/extrapolation. The data show that the sub-meters do not appear to monitor all the incoming electricity usage, with 25-40% of the school's energy use unmetered.

Figure 6.6: Comparison between main incoming electricity and sub-meters

Date interval	Energy Usage in Interval (,h)		Percentage sub-meters to total electricity use
	Main Incoming plus wind energy used in building	Sum of Sub-meters	
9/11/11 to 06/01/12	16725	10,266	61
06/01/12 to 13/03/12	21,150	13,899	66
13/03/12 to 15/05/12	14,623	9615	66
15/05/12 to 19/09/12	24,109	16,143	67
19/09/12 to 10/10/12	5603	4118	73
10/10/12 to 08/11/12	7239	5145	71
08/11/12 to 26/11/12	5253	3890	74
26/11/12 to 11/12/12	4980	3526	71
11/12/12 to 07/02/12	16,260	10,871	67
Annual 09/11/11 to 08/11/12	89,434	59,186	66

The wind energy causes about 10% of this discrepancy and it can be seen that the percentage of the total energy accounted for by the sub-meters was slightly higher in the middle of the period when the wind turbine was not working.

Possible causes of the remaining discrepancy are unmetered loads or problems with meter functionality. The following electrical items are unmetered:

- DB tank room
- DB sprinkler room
- Security panel
- Fire alarm
- MUGA lighting
- Surge protector
- Plant room small power and lighting

These are all separately identified on the mains panel in the switch room as un-metered except the plant room which has a meter which has never worked. The energy usage of the plant room for lighting and plug-in loads is expected to be very low.

Electricity usage from all except the sprinkler room is expected to be low. The sprinkler room includes a frost protection fan, trace heating and immersion heater in the sprinkler tank, all of which are candidates for this un-metered energy usage. More detail of this un-metered energy is presented in Section 8.6.

6.2.3 Conclusions on meter reconciliation

Whilst there appears to be reasonable agreement between manual and automatic readings from the gas and electricity meters, there is a large and variable discrepancy between the fiscal gas meter at the entrance to the car park and the main incoming gas meter in the plant room. The fiscal and main incoming electricity meters agree reasonably well. There is a reasonably constant discrepancy between the main incoming electricity meter and the sum of the sub-meters, which is most likely to be attributable to sprinkler room and tank energy usage.

At this stage the causes of these discrepancies are not known, but for the purposes of further analysis it is assumed (conservatively) that the fiscal gas meter in the plant room is accurate (and that the error lies with the main incoming meter in the plant room. It is understood that the DEC has been produced based on billing data and therefore the approach taken in this study will be consistent with the DEC. If this assumption turns out to be incorrect the interpretation regarding when the plant are operational and the relative gas energy usage between day time, night time, weekends and holidays as well as seasons will still be correct.

6.3 TM22 simple assessment

A 'simple assessment' was undertaken using TM22. Total gas and electricity usage for the building was taken from the main incoming meters on the BMS for the period 1 March 2011 to 29 February 2012. Heating gas usage was corrected for degree days (2418 degree days in period compared to standard of 2462).

The wind turbine was not operational from April to November and the figure entered into the TM22 was the actual energy generated over 12 months.

The following benchmarks were added into the TM22 assessment:

- DEC benchmark is for a typical primary school of this size;
- The User Specified figure is from GPG 343 (Energy Saving Trust, Good Practice Guide 343).

The results of the TM22 simple assessment are summarised in Figure 6.7, Figures 6.8a and 6.8b (building energy and carbon respectively excluding renewables) and Figures 6.9a and 6.9b (building energy and carbon respectively including renewables).

Figure 6.7: Building energy summary

Energy, carbon and cost summary	Units	Electricity	Fuels	Thermal
Non renewable fuel or electricity supplied to site	kWh/annum	85,089	110,250	0
Separable energy uses	kWh/annum	0	0	0
Renewable energy used on site	kWh/annum	4,345	0	1,258
Renewable energy exported	kWh/annum	667	0	0
Output from CHP used in building	kWh/annum	0		0
Exported CHP	kWh/annum	0		0

	Energy supplied (kWh/m^2 GIA)	
	Fuel/thermal	**Electricity**
Supplied	60	46
Good practice (GPG 343)	113	22
Typical from DEC	154	40

Some observations on the results are as follows:

- The split between thermal and electrical energy usage was approximately 60:40;
- The thermal and electrical energy usage was less than the typical DEC benchmark, with the difference between the actual energy used and the typical DEC figure heavily weighted towards thermal energy with electrical energy usage being similar to the typical figure;
- The thermal energy usage was much less than the good practice figure, but the electrical usage was much more;
- The wind turbine generated about 6% of the electricity used by the building;
- The solar thermal generated about 1% of the heating energy used by the building;
- In terms of emissions, the split between thermal and electrical energy emissions was about 1:2 with electricity being responsible for twice the emissions of gas;
- The emissions savings of the wind turbine become more significant (than the energy savings) due to the higher carbon factors of electricity compared to gas.

It should be noted that the ‘typical’ and ‘good practice’ benchmarks above are based on studies of buildings which are typically at least ten years older than Rogiet primary school and that the differences in energy usage reflect changing times with buildings becoming much more thermally efficient with increasingly stringent Building Regulations, but with electricity usage increasing due to increased levels of equipment in schools.

Figure 6.8a: Energy supplies excluding renewables

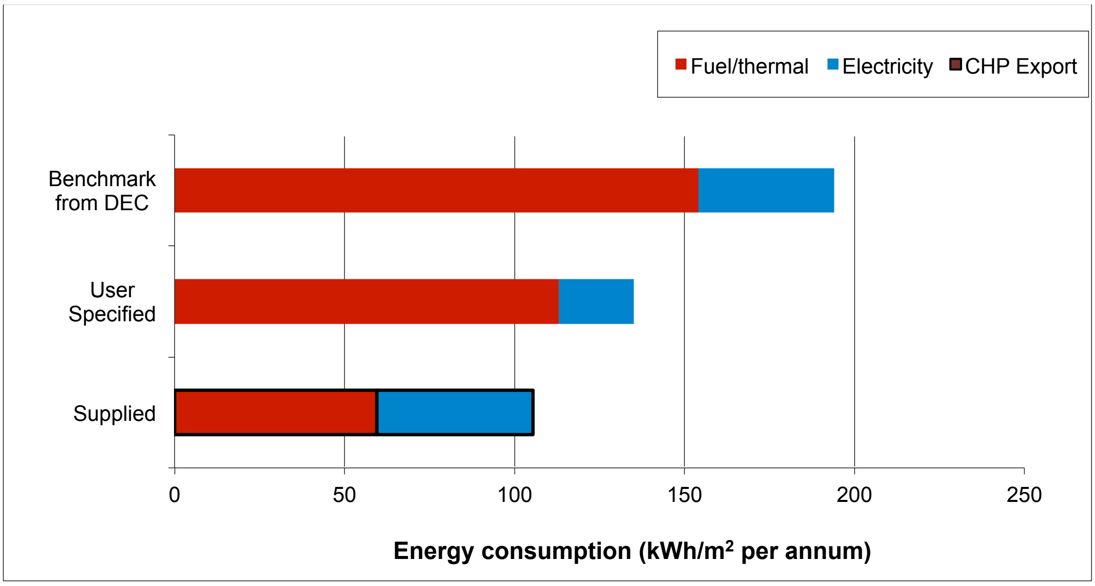


Figure 6.8b: Carbon emissions

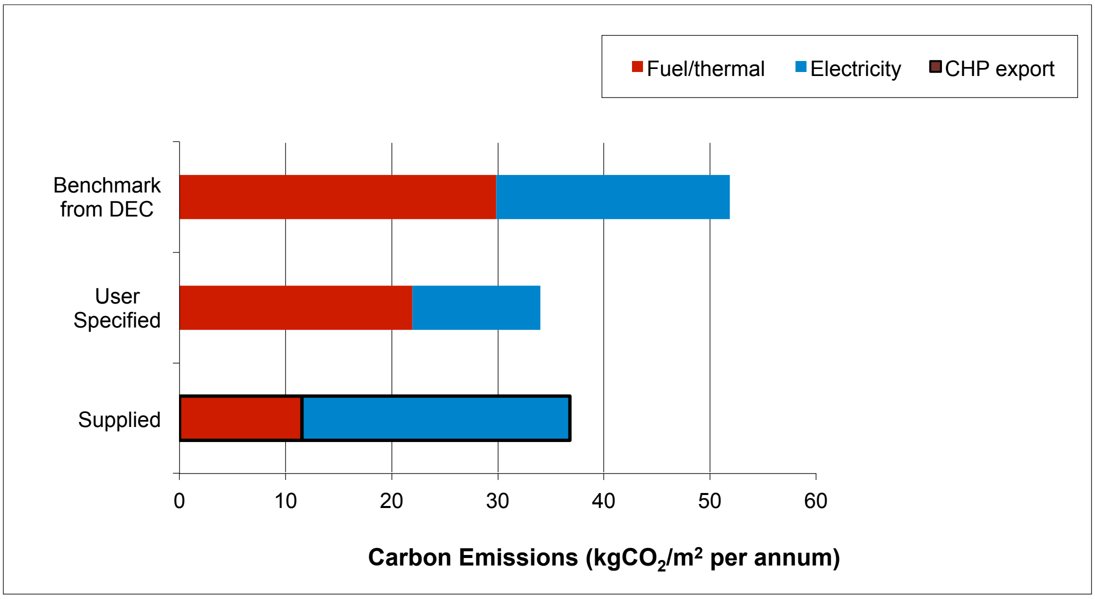


Figure 6.9a: Fossil-fuel equivalent energy consumption and generation

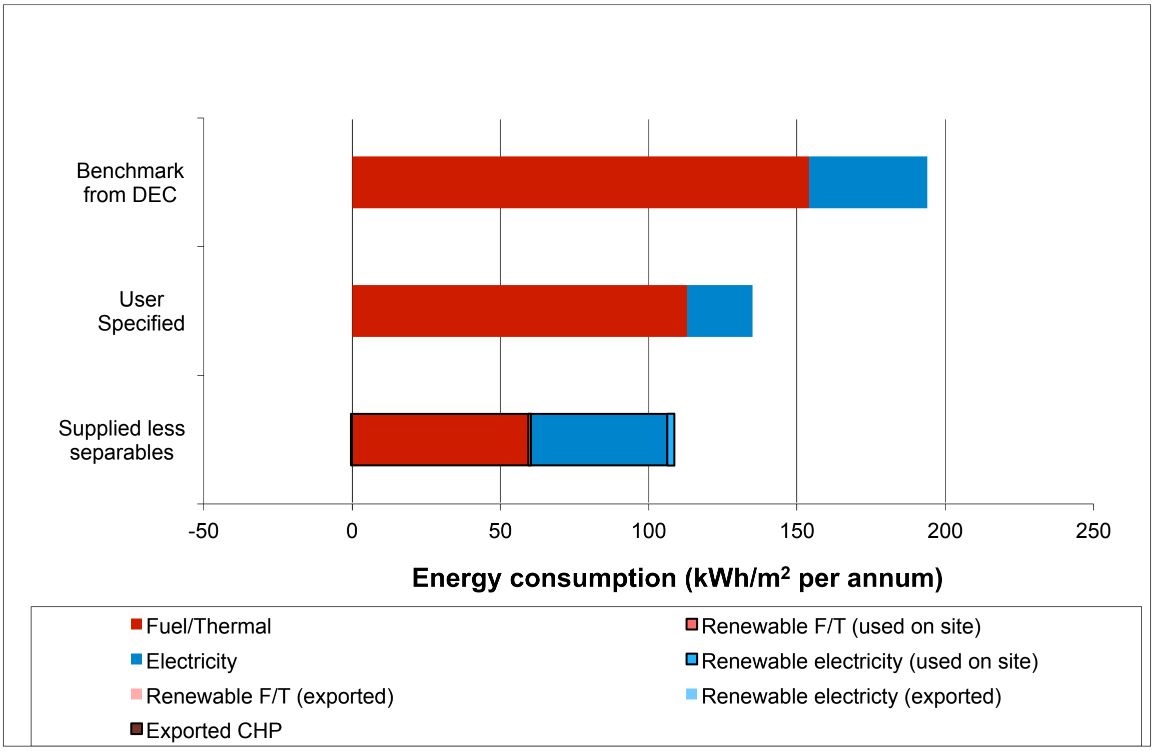
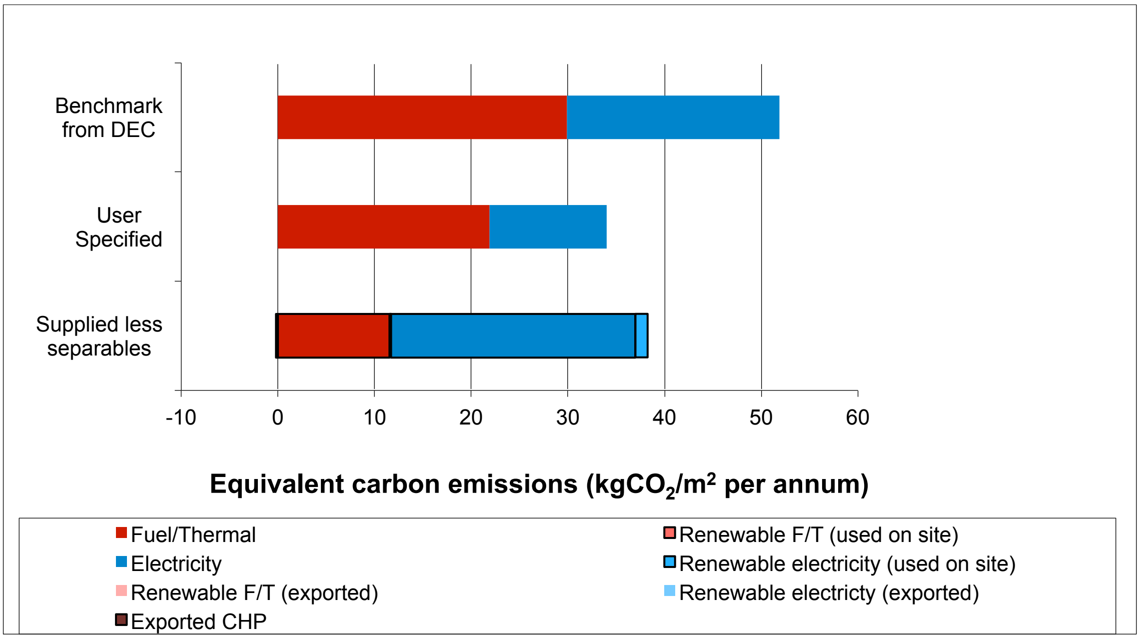


Figure 6.9b: Fossil fuel equivalent carbon dioxide emissions



6.4 Comparison of overall energy usage with other schools

Energy data has been obtained from DECs from a number of other schools in the area for comparison with Rogiet. The schools were selected by Monmouthshire County Council's energy officer to reflect a range of different constructions and ages. The schools reviewed are listed in Figure 6.10, and the energy and emissions from each are summarised in Figures 6.11 and 6.12.

Figure 6.10: Details of schools in Monmouthshire for comparison with Rogiet (although limited background information is known regarding the context for each school. E.g. is the kitchen used more in one than the other?)

Site	DEC Ref	Year Built/Comment
Llanfoist Primary	9900-2935-0170-7260-0074	White Design School, 2008
Archbishop Rowan Williams Primary	0340-0912-6539-7808-7002	2001
Cantref Primary	0590-0412-5749-6609-2006	Grade 2 listed building, refurbished 2008
Chepstow St Mary's Primary	0820-0412-0889-3408-1002	1969
Deri View Primary	9111-1008-0424-0700-8105	Large primary, 2005
Durand Primary	0080-4992-0132-0350-6040	Flat roof, 1973
Goytre Fawr Primary	0893-2568-6310-1000-7003	1976
Llantilio Pertholey Primary	0730-0312-9849-1698-6006	1991
Magor Church in Wales Primary	9808-1008-0721-0200-3101	Various extensions and refurbishments from 1999, major in 2009.
Pembroke Primary	9808-1048-0024-0500-1701	Extended and refurbished 2008
Ysgol Gymraeg Y Fenni	0640-0711-7790-2524-0006	Electrically heated demountable buildings

Figure 6.11: Monmouthshire primary schools energy data

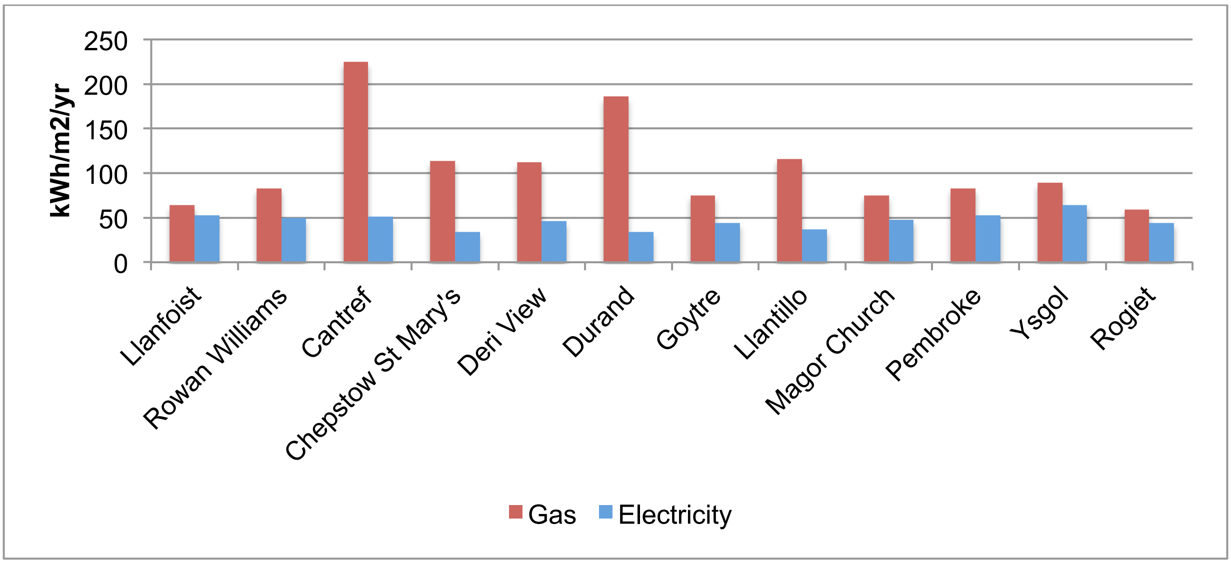
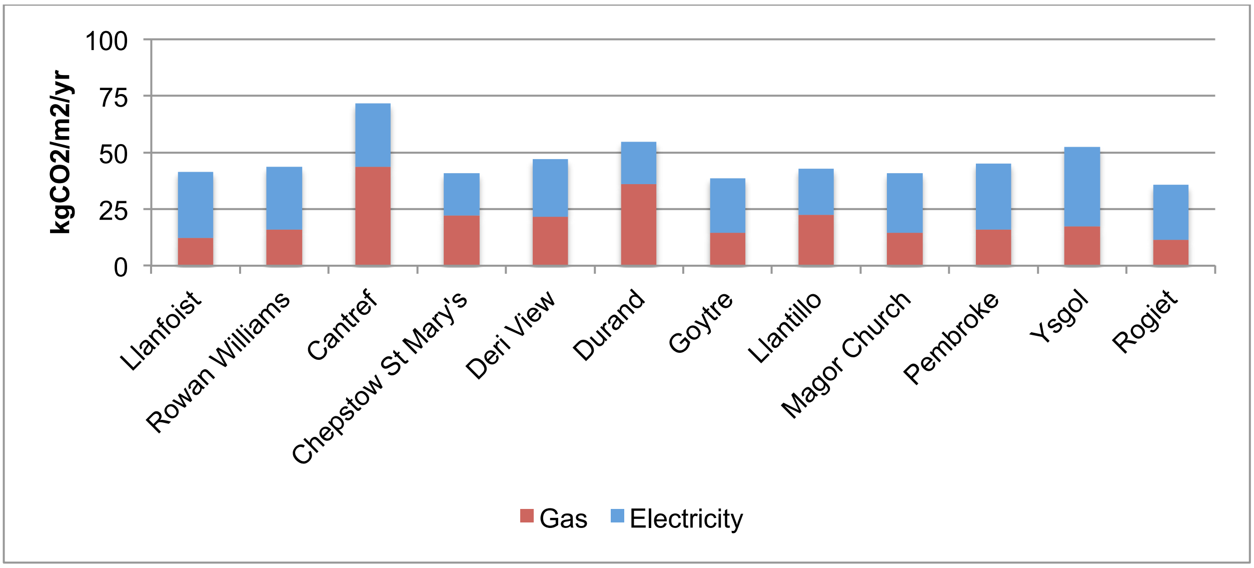


Figure 6.12: Monmouthshire primary schools emissions data



The data above show that Rogiet is the best performing school of those selected in terms of overall emissions and thermal energy, but not in terms of electrical energy. A number of the other schools have only slightly higher emissions than Rogiet and these schools are of a variety of ages. The worst performing school is Cantref, which is a refurbished listed Victorian building. The original radiators were retained due to the listing, but boxed in due to safety concerns, and it has proved difficult to heat the building, so the heating is on almost permanently. The boxing in presumably causes high heat loss through the fabric. The highest electricity usage is at Ysgol which is electrically heated and accommodated in 'Portakabins'. The high emissions result from the high carbon factor of the electrical heating rather than due to high energy usage. Other schools performing well are Llanfoist (another new school) and Goytre (built in 1976). The occurrence of this school, which is unlikely to be well insulated amongst the better performing schools, is indicative of very good energy conserving behaviour. Durand, by contrast, built at a similar time is amongst the highest heating energy users and but has the lowest electricity usage.

6.5 Energy review by sub-meter

This review considers the building energy usage at a high level by sub-metered usage to assess the relative energy usage of different parts of the building and by different energy sources. This assessment has been undertaken outside the TM22 model and feeds in to the TM22 spreadsheets where appropriate. Key findings from this section feed in to subsequent parts of the analysis and are discussed in more detail in subsequent sections.

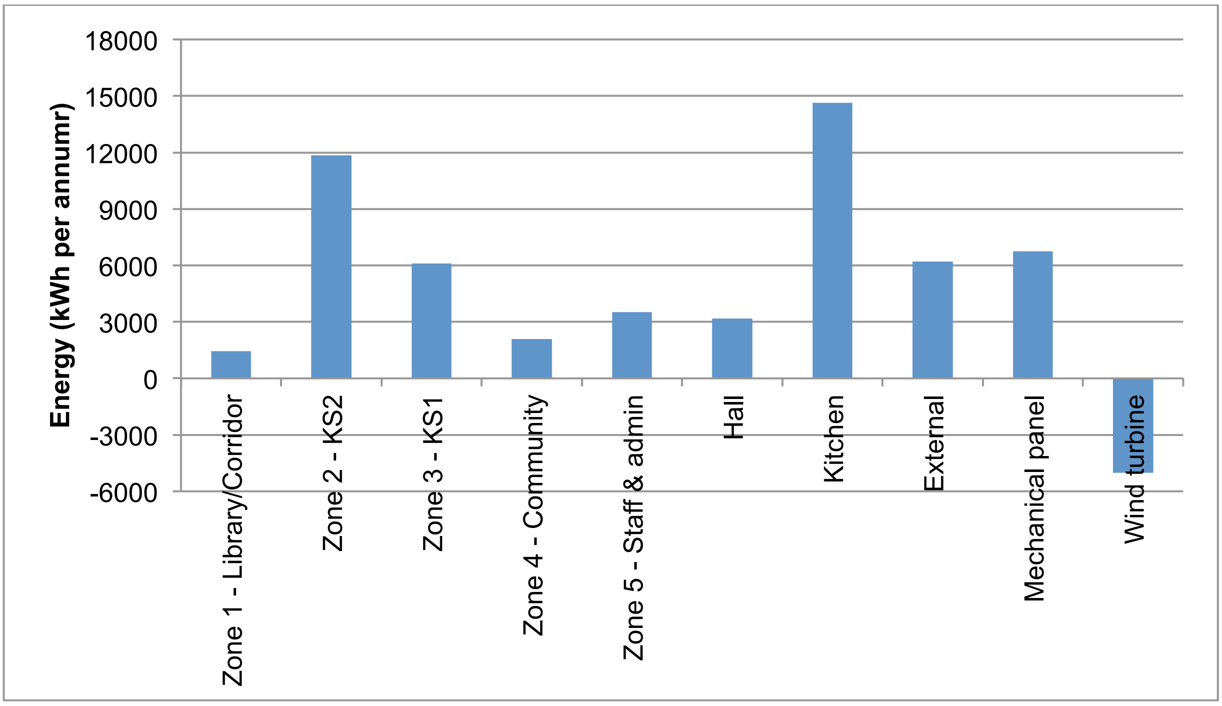
Electricity

The school is divided into 9 separately metered zones, as shown in Figure 3.2 and listed in Figure 6.13. The energy usage per zone for the period November 2011 - November 2012 has been taken from manual meter readings and plotted in Figure 6.14. This shows the kitchen and Zone 2 to be the largest energy users. The kitchen has a lot of electrical plant in a small area, whilst Zone 2 is the largest of the zoned areas. The energy generated by the wind turbine is significant and represents a similar amount to the energy demand of one of the larger zones Key stage 2.

Figure 6.13: Sub-metered areas

Sub Meter	Use	Area supplied (in m²)
DB01 (Zone 1)	Corridor and library	137
DB02 (Zone 2)	Key Stage 1 Classrooms	494
DB03 (Zone 3)	Key stage 2 classrooms and IT room (excluding server)	334
DB04 (Zone 4)	Community Room	147
DB05 (Zone 5)	Offices, foyer, staff room	204
DBHall	Hall	231
DBPlant	Plant room	50
DBKitchen	Kitchen	65
DB External	External lighting	N/A
DB Mechanical	BMS and Mechanical Panel	N/A

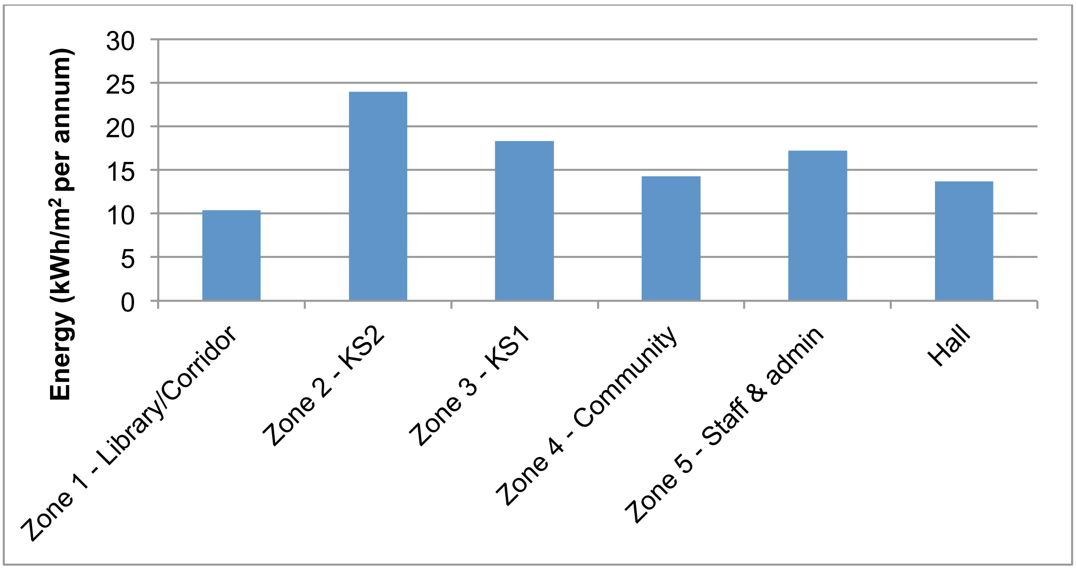
Figure 6.14: Electrical energy consumption by sub-metered area (plus wind turbine)



The plot shows that the kitchen and Zone 2 are the biggest electricity users, with the mechanical panel and external lights next. The wind turbine generated a similar amount of electricity to that used by the mechanical panel and external lights.

To obtain additional insight into the energy usage of the different parts of the building, the data have been normalised for area and the energy use per metre squared is plotted in Figure 6.15. This has been undertaken to enable any significant anomalies (positive or negative) to be identified, particularly in areas of similar activity such as classrooms and corridors. The kitchen data are not plotted as the energy intensity of the kitchen dwarfs other areas and makes comparison of the other areas difficult. Similarly the mechanical panel, external and wind turbine have not been plotted as these do not represent a particular area of the building.

Figure 6.15: Electrical energy intensity by sub-metered area



There are no particular anomalies shown by this plot. Zone 2 has the highest energy usage per unit area, presumably because it includes the IT server room cooling unit. Whilst Zone 1 has the lowest energy usage, this zone is mainly corridor with only one computer in the library.

On a per metre squared basis the energy use compares very favourably with Oakham School which was the subject of another TSB BPE study by the same team, where the lowest energy use for spaces with equivalent end uses (ie lighting and small power in classrooms and corridors) were 26kWh/m^2 per annum, which is more than the highest energy usage at Rogiet.

Thermal Energy

There are five gas/heat meters installed on the site:

1. The fiscal gas meter, located on the site boundary, not connected to the BMS
2. The main gas meter, located in the plant room.
3. The kitchen gas meter, located in the plant room.
4. The community heat meter, located in the community room.
5. The solar thermal heat meter, located on the eco-wall in the library.

There is also an additional meter, measuring the flow of mains cold water into the hot water cylinder (m^3) – this can be used to calculate the DHW energy used.

Figure 8.16 shows how the various supplies are metered. The approach to calculation of the un-metered energy usage is as follows:

- The energy within the delivered hot water was calculated from the metered hot water usage, assumed uplift temperature and specific heat capacity;
- The school heating energy was calculated from the boiler efficiency assuming boiler efficiency of 91% and by subtracting other measured or estimated amounts (kitchen gas, gas energy to heat the DHW) from the total metered gas usage;
- The losses from the hot water system (not including boiler losses) were estimated from the gas usage in summer when the hot water system was active but no hot water was being used;
- The kitchen gas meter was found to indicate much less gas usage than estimated based on discussions with kitchen staff and the ratings of the appliances and therefore a figure was estimated from likely usage of the kitchen appliances.

The results of the assessment based on total gas energy from the fiscal meter are presented in Figure 6.17. The figure shows the breakdown of the thermal energy into its different components in the main chart and on the right the breakdown of the DHW energy into 'Energy in DHW delivered' (the energy required to heat the water from the hot taps) and 'DHW losses' (the energy losses from the DHW circulation and storage systems). The pie chart below also shows the breakdown of DHW energy into that produced by gas and that produced by the solar thermal system.

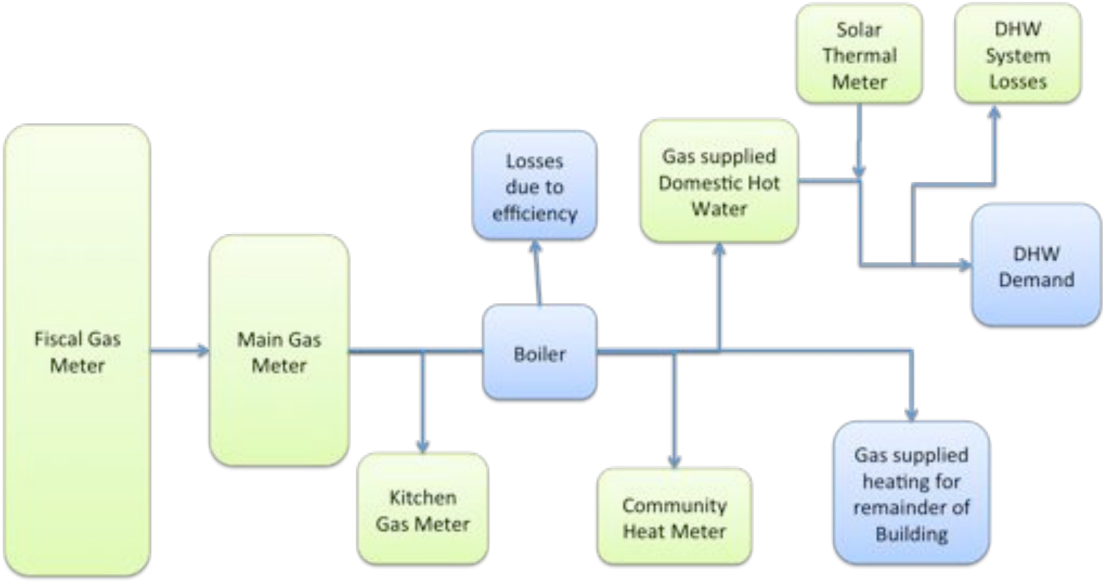
The most striking finding is that the losses from the DHW system are approximately equal to the heat delivered to the building, with hot water energy being almost half the total thermal energy usage of the building. The pie chart on the right indicates a system efficiency of about 7% and importantly, that the losses from the system account for almost 40 times as much energy as that generated by the solar thermal system.

The heating energy usage (not including boiler losses) for the community room and the rest of the school have been calculated as 23 and 32kWh/m^2/yr respectively. The community room energy use is probably low due to relatively lower occupancy of this area, but both compare reasonably with the Passivhaus standard of 15 kWh/m^2/yr, given that the building was not designed with this in mind.

It is likely however than the unwanted losses from the hot water system contribute to the heating of the building and that the heat demand from the underfloor heating is reduced as a result, because much of the secondary circulation pipe work is within the thermal envelope of the school.

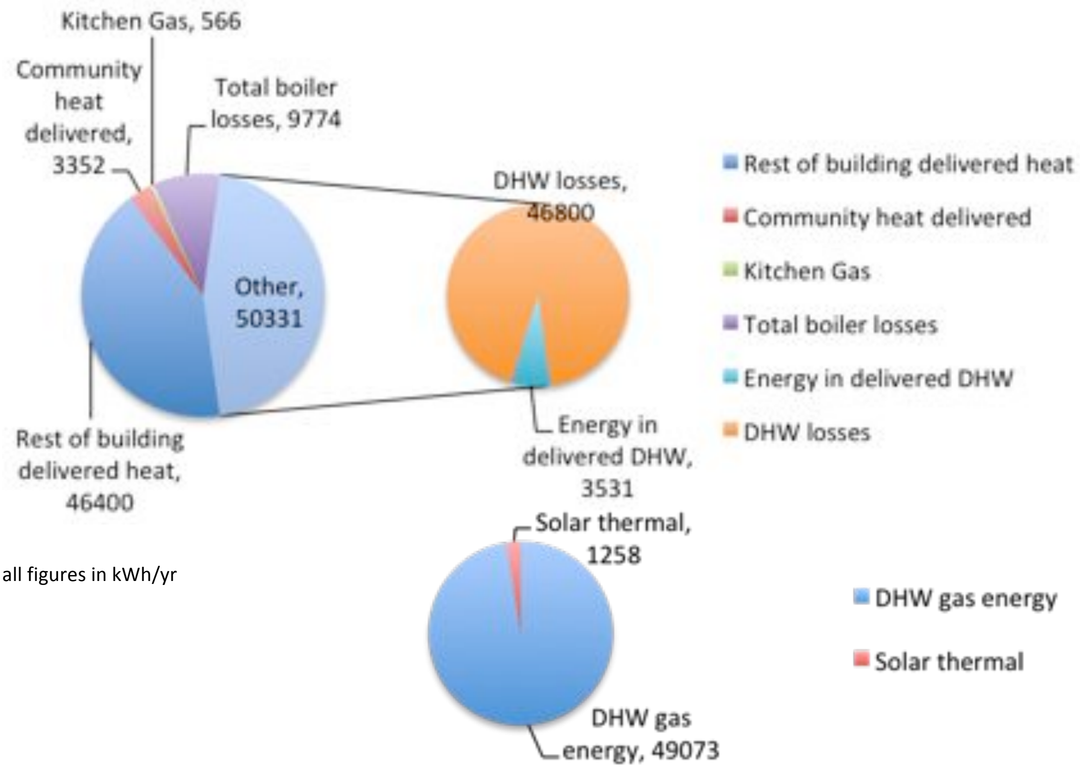
Further investigation of the DHW system is presented in Section 6.4.

Figure 6.16: Gas and heat metering



Items in green are metered, whilst those in blue have been calculated

Figure 6.17: Thermal energy breakdown



all figures in kWh/yr

6.6 Detailed assessment of energy usage

Detailed assessment of the energy usage of the building by fuel and end-use and reconciliation between the energy usage by end-use and the metered usage has been undertaken using TM22. The calculations for fuel/thermal energy in TM22 are fairly simple as fuel is not usually sub-metered down to the same level as electricity and there are fewer fuel consuming end-uses. The calculations in Section 6.3 form the basis of the TM22 data entry, but the energy usage has been normalised with respect to external temperature using degree days.

For the electrical energy usage, annual totals of energy usage in kWh were entered into the TM22 model together with estimates of the energy usage during the core hours, night and week-ends. These estimates were taken from a manual review of half hourly data for different periods of the year. Due to the cumbersome way the BMS collected and allowed retrieval of half hourly data, input of a full half hourly dataset into the TM22 model was not possible.

The aim within the TM22 model was to 'match' the metered energy usage with the estimated end-use energy for each meter and for core hours, night and week-ends. This was achieved with a reasonable degree of accuracy for total annual energy and core hours, but the errors in the out of hours energy usage and weekend energy use were often significant, mainly because small numerical errors resulted in significant percentage errors, but in some cases because insufficient information was available on installed loads, load factors and usage factors to provide an accurate entry into the model.

It should therefore be borne in mind that the TM22 provides a good overall assessment of where and when the energy usage in the building occurs, but that some of the end-use energy figures in the model are subject to significant uncertainty.

Electricity breakdown

For the TM22 calculations for electricity usage the following data are needed:

End use data

- Name plate rating (rated power)
- profile of item usage - periods during which the pattern of usage is the same, such as the working school day
- load factor - the proportion of the rated power of an item used in its operation.
- usage factor - the proportion of time that the device is in operation within the profile period, for example if the office lights were in operation for 100% of the time during the School Day their usage factor would be 1, between 08:00 and 17:00.

Metered energy usage

- sub-meter usage

The in-use energy for a particular item within a particular profile period is equal to:

Rated power x load factor x usage factor.

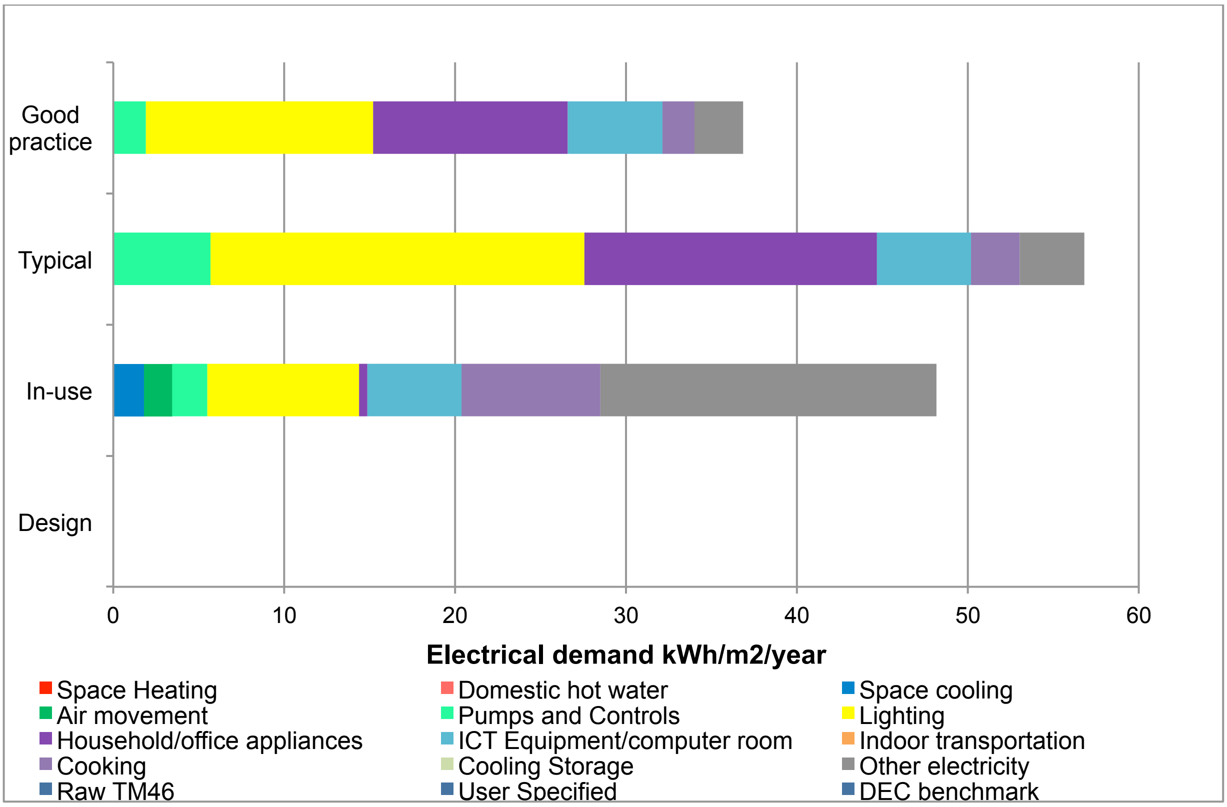
Details of the assumptions used for TM22 end-uses are provided in Appendix F with further detail provided in the comments sections of the TM22 spreadsheets.

The results of the TM22 electricity breakdown are presented in Figures 6.18 and 6.19. The ISO 12 breakdown has been selected for this project. The breakdown follows the guidance for end-use categories given in ISO 12665 'Energy Performance of Buildings – presentation of Real Energy Use of Buildings'. The breakdown also includes benchmark data for offices from ECON 19 (Energy Consumption Guide 19, Energy use in offices, CIBSE, 2000). The office benchmark data is considered useful because, although it is for a different type of building, this is the only benchmark, which breaks the energy consumption data down into the different end uses and the similarities are sufficient for the comparison to be instructive.

Figure 6.18: Electrical energy demand by end-use

System	In-use electricity (kWh/m2/year)	Typical benchmark (kWh/m2/year)	Good practice benchmark (kWh/m2/year)
Space Heating	0.0		
DHW	0.0		
Space cooling	1.8	0.0	0.0
Air movement	1.6	0.0	0.0
Pumps and Controls	2.1	5.7	1.9
Lighting	8.9	21.9	13.3
Household/office appliances	0.5	17.1	11.4
ICT Equipment/computer room	5.5	5.5	5.5
Indoor transportation	0.0		
Cooking	8.1	2.9	1.9
Cooling Storage	0.0		
Other electricity	19.7	3.8	2.9
Total	48.2	56.8	36.9
Metered building energy use	48.3		
Variance TM22 versus metered total	-0.1		
Variance TM22 versus metered total	0%		

Figure 6.19: Electrical energy demand by end-use



NB there is no design data for this project

The energy benchmarks shown in Figures 6.17 and 6.18 are for naturally ventilated offices, with key differences between the requirements of an office and a school. The most significant difference is likely to be that the school is only occupied for about 75% of weeks in the year, so significant relative energy reductions would be expected as a result. Despite this short-coming, some useful information can be derived from a comparison between the study building and benchmark offices:

- The IT cooling unit and kitchen ventilation represent energy uses in the categories ‘cooling’ and ‘air movement’ respectively, which are not present in the naturally ventilated offices and can’t be compared.
- Energy use for ‘pumps and controls’ at Rogiet is similar to the ‘good practice’ office;
- ‘lighting’ is considerably lower at Rogiet than the ‘good practice office’, perhaps reflecting improvements in lighting and particularly lighting controls over the time between the office design/construction and that at Rogiet.
- ‘ICT equipment’ energy usage in the benchmark offices defaults to the same as in-use so doesn’t provide a comparison.
- ‘Office equipment’ energy is much less in the school than the benchmarks. This could be, in part, a result of categorisation, as in this study photocopiers and printers have been included as ICT equipment. There is very little office equipment in the school which has not been categorised as ‘ICT equipment’, but even if this is the case, ‘office equipment’ and ‘ICT equipment’ combined use less energy than ‘office equipment’ in the ‘good practice‘ office.
- ‘Cooking’ energy in the school is much greater than in the offices – due to the catering facility at the school which would not be present in most offices.
- The ‘other’ category in the school represents the sprinkler room frost protection, sprinkler system trace heating, fire and security systems and an unidentified load of about 2kW continuous usage. These together use much more energy than the equivalent category in the typical or good practice office.

The main differences between the school and the offices are significantly reduced lighting and office equipment energy in the school and significantly increased 'other' energy. Part of the 'other' category could probably be reduced if the use was identified and the part related to the sprinkler room could probably be improved with design attention paid to the energy usage of the sprinkler system.

Further discussion of some of the key electrical energy uses in the school is presented below, with detailed information about estimation of in-use energy in Appendix X.

Lighting

A comparison of the benchmark (good practice, cellular office) and in-use loads for the school is presented in Figure 6.20. The data in the figure show that hours of usage are similar and that the main difference is due to a reduction in the installed full load in the school compared to the benchmark office. This is probably partly due to improved efficiencies over time as well as a lesser requirement for lighting in schools than offices due to larger proportion of circulation areas etc.

Figure 6.20: Comparison of in-use lighting with benchmarks

	Good practice (ECON 19)	**In-use (Rogiet primary)**
Installed Full Load (W/m^2)	12	7.9
Hrs/yr*	2500	8760
% Utilisation*	45	13
Hrs operation at full load	1125	1140
Annual energy (kWh/m^2/yr)	13.5	9

*TM22 and ECON19 deal with the hr/yr and % utilisation in different ways with TM22 using the percentage of the total hours in the year and ECON19 using % of typical office hrs per year.

IT server room air conditioning unit

The energy usage by the IT cooling unit was estimated from the specification of the unit itself and also by the differences between the energy usage of Zones 2 and 3 and the weekday and weekend usage of Zone 2.

The annual energy usage of the unit as it was set up in 2012, with a temperature set point of 20^{o}C, was estimated at about 3300 kWh/yr. The average usage factor was estimated at 51% based on measured usage in November 2012 adjusted for degree days and then seasonal adjustments were made to account for a greater cooling requirement in summer than in winter.

The key issue with the IT cooling unit was that it was cooling the room to below 20^{o}C: much cooler than required and therefore was wasting energy. The setting of the controls is complex and it is difficult to ensure they have been set to cool only. This is much more significant in energy terms than the appropriate sizing or energy efficiency of the plant item itself. Further discussion of this is presented in Section 8.7 'Improvements'.

Un-metered loads

The high level energy analysis (Section 8.2) identified 30,248 kWh/yr of un-metered electricity usage in the period November 2011-2012 out of a total electrical energy usage of 89,434 kWh/yr (including wind energy generated and used in the school). Un-metered loads are listed in Section 8.2 and the potential electricity usage of these is discussed below.

The fire and security have been estimated based on discussions with the project evaluator to be continuous loads of around 200W each (3500kWh/yr). These are reasonably small loads which are unavoidable and therefore no further investigation was considered to be warranted.

The MUGA lighting runs on a token system but apparently no tokens are ever bought and the lights are not used. The MUGA lighting energy is therefore expected to be close to zero.

The surge protector energy usage is expected to be minimal and whilst the plant room lighting and small power has a meter the meter doesn't work.

So, of these un-metered loads, the only ones which appear to have the potential to have a significant demand are the sprinkler system related end-uses.

The sprinkler room is a small fibreglass shed located in the front car park, housing the sprinkler equipment. The room is protected from frost by a 3kW Dimplex wall mounted fan. The fan has an in-built thermostat with 6 settings from frost to 5 representing temperatures of 5-35°C. There is also a more finely graduated thermostat on the wall which does not work. The setting on the fan has been changed during the project as follows:

- from start of project the fan was set at 4 which maintained a near constant temperature in the room of 26oC;
- in December 2012 as part of the project the thermostat was moved to 1, which was found to maintain the temperature at about 12oC;
- in December 2013, again in response to the findings of the project, the fan was set at 'frost' which is understood to be 5oC.

Investigations of fan running time and room temperature were undertaken in November and December 2012, before and after the first changes to the thermostatic reading. These investigations enabled the heat loss from the room to be calibrated to a simple heat loss model and using degree days the energy to maintain the temperature before and after the changes to the thermostatic setting was estimated.

For the period up to 14 December 2012 the annual energy from the fan was calculated at approximately 7800kWh/yr with an average annual usage factor of about one third.

Other potential energy end-uses associated with the sprinkler system are:

- 2x 1.5kW immersion heaters in the sprinkler tank;
- sprinkler system trace heating;
- sprinkler system jockey pump;
- sprinkler system main pump;
- controls.

The jockey pump is a 150W pump which appears to be off most of the time. The main pump is rated at 11kW but is only switched on for a few seconds per week for testing, so it is likely that these two pumps do not use significant amounts of electricity. The main usage is therefore likely to be for the immersion heaters and trace heating. Tyco, the fire system designers and maintenance contractors indicated that the immersion heaters come on when the outdoor temperature falls below 5°C. Very little is known about the trace heating system, except it is assumed that it is required only for those lengths of pipework between the sprinkler room and the school or outside the thermal envelope of the building (ie above the insulation). The trace heating system is electrical resistive heating which follows the route of the pipework and prevents it from freezing whilst it is not being used. It is likely that this also works on a 5°C outdoor air temperature set point.

In order to quantify the un-metered loads and see how they varied with time, half hourly electrical energy data was analysed for the periods immediately before and after the thermostatic setting on the sprinkler room frost protection fan was changed on 14 December 2012 (Figure 6.25). The calculation is summarised in Figure 6.21.

Figure 6.21: Un-metered loads calculation

Item	12/12/12 external temperature -2°C	18/12/12 external temperature +4°C	Comment
Measured un-metered energy usage (kW) Continuous load equivalent	7.1	2.9	
Sprinkler fan energy (kW)	1.4	0.5	Estimated from sprinkler room heat loss model
Immersion heater (kW)	3	1.5	Assumed continuous on 12/12 but only 50% used on 18/12
Other (kW)	2.5	0.9	

In addition the un-metered energy usage was calculated for a 4 ¼ hour period on 7 March 2014 by direct reading of the meters. The outdoor temperature on this occasion was 12°C so the sprinkler room fan was off and it is assumed that the trace heating and immersion heater were also off. The un-metered electricity usage on this occasion was 15kWh, equivalent to a continuous load of 3.5kW.

The information does not sum to a neat conclusion to the un-metered loads and how they vary with external temperature, but based on the information available the following has been assumed and has formed the basis for the TM22 data entry:

Continuous un-metered load (not related to external temperature)		38.4kWh/d (1.6kW)
Sprinkler room fan 2013	winter	27kWh/d
	spring/autumn	22kWh/d
	summer	15kWh/d
Immersion and trace heating	winter	19 kWh/d
	spring/autumn	0.5kWh/d
	summer	0 kWh/d

These figures were a compromise between achieving a reasonable match with the observations and inventing data to achieve this match.

Whilst there is some evidence that the un-metered loads vary between day and night with daytime load being about 0.5-1kW more than night, given the uncertainties an assumption for a continuous 24hr profile is reasonable.

Wind turbine

The wind turbine was funded under the Low Carbon Buildings programme, which is now closed. Consequently the electricity generated is not eligible for the feed-in-tariff and no money is available for the electricity generated. The only financial gain is the savings made on the energy generated and used on site.

The wind turbine generated 5012kWh in the period 9 November 2011 to 8 November 2012 (2012 data), but during this period it was out of commission from 6 April ie it was only in operation for 149 days of the year. Scaled up to 365 days operate this generation amounts to 12,277kWh generated in the year.

In the period 7 February 2013 to 20 January 2014, the turbine generated 7225kWh, but again the turbine was not in operation for part of this period.

The wind turbine meter in the plant room indicates that approximately 87% of the energy generated by the wind turbine is used on site. This makes sense because there is a continuous base load at the school of 2-4kW, which would use much of the electricity generated out of hours.

The turbine was under warranty until the start of the school year 2013-14. The cost of maintaining the contract is £600/yr and a further £200/yr for access to the Quiet revolution microsite, which shows details of turbine operation and generation. Assuming an electricity saving of £0.12/kWh generated the turbine would have to generate 5000kWh to pay for the basic maintenance contract and 6666kWh to pay for maintenance and the microsite. It was just about achieving this when under warranty, but if it could be operational year round, a 'profit' of ~£700-900 could be expected annually.

During the warranty period there was some correspondence between Quiet Revolution and the acting head teacher about ways of achieving greater energy generation, perhaps by adjusting 'cut-in' and 'cut-out' wind speeds. It appears that the average wind speed at the school of 3.6m/sec was less than had been predicted, but lowering the cut-in and cut-out velocities was not recommended because the electricity used in frequent start and stop of the system was considered to be more than any gains from additional running time.

The project team and Monmouthshire County Council attempted to contact Quiet Revolution to discuss the turbine and to decide on whether and how to continue with its operation during the project but were unable to speak to the right person. It appears that Quiet Revolution was being taken over by another company right at the end of the project, which explains the lack of communication.

Thermal energy breakdown
The thermal energy breakdown in the TM22 model is a straight-forward split between space heating and DHW. This is presented in Figure 8.32 under improvements. A more detailed breakdown has already been presented and discussed in Section 8.5. This detailed assessment therefore only covers investigation of the DHW system and its losses.

DHW system
According to the thermal energy balance in Section 8.3, the annual heat loss from the DHW system was 46,800kWh. This was estimated from the summer gas energy usage of 180kWh/d when the DHW system was the only system using gas. The hot water system is understood to have been active from 06:00 to 19:00, so the rate of loss (power) of the system is approximately 13.8kW.

The length of secondary circulation pipework has been estimated from mechanical service drawings as approximately 400m, starting at 54mm diameter and reducing to 15mm at the extremities. The observed heat loss occurs through the pipe when the circulation is on, but also from the cooling hot water in the pipework when the hot water system is off. Heat losses also occur from the DHW cylinder and associated valves and pipework.

The DHW system was investigated with a thermal camera during the study. The investigation showed that the pipework was generally well insulated, but the pipes were often found to be warmer than the surroundings (Figure 8.22) and heat loss was especially marked where the pipes pass through partition walls (Figure 8.23). The investigation was undertaken during hot summer weather in July 2013 when the general temperatures in the building were in the mid to high twenties centigrade, so the contrast with the pipe temperatures is not as significant as it might have been.

Figure 6.22: Thermal image showing heat loss from insulated DHW pipework in roof void

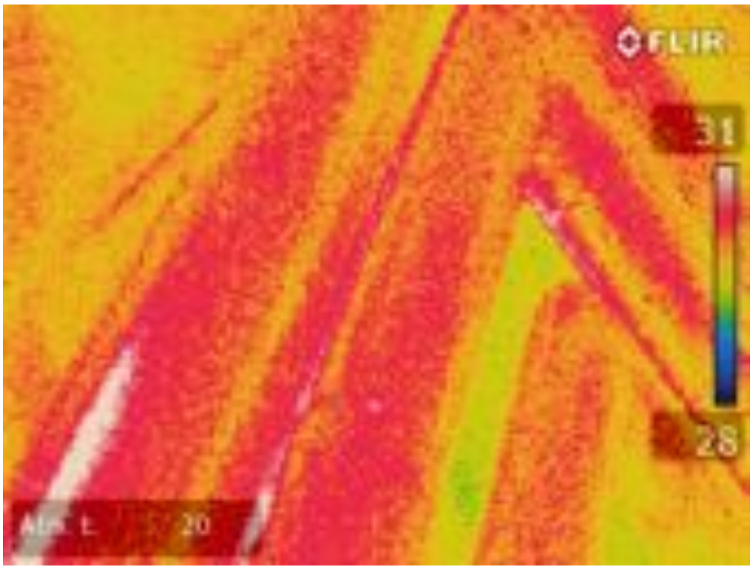


Figure 6.23: Thermal image showing heat loss from pipe at partition wall

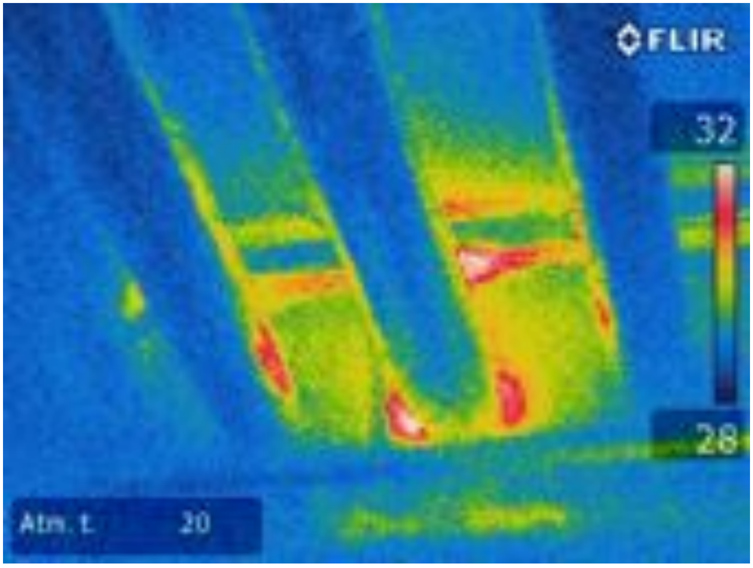
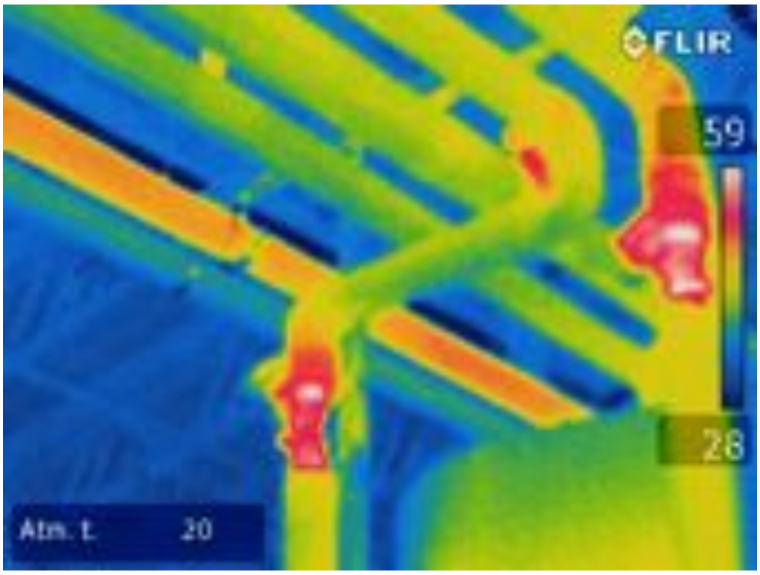


Figure 6.24: Thermal image showing heat loss from DHW cylinder and associated pipework



Assuming that half the heat loss is from the secondary circulation system, then the average heat loss from the pipes is 17.25W/m. Whilst a more typical figure for well insulated pipework would be less than 10W/m, given the observations from the thermal imaging this is not unreasonable. Based on Figure 8.24, the heat loss from the cylinder and associated pipes and valve could reasonably account for the remaining 6.9kW losses (especially as much of this would be spread over 24hrs/day as the cylinder cools down overnight.

6.7 Comparison of DEC with EPC

The building industry has identified a consistent performance gap between the predicted energy usage by SBEM modelling at the design and construction stages of non-domestic projects for EPC production and the actual energy usage during operation of the building as indicated by the DEC. The heat energy for the EPC and DEC is the same load, whilst the electricity is different as the EPC only includes auxiliary power (pumps and fans) and lighting, whilst the DEC includes all power. SBEM is a tool that provides an asset rating for the building based on standardised assumptions and isn't strictly a predictive tool, so the results of the SBEM modelling are referred to as 'design estimation'.

Rogiet school follows this general rule and an objective of this study was to establish as far as possible the reasons for this. The energy breakdown of the DEC and EPC is shown in Figure 6.25 together with data from the TM22 assessment in the appendices The difference between the DEC and this assessment is the period plus in this study it has been possible to separate out the auxiliary power and lighting. Both the DEC and the TM22 assessment have been based on the fiscal gas meter readings with comment made on the implications if the main plant room gas meter was correct. In addition the renewable energy has not been taken into account in the EPC or DEC so does not contribute to the differences between EPC and DEC.

The data show that the actual thermal energy used is approximately 2.7 times the amount in the EPC and the auxilliary power is about 2.5 times the design estimation. In this case therefore the auxiliary power is about right as a proportion of the thermal energy used, so the focus can be on the reasons for the difference between the thermal and lighting energy loads.

From the work in this study the lighting energy usage is about 27% greater than that indicated by SBEM. The figure from this study is an estimate based on the installed lighting and usage profiles so could be inaccurate by a few per cent. There is insufficient information available to assess the reasons for the differences which could be related to changes in the installations between design and construction, differences in occupancy patterns, day lighting effects or automatic switching assumptions. Review of all these items in the SBEM technical documentation suggests there is no reason to believe that any of the assumptions at the design stage was optimistic or that there should be a systematic difference between EPC and actual lighting energy usage.

The main difference between the SBEM design estimation of thermal energy usage and the actual is the energy wasted by the DHW system. If the actual energy used was reduced by this amount (say 45,000kWh per annum) then the annual thermal energy usage would be 60,000-65,000kWh per annum. This still amounts to about 1.5 to 1.6 times the design estimation. Review of SBEM heating profiles for educational buildings indicates that the heating schedules are realistic and conservative. The main difference between the SBEM model profiles and the in-use situation is that the occupied temperatures in SBEM are 18^{o}C, whilst the actual temperature is usually around 21^{o}C. With a 10^{o}C average delta T in the heating season in SBEM, this would lead to a 30% increase in energy usage. This is clearly an SBEM issue as 18^{o}C is a low temperature for most uses. A further contributory factor could be ventilation heat losses due to the natural ventilation system because the windows open due to high CO_2 concentrations ie actual ventilation being higher than the SBEM model estimation.

Figure 6.25: Comparison of EPC, DEC and in-use Data

Source	Heat (kWh/yr)	Electricity (kWh/yr)	
EPC	40857	Auxiliary	2763
		Lighting	13715
DEC (2012)	105621	90797	
This study	109164	Total	85089
		Auxilliary	6752
		Lighting	17413

6.8 Conclusions

The main conclusions drawn from the energy analysis presented in this section are outlined below:

Meter reconciliation

Conclusions on the metering and its adequacy are presented in Section 4.2. These conclusions relate only to reconciliation.

There is a major discrepancy between the fiscal gas meter (which is the basis of billing) and the main incoming gas meter in the plant room. It appear that this discrepancy is related to meter calibration or installation. The fiscal meter measures 80% more gas than the plant room meter, although this ratio is very variable. It is considered most likely that the fiscal meter is correct, although the energy does not provide evidence to support either meter.

This variability demonstrates the lack of attention to detail when metering is installed, especially if the purpose of that metering is unclear eg in this case it is thought that its purpose was to obtain BREEAM credits.

If the plant room meter is correct, the school is paying almost twice as much for its gas supply as it should be. Most of the other conclusions related to thermal energy remain the same except that the heat loss from the DHW system would be much reduced, but still very significant.

In terms of electricity meter reconciliation, the main conclusion is that the un-metred energy is about 25% of the total energy usage. It is likely that these un-metered uses were thought to be low or not considered in detail at design stage, leading to difficulty in attributing 25% of the school's electricity usage to any particular end use.

Investigation of un-metered energy indicates that the sprinkler system accounts for a large proportion of this and that energy usage of the sprinkler system was not considered as part of the design.

BMS and data collection

Whilst the BMS was set up with data collection from some meters when the school was completed, a number of meters were not connected. It would appear that this was done without consideration of need or functionality, but instead to show that metering was on the BMS and therefore a particular box was ticked eg specification or BREEAM.

Making changes to the system in order to collect energy data required a specialist controls contractor, but this was not straight forward as the controls contractor was not particularly responsive. It took several months to engage the contractor to make the required changes. Changes were made to the BMS which enabled half hourly energy data to be collected for all the energy sub-meters, but the resolution of the half hourly data was poor (1kWh) and the data was difficult to recover.

These experiences show that the BMS has been set up to appear as if it was fit for energy data collection and monitoring, whilst in reality it was not fit for this purpose.

Electrical energy analysis

The electrical energy usage of the school was higher than the good practice benchmark, higher than the 'typical' figure on the DEC and higher than some of the other schools in the county. This probably reflects the increased equipment in this new school compared to those used for generation of the benchmarks and many of those in Monmouthshire.
The kitchen has the highest electrical energy usage of the sub-meters at 17% of the total, with other significant uses being external lighting, mechanical panel and key stage 2. The wind turbine generation accounts for about 6% of the total electricity usage, with about 87% of this energy used on site.

The lighting performance is very good compared to the good practice benchmark for offices (Figure 8.19). This reflects improved lighting efficiency and perhaps the benefits of automated controls.
ICT and appliances are also much lower energy users than in the good practice office, although this probably reflects differences in the building use more than improved energy performance of appliances.

The IT cooling unit uses a significant amount of energy for a small server. It was fond that on commissioning the server room was set point was 20^{o}C and that the unit cooled the room below this figure, so this was the maximum. The energy usage was estimated to be approximately 3300kWh per annum at this setting. However, the temperature was unnecessarily low and it was agreed with the council's IT department that it could be increased to 24^{o}C.

Un-metered electrical energy usage account for about 35% of the total electricity usage. This is reflected in the 'other' category of end use in the energy breakdown by end-use (Figure 8.19). This is a much larger proportion of the energy usage of the building than the benchmark buildings and is the main reason that the building electricity usage exceeds the good practice benchmark. Investigation of the un-metered energy usage suggested that the majority of this energy usage is attributable to the sprinkler system:

- sprinkler room frost protection - 7800kWh per annum;
- sprinkler tank immersion heaters – 4500kWh per annum.

There is also a continuous un-metered load which does not appear to relate to external temperature. This is estimated to average 1.6kW accounting for about 14,000kWh of the un-metered energy. It is possible that this is attributable to trace heating, but it is not clear whether the trace heating is a temperature sensitive use or whether it is continuous. No other potential end-use has been identified despite inspection of all the distribution boards and the end uses associated with them.

The wind turbine generated about 5000kWh during the 2012 period monitored but was only operational for less than half the year. Extrapolated to the full year the generation could have been over 12,000kWh. This generation was during a period when the turbine as under warranty and essentially under a service contract. Without the service contract the evidence suggests that the wind turbine will not be functional because frequent interventions are required. The cost of the service contract is £600-800/yr and the wind turbine appears to roughly cover these costs accounting for periods out of operation. It is therefore concluded that it is only worth continuing wind turbine operation if continuous operation can be almost guaranteed, or if there is some means of increasing production.

Thermal energy analysis

The thermal energy performance of the school is very good compared to the good practice benchmark (albeit a benchmark for offices) and compared to other primary schools in the county.

The space heating energy usage at 23 and 32kWh/m^2 per annum for the community room and rest of the building respectively are excellent and are relatively close to the Passivhaus standard of 15kWh/m^2 per annum although the community room usage reflects reduced hours of use.

The school was found to be using considerable quantities of gas in the summer. This usage was to operate the DHW system without any water actually being used. The energy used therefore represents the system loss and is about 180kWh per day or 46,800kWh per annum. The actual energy to heat the hot water used is a small fraction of this and the DHW system was found to be about 7% efficient. The solar thermal energy generated about 5% of the losses, leading to the conclusion that the money spent on the solar thermal system would have been better spent on reducing losses from the DHW system. Furthermore it is likely that the requirements of the solar thermal system dictated the design of the DHW system and contributed to the losses eg larger DHW cylinder and more complex pipework. The losses are considered likely to be split approximately equally between the secondary DHW circulation system, which comprises about 400m of pipework around the school, and the 1500l cylinder and associated valves and pipes in the plant room.

Improvements

Preliminary improvements made during the study were:

- decreasing the temperature set point of the sprinkler room fan;
- increasing the temperature set point of the IT server room cooling unit;
- reducing the DHW flow temperature and holiday active hours;
- increasing the natural ventilation CO_2 set point.

Energy data for the school was reviewed for 2013 following these changes showing the following:

- large un-metered electricity use reduction;
- moderate increase in Zone 2 electricity usage despite changes to the operation of the IT cooling unit set point;
- large increase in the mechanical panel energy usage;
- degree day corrected thermal energy usage significantly increased, perhaps because of insensitivity of system to the much warmer conditions generally in 2013.

Further improvements have been suggested as follows:

- investigation of the un-metered base load and sprinkler system particularly to assess opportunities for reducing this energy usage;
- investigation of IT server cooling unit controls to prevent operation when temperature is below the set-point and also to ensure that it is not and cannot be used inadvertently to heat the space;
- addition of two point of use electrical water heaters in the community room and the caretakers room for use out of hours so that the DHW system operation hours can be reduced by about 1200 hours per year saving approximately 17,500kWh per annum;
- reduced lighting run-on times;
- investigation of wind turbine viability with Quiet Revolution;
- investigation of fiscal and incoming gas meter discrepancy, fixing kitchen gas meter and lighting sub-meters.

The combined energy savings of these measures are expected to be 8% of thermal energy and 11% of electrical energy. In addition to these improvements, which can be made to the existing building a number of potential design improvements were also suggested, most significantly:

- detailed consideration of sprinkler system energy usage and opportunities for energy saving at design stage;
- if renewable energy generation is required use PV rather than wind;
- DHW for kitchen only with short run lengths from the boiler – use point of use electric heaters elsewhere;
- Consider using air tight construction with mechanical ventilation and heat recovery to better manage the conflict between air quality (CO_2) and thermal performance – particularly for schools where large numbers of people are concentrated into small areas;

7 Technical issues

7.1 Introduction

This chapter investigates the technical issues that have been identified throughout the study through , anecdotal evidence, BUS data, walkthroughs, observation and reviews of the design construction and handover processes. The five studies are;

1. Follow up from Seasonal Monitoring,
2. Lighting analysis,
3. Buffer zone analysis,
4. Natural ventilation effectiveness review, and
5. Acoustic Investigation.

7.2 Seasonal Monitoring

Environmental monitoring was undertaken in winter and summer as a spot check of the performance in terms of light levels, air quality and comfort. Instruments used and the parameters measured are listed in Figure 8.1.

Figure 7.1: Monitoring Instrumentation

Instrument	Parameter
TSI Instruments Ltd., IAQ Calc, Model 7525	Temperature (^oC)
TSI Instruments Ltd., IAQ Calc, Model 7525	CO_2 (ppm)
Gemini Tinytag View 2	Relative humidity (%)
Sky Tronic, LX-101 600.620	Light (Lux)

The objectives of the monitoring were to evaluate the environmental conditions in key spaces around the building in winter and summer.

Winter Monitoring

Monitoring was undertaken on 7 February 2013. The weather was cool and overcast and the results are relevant in this context. The results are presented in Appendix G.

Temperature
The external temperature was measured at 6.8^{o}C at the beginning of the survey and 7.6^{o}C towards the end. Internally the temperatures tended to be close to the set point of 20^{o}C, typically ranging from 19-21^{o}C. The northern 'wing' of the building tended to be slightly warmer. It is likely that this is because the school was warming as the survey went on and because the warmer part of the building is more active with teaching. However, in general the temperatures were comfortable and therefore the subtle differences across the building are not considered significant.
There were a few exceptions to the general observations:

The staff room and heads office were cool at 17.8 °C and 18.3°C respectively at about 09:30. This is most likely due to the front doors having been open in the morning before 09:00 when the children were arriving.

The KS 2 corridor, year 5/6 pod and the group room were all over 21°C, but none were excessively warm.

The year 3/4 pod has consistently been reported to be cold (as reported in the BUS and indicated by follow-up discussions) and when the temperature was measured it was 19.0°C which is slightly cool. Similarly the kitchen was reported by staff (on the day of the survey) to be cold but measured at 19.7°C just before serving time. The staff say that the room had warmed up when the serving hatch was opened to the hall.

The IT server room was 22.7°C. This is a little warmer than the surrounding rooms and reflects the temperature set point of 24°C. The fan coil unit was blowing at the time of the survey, but the air did not feel cool. The temperature in this room was reset from 20°C in December 2012. This change was made as part of the study as an improvement to the school's energy management because the IT server room was being cooled excessively. It is anticipated that the energy consumption of the air conditioning unit in winter will now be close to zero.

The sprinkler room temperature was 11.8°C. Previous monitoring of the temperature indicated that it was above 25°C in November/December 2012. The purpose of the heating is for frost protection, so the indicative thermostat on the heating fan was reduced to lower the temperature. This temperature justifies further reduction.

The Trend system was viewed to check the monitored temperatures on the BMS against those measured in the survey. Surprisingly the only temperature sensors shown on the BMS which coincided with the monitored spaces were for the hall, corridor (unspecified) and kitchen. The temperatures measured by the BMS in these spaces at about 14:30 were 20.0°C, 20.2°C and 20.6°C respectively. These are in broad agreement with the spot-check measurements, but cannot be compared directly due to the time differences between the readings. Perhaps more interesting, the BMS was showing numerous sensors and set points for the small rooms and storage cupboards around the school, whilst showing three set points for the main areas of 'school', 'hall' and 'community'. No sensor data was available for any of these areas.

CO_2

The external CO_2 concentration was measured at 386 ppm during the monitoring survey. Typical values in the school were between 1000 and 2000 ppm, with high levels in key stage 2 in particular. The lowest levels were in the staff room and head teachers office at around 09.30, supporting the interpretation that these areas were cool due to recent ventilation with external air as children arrived at school, and in the kitchen – ventilated by its air handling unit.

The CO_2 concentrations were generally very high throughout the building and above the recommended level for classrooms of 1000ppm (Building Bulletin 101) in all the classrooms and teaching areas. Exceptionally high CO_2 concentrations were recorded in the KS2 classrooms, corridor and neighbouring rooms, particularly the year 6 classroom which recorded 3354ppm in the afternoon. The meter was functioning correctly and recorded the correct outdoor CO_2 concentration. The community room was surveys at about 2.00pm, 2 hrs after the nursery had finished and still recorded 1136ppm.

It was notable that windows were closed throughout the building during the survey and the highest recorded levels in the year 6 classroom were when the door was closed. All the other classrooms had open doors. The suggestion is that the air leakage is very low and ventilation through the Window Master system is not operating correctly.

On the previous visits to the school following up issues arising from the BUS and energy assessments it was established that the windows in the KS2 classrooms were open most of the time even in cold weather. This was ascribed to an adjustment made in summer when the rooms were over-heating. The Window Master system was adjusted in December to correct this and now it seems the windows are not opening at all anywhere in the school. Please see the Natural Ventilation effectiveness review later in this chapter, which presents analysis of this issue.

Relative Humidity (RH)
The RH levels were very consistent throughout the building at 40-46%. The only exception was the IT room which is air conditioned. The external RH was 43.1%, and whilst moisture content of the spaces might be expected to increase with occupation (especially if areas are poorly ventilated), it would appear that the higher temperatures in the more heavily occupied areas resulted in RH remaining approximately constant. The meter has been checked and responds well to a range of conditions.

The results are within the 30-70% indicated as acceptable in CIBSE Guide F and therefore humidity in winter is unlikely to be a problem. It is possible that if higher fresh air supply rates ventilated the school could become dry in winter.

Summer Monitoring

Monitoring was undertaken on 8 July 2013. The weather was hot and sunny and the results are relevant in this context. The results are presented in Appendix G.

Temperature
The external temperature was measured at 26.2oC at the beginning of the survey. These hot and sunny conditions were fairly unusual and occurred during a period of several weeks of hot weather. It is reasonable to assume that the temperature conditions were at the extremes that the school is likely to experience and they may be outside the design conditions. Internally the temperature typically ranged between 25 and 26oC in the morning when most of the survey was undertaken. The exceptions were as follows:

- the hall which at 24.5oC was cooled by large open sliding doors on the north side and was perhaps still cool from the previous night;
- the cleaner's room which was being heated by direct sun through its eastward facing windows;
- the kitchen and servery which were suffering from the high internal gains of all the catering equipment;
- the library, which has a high thermal envelope area and east and southeast facing windows;
- the community room which had all its windows closed, the high level glazing does not open, the low level glazing is kept closed due to concerns about safety and the doors are only opened when the children are playing outside.

In the afternoon the school had generally warmed heated up further with temperatures measured in several spaces exceeding 27°C.

The results of the monitoring show how, in hot conditions, the school started the day cooler than outside and gradually warmed throughout the day to exceed the ambient temperature. The natural ventilation (generally aided by propped open doors) provided some comfort, but it was not possible with the strategies adopted to keep the temperatures below the external temperatures. Those spaces with east facing windows were particularly warm in the morning and it is likely that those with west facing windows (library, community room, reception class) would have got hotter still as the evening drew on.

The kitchen had insufficient cooling, either from the air handling system or the windows to keep it cool and this was exacerbated in the servery due to absence of any windows or supply/extract in this space. The temperature in the community room was the highest in the school due to lack of opened windows.

The night cooling capability of the natural ventilation system was not in use.
There is a design question to be answered here:

- why were high level opening windows not included as they have been in the rest of the school?
- There are also some design/handover lessons:
- night cooling ventilation in naturally ventilated schools should be communicated to building users, easy to operate and secure, please building users guidance enhancements chapter 5;
- the natural ventilation strategy should have been incorporated in the kitchen and server or some sort of cooling capability incorporated into the AHU;
- make sure low level windows do not pose a risk of jammed fingers in spaces to be used by young children.

CO_2

The CO_2 measured outside was lower than would be expected at 305ppm and may suggest calibration issues with the instrument. Nevertheless the instrument was found to respond to variations in CO_2 and the results can be considered indicative rather than absolute. Since the doors and windows were open throughout the school CO_2 concentrations were generally slightly increased above ambient conditions (350-450ppm). The community room had the highest concentration (565ppm) due to having its windows and doors closed, but the concentrations measured were not of any concern, being well below guideline concentrations (Building Bulletin 101).

Relative Humidity (RH)

As with CO_2 the RH levels measured throughout the school (40-50%) largely reflected ambient conditions (40%) with the effects of activities in the building being offset by high air change rates due to open doors and windows. The exception again was the community room (38.9%), where the RH was lower due to the high internal temperatures.

Light

The survey was undertaken on a bright sunny day with 9400 lux measured in the shade outside. Light levels in the school spanned a wide range depending on whether direct sunlight entered spaces, lights were on or blinds were open or closed, with a range of 53 lux in the year 1 classroom to 1450 lux in the staff room.

The lowest light levels in the year 1 and 5 classrooms and year 5/6 pod were measured with the lights mostly off and the blinds drawn in the classroom. These are very low levels for such a bright day illustrating the combined effects of the paint colour (yellow), drawn blinds and the north facing windows with the coloured external canopy. Where the blinds were open (eg year 6, 470 lux) or the lights were on (eg year 2 and year 4, 652 lux and 493 lux respectively) conditions were much brighter.

The brightest spaces were where direct sunlight was shining in (cleaner’s room, 1154 lux; reception class 1150 lux), spaces with large south facing glazing (staff room, 1450 lux) and the brightly lit toilets (KS1 toilet, 1170 lux).

The key finding is that even with bright sunny conditions outside the classrooms have a slightly gloomy feel. This builds on the findings of the winter survey and the BUS. The conclusion is that the combination of north facing windows, covered canopy and slightly dark paint colour restricts lux levels in the classrooms. Where blinds were open this was ameliorated to some extent, but there was a tendency for blinds to be closed, either because they hadn’t been opened after using screens or because they were deliberately closed to avoid glare.

Generally the spaces on the east and west and south sides of the building were much brighter.

7.3 Lighting Levels further investigation – BUS Follow up and recommendations

The lighting concerns, which are shown in some of the comments BUS comments below, were repeated by staff through follow up conversations on subsequent visits to the school, although they were not backed up by the Head-teacher or necessarily presented through the BUS data. The Head teacher Kath Evans is very proud of her school and there is a resistance to be critical. She also spends less time in the classrooms compared with the teachers. During the structured review, which was a cloudy and dull day, the natural light levels were low and in nearly all classrooms visited, the roof blinds and high level wall blinds were drawn. The structured review also discussed the parameters therefore for the future tasks of the BPE to consider the inclusion of measures to improve natural light levels in the classrooms by for example, changing the internal wall colour, prompting users to open blinds and potentially trialling the removal of the external dark coloured canopies. Whilst comments on the lighting were received through informal review with staff, the lack of BUS data is slightly to the contrary however the issue has been followed up in more detail below.

Lighting (BUS Comments)

- I feel that my classroom is too gloomy. Windows let no sunlight in so lights are required even on sunny days. However, roof-lights let a strong beam of light which shines in pupils eyes in the afternoon, therefore we have to block out the small amount of natural light available.
- Lighting conditions good especially outside on dark mornings and evenings.
- Lights are good, although a switch rather than a key to operate in the classroom, I think, would be better.
- Lights are too low in summer. Classrooms are a bit dark and corridors are light.
- Some glare from sun depending on the time of day but not enough to complain about. Only depressed that I cannot be out there!
- Sometimes feel it is a bit dark. Very good. Very good. We have no sun in the pods, only some natural light and on a dull day, it's dark. Would be nice to have larger windows that open wider for fresh air.

Light - levels

The external light level was measured at 6950 lux at the beginning of the survey reflecting the overcast, gloomy winter conditions which persisted throughout the survey. The survey was undertaken with the electric lighting generally on except in some spaces where measurements were taken with the lights on and off. Internally light levels ranged between 90 and just over 1000 lux. The lowest levels were in the KS1 and KS2 corridors at around 90 lux. This is within the range recommended in Building Bulletin 90 of 80-120 lux for corridors. The breakout areas/cloakrooms, which occur within these corridors, are amongst the brightest areas at 880 and 1047 lux. These areas benefit from excellent natural lighting from the roof lights (although the electric lights in these areas were still on).

Light levels in the classrooms with lights on were generally 350-500 Lux. Again these are within the levels recommended for classrooms of 300 lux general and 500 lux for detailed work e.g. art and craft. The locations chosen for the measurements were on desks and away from direct light, suggesting that lux levels would generally be higher rather than lower than the measured values in other parts of the rooms. Such as the kitchen work surface which was bright at 883 lux. The lights could not easily be turned off for comparison due to automatic presence detection so the only area where there is a lights off comparison is the head’s office where the light level reduced from 347 lux (lights on) to 168 lux (lights off). The BUS comments indicated that the classrooms are considered gloomy and these light levels, whilst acceptable are close to the recommended minimum and may contribute to the gloomy feel along with a number of other factors.

Follow up from BUS on lighting

As mentioned above, lighting levels experienced in the classrooms were reported by some teachers as being gloomy. Analysis of the classroom lighting levels suggests the lux levels are within an appropriate range. However there are several factors that have been identified to produce the overall feeling of gloominess and these can be summarised as follows.

Design factors

The following design factors have been listed which we believe have added to the feeling of gloominess in the classrooms these are ranked by us in what believe is their relative order of importance;

- The wall to glazing ratio is at the lower end of schools recently completed by White Design. The impact of this is more acutely noticed when we add in the additional area made open to the classroom by the change to the cloakrooms making the area of glazing per the area of classroom even lower(see comment below). The table below highlights that each of the schools are similar, some with more, and some with less, though there is a difference with the area of the space and proportions of the room and how that it is used, which would have an effect on the distribution of the daylight.

Figure 7.2, Comparative glazing and classroom area analysis

Project	Area (m2)	Glazing (m2)	Rooflight glazing (m2)
Rogiet	70 (inc original cloakroom space)	5.9	1.57 (total = 1 rooflight)
Ynysowen	66.2 (inc cloakroom space)	7.5	1.79 (total = 2 rooflights)
May Park	54	6.4	- (total = 0 rooflights)
Anns Grove	55	4.3	1.33 (total = 1 rooflight)

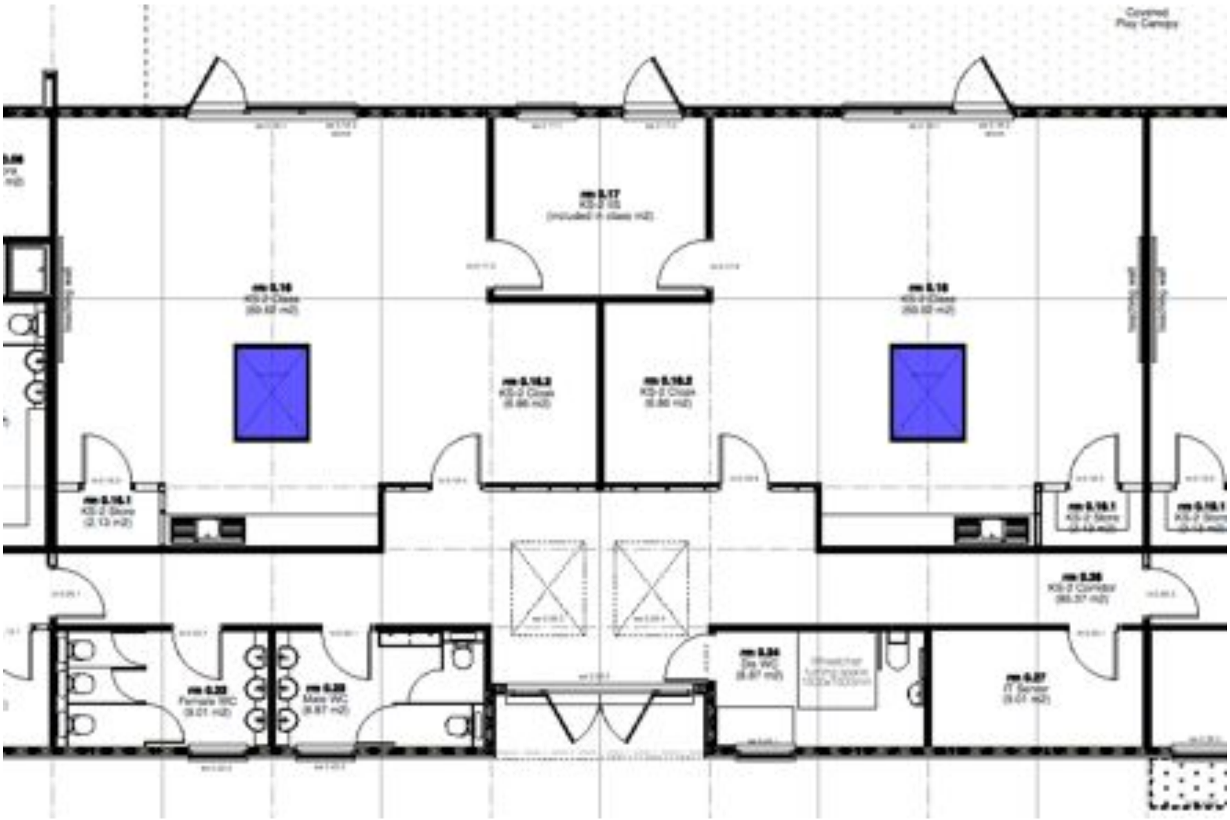
- The classrooms are orientated north to minimise overheating and glare but have external canopies, which extend across the width of the classroom façade reducing light levels. As part of the initial modeling for the daylight calculations, any external features that would effect the daylight within the room have to accounted for. It is not clear if the coloured external canopies were accounted for in the modeling for the teaching spaces.
- The canopies are coloured dark red and blue in places further reducing ambient lighting levels.
- 3) The external wall colour is painted a darker yellow colour and serves to emphasise the dark silhouette of this wall against the windows. Monmouthshire CC aspire within their building to meet the needs of disabled people and use the British Standard "Design of buildings and their approaches to meet the needs of disabled people" (BS8300:2001/2009), alongside the Approved Documents, Building Regulations Part M. Within the colour scheme for the school, the colours selected were to enable there to be a 30 Light Reflectance Value (LRV 0-100) points difference between the wall and the ceiling. With the suspended ceiling generally being White (85 LRV approx), the wall would have been selected below 55 LRV, making it darker in colour. Within BS8300:2009, it has been updated to state that the contrast between the floor and the wall is the most critical, though still states that the same contrast should then apply to the ceiling from the wall.

  "The LRV of a wall should be 30 points different from that of the ceiling and of the floor. To avoid giving the wrong impression about the size of a room, skirtings should have the same LRV as the wall so that the junction between the skirting and the floor marks the extent of the room. BS 8300:2009 , p62"

  However the approach by the Access Consultant on subsequent projects, due to the regular use of the classroom being by the same people everyday and not by new visitors, a relaxation of this guidance has been developed. This concentrates on the critical junction between the floor and the walls or If there is a particular user with a particular need where this would be addressed on a specific basis.

- Investigation of the as built drawings demonstrated a change to the use of the cloakrooms that were designed at the rear of the classrooms. These became a useable space incorporated within the overall classroom area with no additional natural light provided. This has generated a dark space at the rear of the classroom. As part of the daylight and ventilation strategy it could be possible that the area in question was not identified, as a 'useable' space so did not form part of the calculations.

Figure 7.3, Location of central roof-lights



Use factors

- Simple vertical blinds have covered the north facing windows. These are rarely drawn to the open position therefore reducing lighting levels further.
- Glazing in most classrooms has also been covered by displays reducing ambient light levels further.
- On three consecutive visits in the spring and summer at least 50%, and on the last visit 100%, of classroom roof window blinds were closed. (these were observed closed even when the whiteboard was not in use). A BUS comments suggested this was due to points of glare in the classroom as indicated by the photo below, forcing teachers to close the blinds, however the blinds have still been closed on days when skies have been overcast and there is no direct sun light.
- The window control for the blinds is hidden behind the door in the teachers cupboard and the default position of the blinds seems to be closed. (consideration of improving this is provided through the Building Users Guide enhancement)

Figure 7.4: Lighting differences with blinds open and closed

Left; Glare to centre of room from south facing rooflight. Vertical blinds on windows further obscuring light.
Right; Roof blind open bottom; roof-blind closed top

Recommendations

Low capital cost changes

- Introduce of culture of leaving roof window blind in open position.
- Help implement by repositioning control adjacent to white board.
- Introduce a screen saver to the white board that prompts the opening of the roof window blind if the session on the whiteboard has concluded.
- Discourage or remove window displays.
- Remove window blinds, which do not achieve blackout and are not needed for glare. If needed replace with better quality black out blinds that demand being opened when the need for blackout conditions has concluded.

Higher cost changes

- consider painting inside face of external wall to an off-white to match other walls
- consider replacing dark coloured canopy polycarbonate with clear colour to improve ambient lighting levels.

In follow up with Vicky Curtis (acting head teacher) in May 2013 some of these recommendations were discussed. The development of the screen saver to encourage use of the roof blinds will be taken forward as well as the identification of a ‘light/eco class monitor’. A member of the class tasked with noticing and suggesting the blinds could be opened. Removal of window displays will be taken forward. Due to the capital expense, changes to the blinds, painting walls or replacing the canopy sections would be considered when other needs may demand these changes. i.e. the current blinds break or when the walls need repainting.

Further follow up through the Building Users Guide amendments in Quarter 10 is planned alongside a dissemination activity with returning head-teacher Kath Evans in January to implement the most appropriate opportunities listed above. This will discuss what wall mounted information sheets might help staff and students maximise the operation of different aspects of the building.

7.4 Buffer Zone use, and recommendations

The design investigation describes the experiment to observe and challenge the current use of the lobby space against the designed intention. The introduction and the conclusions from the report are shown below

Introduction
The analysis of the design of lobby spaces incorporated into many White Design school buildings has been developed through the Oakham TSB BPE study and this has informed the further analysis at Rogiet. The Oakham BPE study analysed the design development of lobby spaces and the conflict that arises when these spaces are asked to take on both an educational function and an environmental function. The Oakham study established a set of design recommendations for how White Design or other designers could balance and understand the implications on both environmental and educational building performance, and the consequential impact on capital cost.

This BPE study has further interrogated the design of the group/lobby spaces at Rogiet Primary School due to the negative impact on environmental performance that is generated by the inclusion of an additional door direct from the class-base to the outside. This has, in practice, made redundant the use of the group space as a potential air lock to the outside and has subsequently increased heat loss from the classroom.

Existing use of the group space
The photo montage below shows how the group space has become an essential educational space for each key pair of classes. It is loaded with furniture and is not useable as a primary entrance and egress point to the classrooms. The room is used throughout the day for small group activities and one to one activities as well as an independent quiet space.

Figure 7.5: The group/lobby space

photo taken from opposite classroom door

room set up for group work

Conclusions

- Heat loss through the door could be reduced if we assume the door is open for 6 mins in total across the three main entrance times, morning, break, and lunch.
- A strategy could be adopted to prevent use of the classroom door throughout the day in the winter. This may prevent the door from being open for approximately 30mins a day direct to the outside within each classroom.
- Any process will require management by staff to organise children passing through the group room. This may be more easily achieved for older students who could enter unmanaged in a more staggered approach. This may however result in the external door being open for longer.
- The main impact however is the use of the group room. The first morning session would have to be scheduled to be a curriculum activity that requires limited set up . i.e mathematics. not “Read Write Ink” that needs easels set up before hand.
- Ideally timetabled use would not occur till after first break and morning group work could be accommodated in the corridor.
- In explaining the staff and students they were interested in the findings of the experiment as they want to help the school reduce the energy loss for the school and to keep their classroom warm in winter. The question was raised as to how effective this was as the windows were open in the winter for ventilation and air quality.

Recommendations and Reaction

It is our recommendation through this study that the school adopts a winter approach to access and egress to the classrooms. This would alleviate some of the heat lost through the open door on colder winter mornings especially.

1. Allow older children to enter through the group as the arrive rather than line up. This would omit the need to re-arrange the group room in advance and would prevent the space becoming overcrowded with the larger year 5 and 6 children. This approach is already adopted at many other primary schools.

2. For the younger years, timetabling should be possible to allow the group rooms to be used flexibly as the main point of access in the morning and allow the first timetabled session to be less dependent on a specific room set up.

3. Alternatively all younger children could enter through the main circulation doors and access their classrooms from the main corridor to reduce both heat lost through the classroom door or the groups room door

It is also fair to state that teaching staff may view this initially as an unnecessary hassle and it changes the process that is currently in operation. The BUS feedback picked up some comments like “Only at the start of the day is it sometimes cold”. Some responsibility for this feedback can be attributed to the combination of the slow response of underfloor heating and the heat purging that happens as the class enters in the morning. Whilst the heating system cannot be changed it is possible to change the entrance sequence to help reduce this negative effect of uncontrolled heat loss.

Recommendations to future projects

The fundamental use of a lobby space was not pursued and communicated thoroughly throughout the design process but for future Monmouthshire schools the benefit of a lobby space has been explored fully in future designs through the realisation of a cool zone. The cool zone is an internal space that is outside the thermal envelope, it is unheated and large enough for some curriculum activities to take place. It therefore has a lower capital cost, reduces heat loss from the classroom, provides the desired direct link to the outside without management and allows for some group work. Please see related study completed as part of TSB Oakham BPE.

7.5 Natural ventilation effectiveness

The full18 -page study investigating the performance of the natural ventilation system can be found in appendix J, The extract here summaries, the changes that were made to the design of the system, the estimated lifecycle costs of the system, and the conclusion and recommendation form the study to ensure best performance from the system as well recommendations for future installations

Changes made to the design of the Natural ventilation System
There were some fundamental changes made to the natural ventilation system throughout the value engineering and construction process. These were identified through the review of the As Built vs Design Drawing report and further discussed with the architect, acoustic engineers and contractor. They can be summarized as follows.

- reduction in number of opening roof-lights; to provide the same opening requirements but reduce the cost of installation
- increase in size of the classroom, in response to client brief changes
- omission of the low level attenuated vents in the external wall of the classrooms, as a result of on site realisation of actual acoustic issues.
- omission of trickle vents replaced with incremental opening facility on the Windowmaster system; due to the inclusion of Windowmaster system to the windows when the attenuated vents were omitted.

Estimated lifecycle Cost analysis
Through this BPE study the on-going costs for running and maintained the natural ventilation system have become clearer. The full study in appendix x analyses this against some indicative cost analysis prepared by Faber Maunsell of natural ventilation and mechanical ventilation systems within schools from 2008. The summary below estimated the energy costs of running the system per annum and identifies the maintenance cost for servicing the system. Windowmaster have assisted in the collation of this data and analysis and have also reviewed with the school the requirements of the maintenance contract which has since been reduced from £1800 to £1500 /annum.

Figure 7.6: Basic lifecycle analysis of WindowMaster system

48 motors, 9 sensors, weather station, control panel, PC, key pads, zone controllers and motor controllers.	1405kWh per annum
Using a 0.550 kgCO$_2$ per Kw/h unit conversion factor – (as used in DEC's and TM22)	772.75 Kg/CO$_2$ per annum
this is equivalent to	0.773 T/CO$_2$per annum
using 16p per unit as an average for the supply of grid electricity, this is approximately equivalent to	£125 / year
The yearly maintenance contract with Windowmaster is	£1,800 / year
The annual running cost and maintenance cost is	£1,925 / year

Conclusions
The following conclusions and main observations are drawn from this study:

- The requirement for acoustically considered natural cross ventilation has dictated the shape of the building, particularly the orientation and classroom section. The design has promoted cross ventilation and to some degree stack ventilation but without any low level opening incorporated into the automated natural ventilation system, this appears to promote air movement and ventilation at high level in the space but not necessarily in the occupied zone of the classroom, (although this solution is advocated by Windowmaster where historic Windowmaster modeling shows cooler air dropping into the occupied space. This modeling is not evident specifically for the Rogiet design) . The acoustic design did drive the ventilation approach rather than the ventilation approach integrating the acoustic needs of the site. If a derogation from BB93 regarding the acceptability of a lower ambient noise level (as observed on site) had been resolved earlier in the design process, this may have allowed the ventilation approach to dominate the design decision process over the acoustic requirements.

- The winter condition illustrates the conflict between temperature and air quality in a building with dense occupancy such as a school. There is a fine line between getting good air quality and causing discomfort through draughts. The system was originally set up with default set points and it caused discomfort. The response to this was too great and discomfort through draughts was followed by poor air quality through insufficient window opening. It is hoped that the optimal balance has been reached with the most recent adjustment.
- The WindowMaster engineer was slightly reluctant to reduce the CO_2 set point for trickle ventilation because it may lead to draughts and discomfort. We have interpreted this to indicate that WindowMaster recognize that draughts and discomfort are easily detectable whilst high CO_2 concentrations are not.
- Monmouthshire County Council will not allow access to their IT systems from outside. This means that changes to the WindowMaster set up have to be made on site. WindowMaster have to travel long distances to site so this is expensive. This is one of the reasons that issues do not get resolved quickly. We have suggested that the head teacher is given instruction in basic operation of the system, but it is most likely that the project team will help to optimize the system in the latter stages of this project.
- Night ventilation was not activated when the system was commissioned which meant that the building was prone to over-heating during hot summer weather. This was to do with perceived concerns over security. It is of note that the school were not aware of this night cooling capability and WindowMaster were not advising them that it should be activated until the project team raised the issue. Security issues were discussed and one of the low windows was not included in the night ventilation set-up.
- The WindowMaster system is expected to use 0.76kWh/m2 per annum of electricity, which is a small but not insignificant amount.
- In the classrooms and adjacent corridors the system is controlled by CO_2 and temperature sensors, which enable sophisticated actions and varied mode of operation for summer and winter.

Recommendations

The following recommendations will be fed back to the school to improve the effectiveness of the natural ventilation approach.

- Review the effectiveness of the new lower CO_2 set point for trickle ventilation in winter mode to assess whether a better compromise between air quality and cold draughts has been achieved.
- Review the effectiveness of the night cooling system in summer 2014.
- Train the head teacher in basic operation of the WindowMaster system controller.
- Gain feedback from Window-master on the need for the £2160 yearly maintenance contract. In comparison to other maintenance contracts it emerged through the study that this cost included VAT hence the use of £1800 in the above revised cost analysis. Also WindowMaster have reviewed this with the school and reduced this to £1500/per annum
- Create better information for the users to encourage them to use the manually openable windows and doors when appropriate. This to be developed through the Building Users Guide enhancement and some locally presented information near the openings themselves.
- Future consideration and improved understanding of the use of wall mounted perimeter radiators in front of low level vents to pre warm fresh air in the winter in contrast to the current inflexibility of the under-floor heating.

7.6 Acoustic Investigation

Due to the critical link between the natural ventilation design and the acoustic site constraints and the BUS data tables, further investigations were made into the acoustic performance and design process that led to the built solution. This is presented in a separate 13 page study in appendices J and K.

The summary below describes the outcome form the on site survey that was carried out in late 2013 and presents the findings and recommendations form the study

Onsite sound survey

In November 2013, White Design carried out an on site external and internal noise survey to test the acoustic design. The survey was carried out using a Norsonic Type 118 sound level meter, set up using octave bands and calibrated for this survey and borrowed form Mach acoustics how were the acoustic engineers for the building. The following Technical specification is provided by the manufacturer; Measurement range: 0.3µV to 7V (RMS) in one range corresponding to –10dB to 137dB with a microphone sensitivity of 50mV/Pa. The maximum peak value ±10V corresponds to 140dB.The purpose of the spot meter readings was to review and test the following;

I. to check the external onsite noise levels ; there has been some commentary by staff and through site visits as part of this BPE study that the background noise of the train and motorway is not that invasive or noticeable.
II. to determine the effect of facing the building away from the noise sources; what is the effect of the fundamental move of facing the building away from the noise source.
III. to test the envelope performance in achieving BB93; does the internal ambient noise level of an empty classroom achieve the BB93 requirements as set out above.
IV. to understand the effect of having the classroom door open continually; in light of the above what is the ambient noise level increase when the classroom door to the corridor is left open.

Check of external onsite noise levels

The spot testing analysis corroborates the noise level assessment carried out at the beginning of the project identifying a consistent external noise meter reading around the front of the school or in the direct sound filed of the motorway and rail line of approximately 60db. A difference of 3-4db was noted by simply turning away from the noise source and facing towards the building.
It is also worth noting the ambient noise level is increased at the beginning and end of the day by the arrival and drop off procedure, however understandably this has limited effect on the internal functions of the school given the school day is yet to begin or had just ended and is what would be expected.

The effect of facing the building away from the noise source

Some samples were taken whilst the playground was empty at the rear of the school but during the same peak times of traffic flow on the motorway. They indicate that a drop in noise level of approximately 10 db is achieved by the obstruction of the school itself and the auditory shadow that it creates. Sample S12 in the middle of the school facing towards the school at 48db can be compared to S5 61db in the same location at the front of the school facing toward the motorway. This indicates that the potentially cost neutral design decision regarding building orientation makes the greatest positive effect on reducing unwanted high ambient noise levels.

Testing the envelope performance in achieving BB93

All internal empty class noise samples demonstrated compliance of the classrooms with BB93 (based on the 2min averages that were measured). The ambient noise level for the classrooms is a fair reflection of the background noise from, a). External noise, e.g. traffic, railways, aircraft, industrial noise and b).Mechanical services, e.g. Ventilation systems and Plant. The ambient readings did not exceed 35db and would have been acceptable up to 40db given the relaxation of this requirement due to the natural ventilation approach.

The school children and staff when these measurements were being taken were in a quiet assembly at the other end of the building and therefore had limited if any impact to these ambient noise levels.

It is also interesting to note;

- the noise of the actuators when the CO_2 sensors adjusted the window opening pushed the readings up to around 40-42db. This is infrequent and should not push the average ambient sound level reading over a 30min period up significantly but is worth noting and is noticeable. Whilst this was nit commented through the BUS, it is noticeable and has been commented on by teachers in this school and other schools with automated openings, largely because it is a stand-out noise which may be noticed when background noise levels are low.
- The noise relating to operation of the blinds created a reading of between 43-46db. The effect of this can be viewed in the same as the actuators above.

The effect of having the classroom door open continually

Some samples tested the ambient noise level of the classroom with the classroom to corridor door open. One sample was taken when the students and most staff were in assembly. There was limited noise within the corridor, which was created by some movement and talking of staff who were not attending the school assembly. The school could have been described as quiet. The ambient meter reading however was still over 40db above recommended levels. Interestingly whilst students were collecting coats from the corridor and preparing to exit for play time – the ambient reading was measured up to 66db. This range 40-66db gives a broad range of the ambient noise level in an empty classroom if we are to factor in the effect of other background noise over and above the effect from a). External noise, e.g. traffic, railways, aircraft, industrial noise and b). Mechanical services, e.g. Ventilation systems and Plant. This gives a closer reflection of the ambient noise levels in classrooms during teaching as a result of the doors to the corridors being continually open.

Is the design suitable?

The noise survey spot check, set within the parameters stated, demonstrates that the design of the school achieves the required internal ambient noise levels acceptable to BB93.

However the requirement of the school to keep the doors to the corridor open can be seen to undermine the design and it could have been designed differently. In discussion with three separate teachers during the noise survey it was identified that the school like having the doors to the corridor open. This was stated to provide both, a feeling of open-ness throughout the school, which is a reference to the layout of their previous school, and to facilitate the use of the corridor group space as an extension to the classroom.

All classroom doors were open during the morning sound meter reading visit and have generally been noted as open on all previous visits. There is an argument that had the designers been aware of this pastoral/teaching requirement for open-ness, they could have developed an alternative response. However given the requirement for other regulatory requirements e.g. fire compartmentation, an approach that incorporates and assumes a closed classroom door may always have been necessary.

It does also question the expense made to achieve the acoustic attenuation between corridor and classrooms. This is effectively made redundant with the doors to the classroom open although it is difficult to know how it could have been designed out. One approach may have been to increase the opening windows in the external wall to help achieve the required natural ventilation without the need to cross vent through the corridor wall and the corridor roof-lights.

Figure 7.7: Classroom doors always open to the corridor

However this would have likely increased the ambient noise infiltration from outside which was recorded externally on the rear façade to be regularly in excess of 50db, well above BB93 guidelines

BB93 also operates as a blunt tool in this scenario where the negative effect of the nearby road and rail line was shown to prevent the achievement of the minimum ambient noise levels. The contractor later challenged this when it was commented that a) the noise dropped off after 9.30 am and b) due to the constant background nature of the noise it was rarely noticed. Staff and students have corroborated this since the school has been occupied.

This derogation was agreed by MCC and the school and led to the redesign of the natural ventilation system and acoustic attenuation on the north facing rooms late in the design process. Interestingly and despite this derogation the ambient noise level according to recent db measurements the design may in fact still comply with BB93.

If the derogation from BB93 had been sought initially and greater understanding of the school's own desire regarding open plan teaching were known the resulting design would have been very different.

Conclusions and Recommendations

It is difficult and possibly unnecessary to identify recommendations for Rogiet school with regards to improving acoustic performance of the school, no acoustic issues have been identified by the school or through the BUS. This study however has been significant with regards to the learning of how the school pedagogy effects the acoustic performance and how and when this is an issue.

The question over the formation of the design brief is relevant and it is interesting to note that the desire of the Rogiet teaching staff to operate a more open plan approach may have informed Monmouthshire County Council's conviction to pursue plaza schools which is defined by MCC as the integration of two or even three class-bases and group, breakouts spaces within one large space. This approach requires a distinctively different acoustic response.

Figure 7.8 Rogiet 2 classroom layout

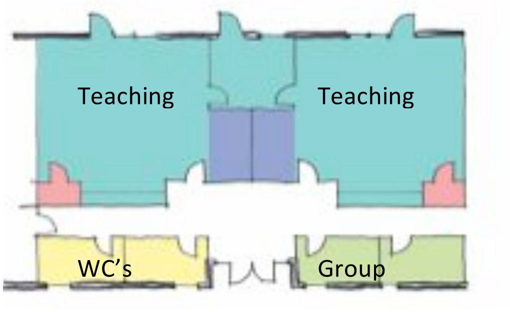
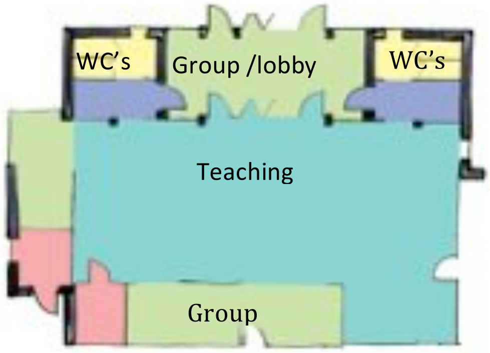


Figure 7.9 Dewstow 2 classroom plaza.



For Rogiet school particularly, if or when, the teaching staff of school ethos changes, the design of the classroom meets BB93 requirements and currently the school staff can choose to close their classroom door if the background noise level become disruptive to class activities.

As a design team it raises the need to further interrogate the design brief and seek if necessary derogations from statutory guidance if a school's vision demands an alternative approach. This should be assessed against the lifecycle cost implications of achieving the statutory guidance. The cost of installing the acoustic corridor attenuators could be assumed to be in the region of £3-5,000 per classroom. Across 7 classrooms this is a budget of between £20-30,000. This capital budget could have been better spent elsewhere within the design process alongside a rigourous and appropriate derogation from BB93. The use of the classroom door as observed was not known during the design stage so this question was not asked.

8 Key Messages for client, owner and occupier

The study has provided the following summary of outcomes, improvements and recommendations for the school itself. These are summarised below and discussed in detail throughout the body of this report.

8.1 Specific Improvements made through the BPE study

Various changes were made during the study at the request of the Building Performance Evaluation project team. The changes are listed in Figure 8.1.

Figure 8.1: Changes Made During the Study

Item	Nature of Change	Date of Change
Sprinkler Room Fan	Reduced thermostat setting from 2.5 to 1	December 2012
	Reduced thermostat setting to 'frost'	February 2014
IT Server Room Thermostat	Increased temperature set point from 20^oC to 24^oC.	December 2012
DHW	Flow temperature reduced from 65^oC to 60^oC	December 2012
	Reduced time settings for holidays from 06:00- 17:00pm to 09:00-11:00 and 14:00-16:00 and reduced temperature from 65^oC to 50^oC.	December 2012
Natural Ventilation (WindowMaster)	Window trickle ventilation set point increased from 650ppm CO_2 to 1200ppm to prevent excessive opening of windows.	November 2012
	Set point reduced to 1000ppm to alleviate problems of high CO_2 in classrooms	January 2014
Heating timing	Set optimisation (max pre-start 300mins). Change start time to 07:30 M-F from 06:00 (but optimisation will create variable start time).	February 2014
Natural ventilation (user guide improvements	In-class static displays describing Natural ventilation process and opportunities for users to effect changes.	February 2014
Lighting	Improved signposting to encourage use of roof blinds.	February 2014
Building Information	The use of QR codes on building control systems to help users interpret what systems are for and how to use them.	February 2014
Natural Ventilation	Change to the cost of the maintenance contract for the natural ventilation system.	February 2014

All the changes were agreed by the head teacher and made with the knowledge and approval of staff from the Monmouthshire County Council Property division or (in the case of WindowMaster) the sub-contracted maintenance engineer.

Energy Performance Update
At the beginning of 2014, the energy performance of the school was reviewed using 2013 gas and electricity data. The TM22 simple assessment was revised to reflect the more recent energy usage data. Data was available covering a

period of 347 days from 7 February 2013 to 20 January 2014. The results are presented in Figures 8.2a and 8.2b and 8.3a and 8.3b. The data have been normalised to 365 days and degree day corrected.

Figure 8.2a: Energy supplies excluding renewables

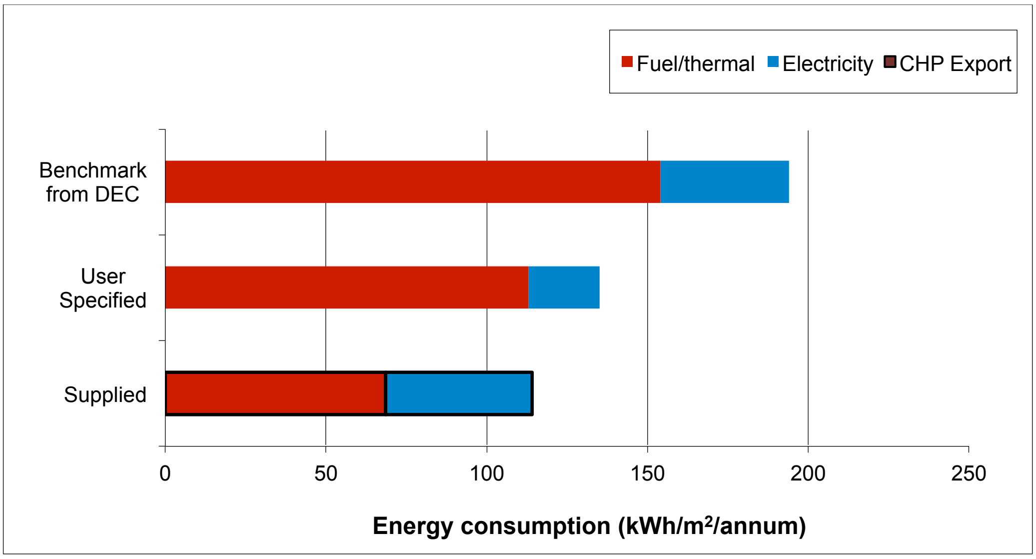


Figure 8.2b: Carbon Emissions

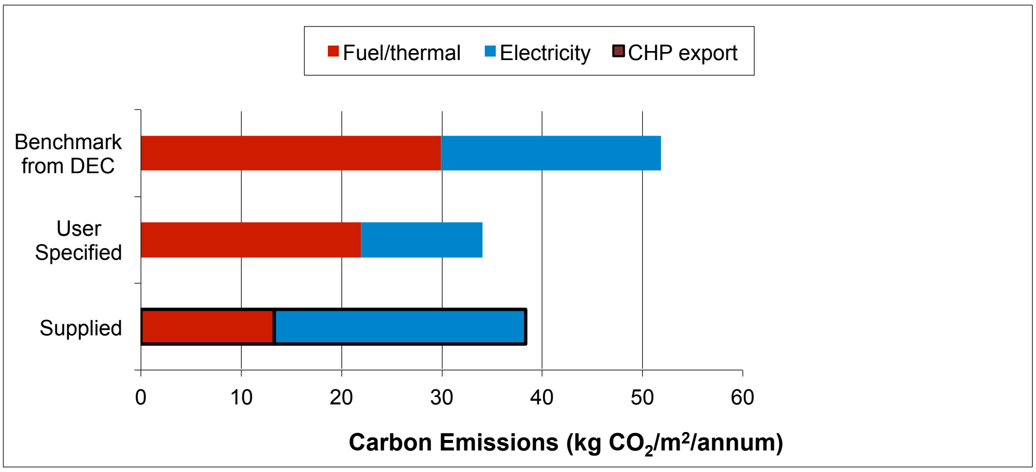


Figure 8.3a: Fossil fuel equivalent energy consumption and generation

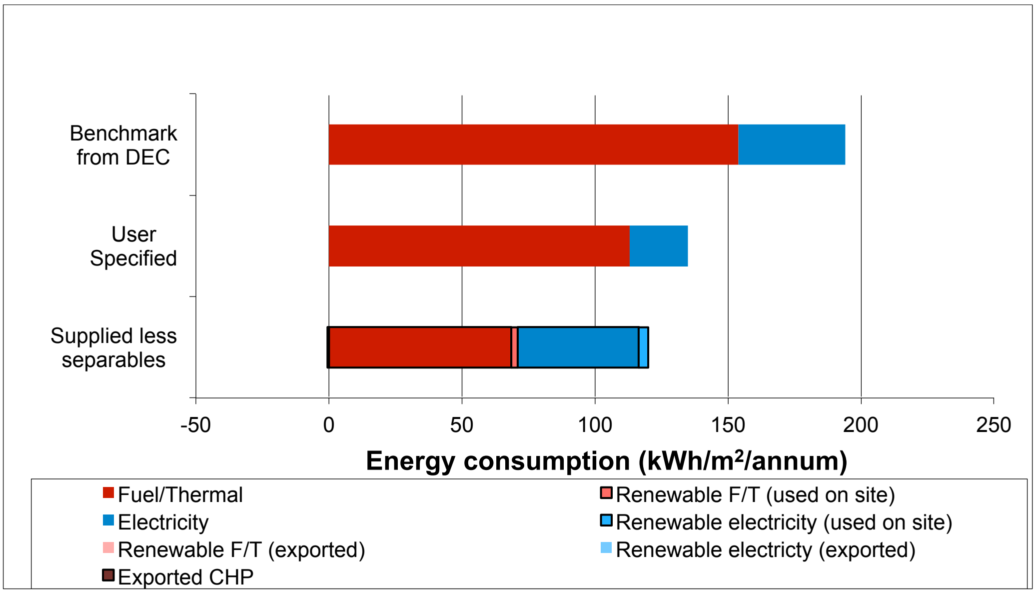
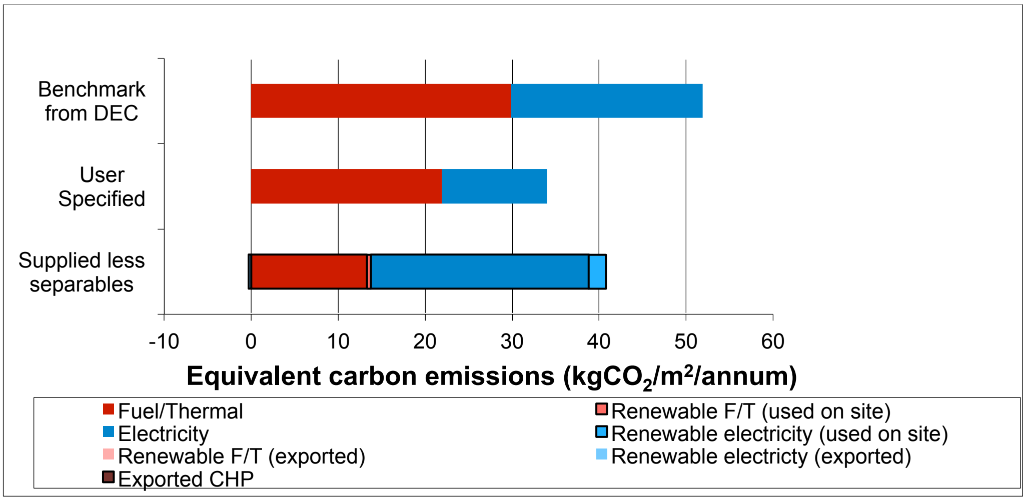


Figure 8.3b: Fossil fuel equivalent carbon dioxide emissions



The plots show similar generalities to those described in Section 6.3, but more detailed review of the energy data reveals some significant changes. The raw and corrected data for the period used in the main TM22 assessment (2012) and this update for 2013 are shown in Figure 8.4.

Figure 8.4 Comparison of Data for Different Periods

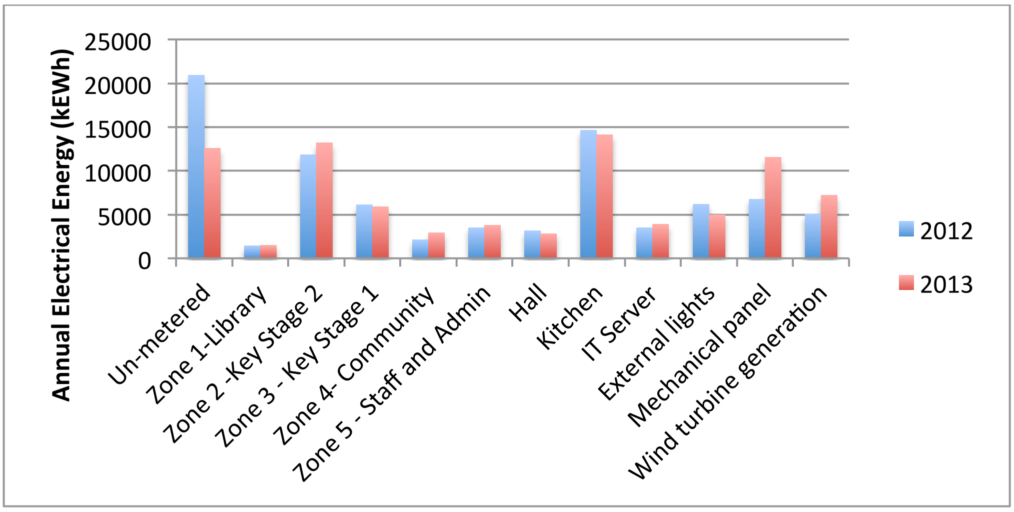
Period	Corrected to 365 days		Annual degree days equivalent	Degree day Corrected gas usage (,h)
	Electricity usage (kWh)	Gas usage (kWh)		
9/11/11-8/11/12	85,089	109,194	2418	110,250
7/2/13-20/1/14	84,434	102,407	1719	126,986

Figure 8.5 shows the breakdown of electrical energy usage by sub-meter for 2012 and 2013. The most significant changes are:

- Large reduction in un-metered energy usage (perhaps due to sprinkler room fan changes outlined in Figure 8.1);
- Moderate increase in Zone 2 energy usage despite changes to the IT cooling unit settings which were expected to reduce energy usage by this zone;

- Large increase in mechanical panel energy usage – unknown cause;
- Significant increase in wind turbine energy usage due to longer running period as the turbine was out of commission for a large proportion of 2012.

Figure 8.5: Energy breakdown by sub-meter – comparison of 2012 and 2013 actual energy usage



The 2013 thermal energy breakdown is not as well established and therefore has not been plotted. The main item of note with the thermal energy is that the 2013 period was much milder than the previous year and although the thermal energy usage as less in 2013, once normalised to degree days it was about 15% higher. This suggested that the changes to the hot water system outlined in Figure 8.21 were not particularly effective (i.e. it is expected that the very high DHW system losses in 20-13 were similar in magnitude to those in 2013) and that the heating system is not very responsive to external temperatures.

8.2 Recommended Improvements still in consideration

A meeting was convened with Monmouthshire County Council Mechanical and electrical maintenance engineers, the energy officer and heat teacher on 14 February 2014 to discuss further improvements that could be made. The items discussed and status are summarised in Figure 8.6.

Figure 8.6: Recommended Improvements still in consideration

Item	Issue/description	Changes proposed	Status/comment
Sprinkler Room Fan	Frost protection temperature not known	-	This was checked and found to be 5°C. This setting will still involve the fan running unnecessarily, but substantial savings should arise from the change.
Sprinkler tank immersion heater (and trace heating although this was not discussed at the meeting)	Control strategy and energy usage not known 2 x 1.5kW elements thought to operate whenever external temperature falls below 5°C	To establish how the immersion heater is controlled and ensure the setting is as low as reasonable.	There does not appear to have been any progress on this.
IT server room cooling	The controls are complex and it is not clear whether the	Investigations to ensure this can be set to cooling only at a temperature of 24°C and	IT department accepted that 24°C is an acceptable maximum

	unit is set to heat as well as cool the space. The setting was adjusted to cool only but the fan continued to run.	how to prevent air circulation when cooling not required.	temperature. There does not appear to have been any progress on this.
DHW	Energy usage in holidays and early mornings for cleaner use only and at weekends and holidays for community room. Cost about £10/d in holidays even when no DHW demand.	To install point of use electric water heaters in the community room and caretakers room. This will provide DHW for the community room and cleaners for out of hours usage. Potential for removal of pipework to reduce run length of secondary circulation system was also considered, but the distances were found to be short so this was not progressed.	The costs have been established at about £2000 for supply and installation and it is understood that this is going ahead.
DHW	BMS settings	Timing to be changed once point of use heaters installed to ensure DHW system is not set for out of hours usage. Changed start time of DHW from 06:00 to 07:00 as cleaners do not come in morning.	
Tap water temperature	Mixer settings need adjusting to increase tap water temperature	Check tap water temperature and adjust as appropriate	Not an energy issue.
Lighting	Run-on times to be reduced	Reduce the following from 20 minutes: Corridor – 10mins Toilets – 10 mins Classrooms – 10 mins Reduce from 5 minutes: Cupboards – 1 min	Cost estimated at £200. It is understood that this is going to be implemented.
Wind turbine	Wind turbine service contract currently not running. Cost is £700/yr +£200/yr for website access. Wind turbine generates 5000-7000kWh/yr worth ~£600-800	Discuss with Quiet revolution options for improving generation. Trial optimised year and review whether to keep the turbine commissioned.	Quiet Revolution have not responded to numerous attempts at contact from all parties.
Sub-meters: lighting, kitchen gas, main gas meters	These sub-meters not working or suspect.	Test meters and replace as necessary. Gas engineer to check expected boiler gas usage versus fiscal and main plant room meters.	These are latent defects as all appear to have been incorrect since the building was opened.

Predicted Energy Savings of Improvements

Changes to the following have been considered within the TM22 model ‘Improvements’ page:

- heating system timing changes (Figure 6.21);
- DHW system timing;
- DHW new point of use electric heaters;
- Lighting run-on timers;
- Sprinkler room reduced frost protection temperature set point;
- IT server room cooling set point and control.

The assumptions made for reducing the energy usage are summarised in the TM22 spreadsheet notes. The results of the improvements assessment are presented in Figures 8.7 and 8.8.

Figure 8.7: Electrical energy demand by end use- comparison between actual measured energy usage (2012) and potential reduced energy usage following improvement activities

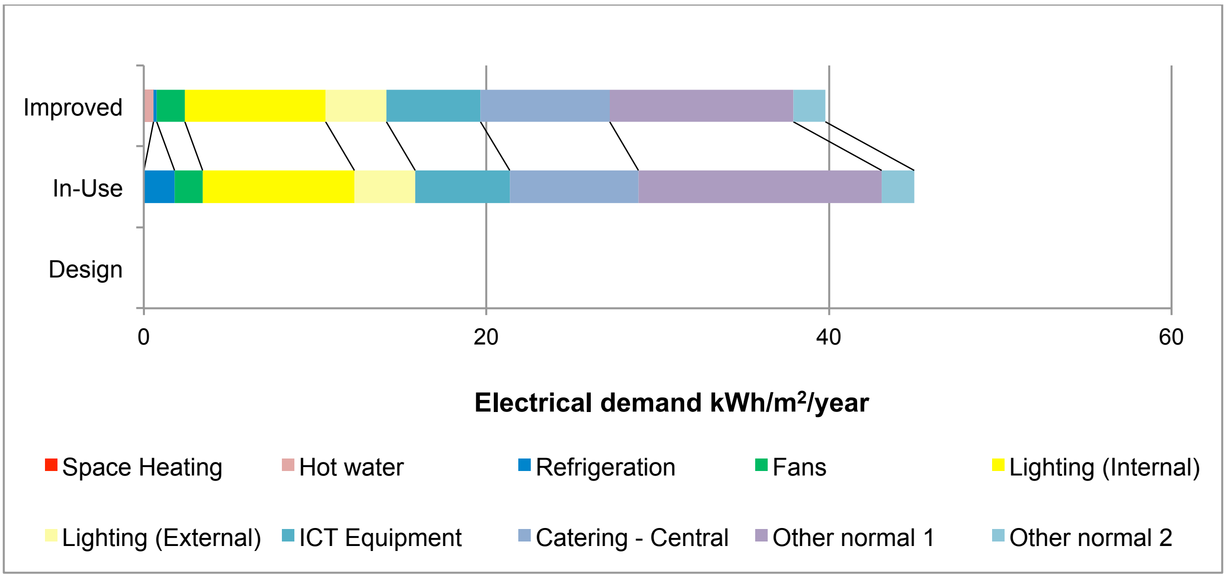
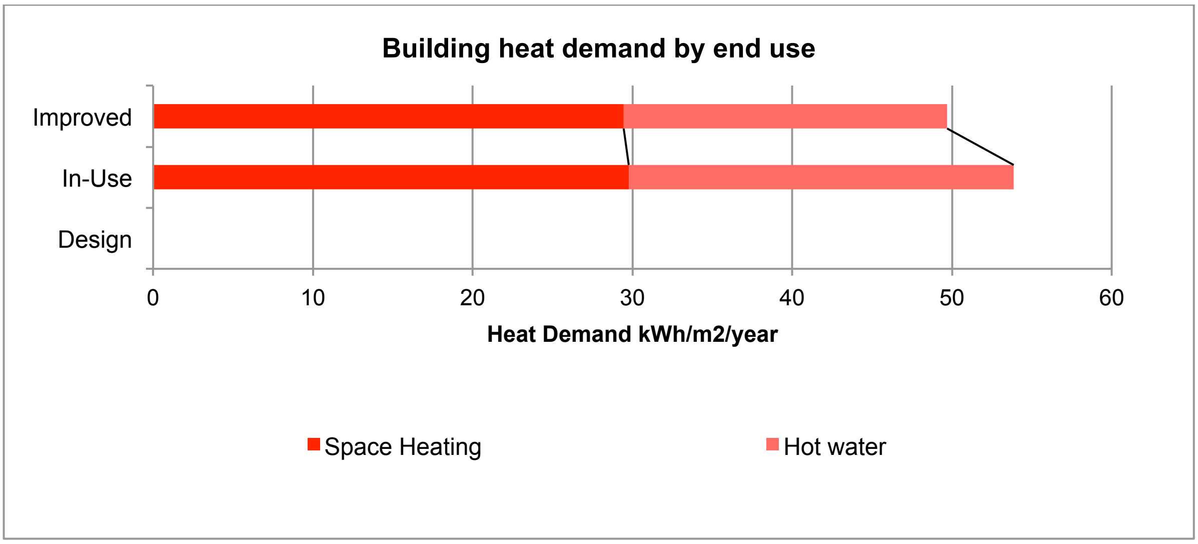


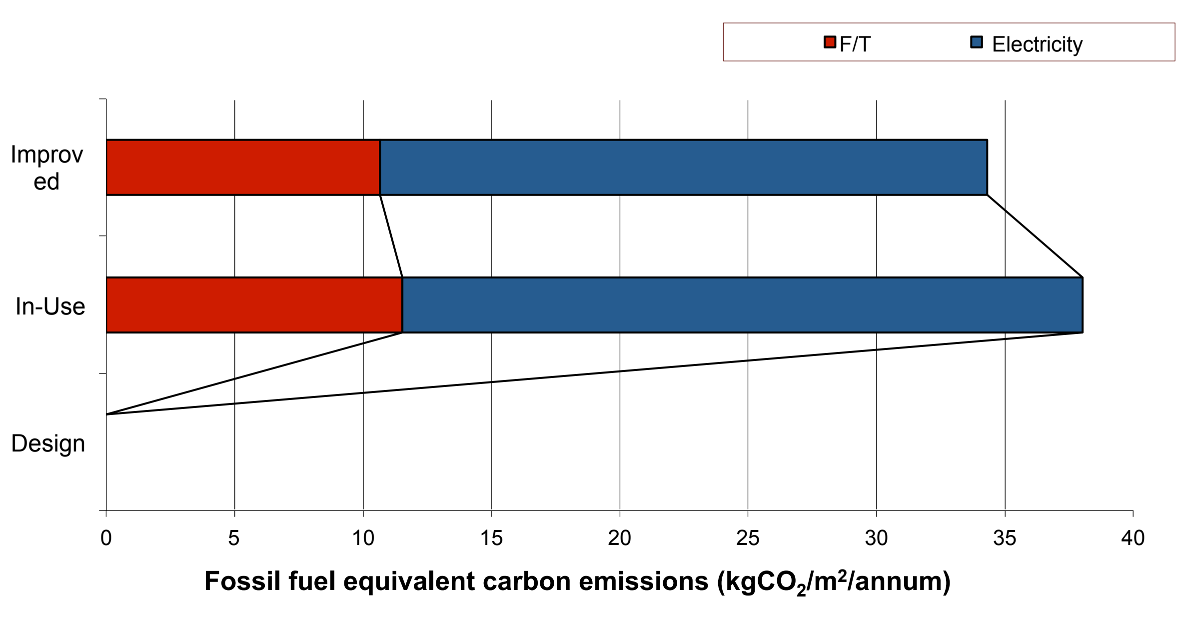
Figure 8.8: Building heat demand by end use - comparison between actual measured energy usage (2012) and potential reduced energy usage following improvement activities



The plots show an 8% reduction in thermal energy demand and an 11% reduction in electrical energy demand, the latter despite the addition of electric water heating to compensate for changes to the hot water system.

Figure 8.9 shows a comparison between the in-use emissions and the building following suggested improvements, indicating a reduction in emissions of just over 10%.

Figure 8.9: Potential fossil fuel equivalent carbon dioxide emissions - whole building, assuming interventions to improve performance.



8.3 BPE Further Recommendations for Rogiet School

Some of these improvements may not be practical due to a significant investment but would be worth considering and are also relevant for new and similar buildings:

- The recommendation to use the night cooling feature as part of natural ventilation system.
- Consider using group room lobby spaces in winter to reduce loss of heat through classroom doors.
- Consider additional Window-master room controls for teachers in individual classrooms.
- Consider changing colour of internal face of external wall in classrooms and swapping dark coloured polycarbonate canopies with clear coloured sheets.

9 Wider Lessons

As well as the above specific changes that have been identified for the school through the study the following conclusions have also been highlighted which provide wider recommendations to client, design and contractor teams regarding future design Strategies; Design, Construction and Handover Processes; and Design Specification. These are listed below and discussed in detail throughout the body of this report and appendices

9.1 Design Strategy and Brief

- More rigorous interrogation of the relevance of Building Bulletin (BB), Education Funding Agency (EFA) and other education guidance to tailor the most beneficial design with regards to site context, education brief and building performance.

9.2 Design Process

- More informed Lifecycle cost information, and client information provided when considering automated natural ventilation systems.
- Adoption of the 'Soft Landings' process and dedicated champion, from the outset of a project to ensure building performance is considered through all stages of design and construction as well as helping to guide the handover and first few years of occupancy. Client teams to ensure procurement processes integrate Soft Landings through all Gateway stages.
- Use of the Soft Landings process to interrogate design changes and value engineering changes to ensure any implications on performance are considered alongside use and capital cost implications.
- Develop user guidance during the first year and develop it as an interactive tool to include better and clearer information as users' needs emerge.
- Client procurement processes should include the requirement for 2 years aftercare, including periodic and systematic POE carried out collaboratively between designers, contractors and users.

9.3 Design Specification

- Understand the user requirements of group spaces when they are anticipated to double in use as lobby spaces to the outside to help prevent heat loss.
- Consider use of high level vertical clerestorey glazing instead of roof-lights for summer ventilation to avoid risks of closing due to rainfall and consequentially temporary loss of ventilation, and to help prevent summer glare.
- Ensure canopies and similar architectural features on north-facing elevations do not critically reduce internal daylighting levels in classrooms.
- Ensure lighting is daylight controlled. Rogiet has a 27% increase in energy use from lighting in comparison to the SBEM design model for lighting usage.
- Ensure provision of zoning and sub metering for non school based activities. Community space at Rogiet requires whole school hot water system to be on to provide to one small kitchen even when school is not in use.
- Be aware of and avoid the cold bridge and airtightness issue generated by the use of steel and timber composite beams with an undulating web when the design incorporates a roof overhang.
- The building achieved a respectable air test result of 3.6m3/(h.m^2) at 50Pa. This was higher than the original designs would have achieved due in part to the use of the composite beams for roof construction (see Section 3.8).

- Better attention to air tightness detailing could have resulted in an air tightness of 2-3m3//(h.m^2)at 50 pa. This would then be compatible with use of mechanical ventilation with heat recovery. This would solve the conflict between high CO_2 build up and ventilation heat losses from the natural ventilation approach. Whilst a properly operate mechanical ventilation with heat recovery system should be cost effective to install and operate, the use of these systems is not without problems and requires careful design, installation, commissioning and operation (as with the WindowMaster natural ventilation system.
- Include the plant room within the heated envelope and ensure that all pipework and valves are insulated. Consideration would have to be given to ventilation and cooling.
- Consider a more compact design with lower surface area to floor area ratio to improve thermal efficiency.
- Provide hot water from the gas boilers to the kitchen only. Maximise use of this hot water for dish washers etc. This system to have a small hot water tank and no secondary circulation system or solar thermal. Replace hot water in the rest of building with point of use electric water heaters. Minimise the number of these by grouping areas which need hot water close together eg WCs. Minimise number of hot water outlets eg consider whether hot water is actually necessary in classrooms. The energy, emissions and financial savings here are very substantial with 46,800kWh per annum of secondary circulation system losses to be saved.
- Detailed analysis and performance of renewables needs to be adhered to rather than political will when determining the appropriateness of renewables.
- Detailed consideration of energy usage when designing the sprinkler system and its controls. Better insulation of the sprinkler room and tank would almost certainly come out as cost effective options. A better understanding of the trace heating arrangements would also be expected to provide opportunities for cost effective energy reduction.
-

9.4 Post Occupancy Process and Performance

- Quality of building documentation needs to be improved - in particular documents should be reviewed to ensure:
    - incomplete and generic information is avoided
    - information irrelevant to building operation and maintenance eg pre-construction demolition surveys is not kept in the O&M manual
    - cross referencing is achieved between different installers eg mechanical engineer and sprinkler system installer
    - all equipment in the building is identified by make and model and that manufacturers literature is limited to that on the installed equipment as far as possible

- Close attention being paid to meter reconciliation before handover so that meter readings are easily useable and the BMS records data in an appropriate manner
- On going energy targeting and performance improvement should become the norm with an improvement to energy benchmarks to allow sensible judgements about what is typical and what is good energy performance.
- Design stage energy prediction should be required - this should be an improved version of SBEM which should include all loads which are specific to the building including sprinkler systems, fire and security and automated controls eg natural ventilation
- Further work needs to be done to ensure that EPCs are based on sensible occupancy, usage and set point information and that if this information is sensible, default building settings meet those requirements
- EDECs to include regulated energy use as well as total to enable comparison with EPC. With better design stage modelling there is no reason that energy in use can't be similar to EPC outcomes and then the comparison between DEC and EPC can become a useful process
- More work required to cosider the energy and air quality implications of natural ventilation systems in schools and to compare capital and operating costs with mechanical ventilation with heat recovery schemes.

10 Appendices

Appendix A - Soft Landings Report
Appendix B - Design and Construction Audit
Appendix C - Thermographic Imaging Report
Appendix D - Equipment Inventory
Appendix E - Building Users Survey - topline summary results
Appendix F - TM22 In-Use Assessment output summaries
Appendix G - Winter and Summer Monitoring data e.g. temperatures, CO_2 levels, humidity etc.
Appendix H - Energy consumption data and analysis (including demand profiles)
Appendix I - Airtightness test
Appendix J - Natural Ventilation Effectiveness review
Appendix K - Acoustic Investigation