Blue Bell Health Centre

Innovate UK project number	450075
Project lead and author	Sustainable Engineering Collective for Renova Developments
Report date	2014
InnovateUK Evaluator	Unknown (Contact www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Healthcare	Huyton, Merseyside	Design and build	2010

Floor area (GIA)	**Storeys**	**EPC / DEC 2013**	**BREEAM rating**
2600 m^2	3	B (37) / D (81)	Excellent

Purpose of evaluation

Causes and effects of different building related issues were examined. Where possible the report compared design intentions with the as-built, in-use reality to see how differences between the two came about. The study involved enery analysis based on sub-meter data. In addition the following systems were analysed for their performance: underfloor heating, domestic hot water (including solar thermal and electric immersion operation), space heating, daylight and illuminance. A review of the building's procurement was carried out.

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

Blue Bell Health Centre is all-electric. Early energy analysis showed that delivered space heating and cooling (air-source heat pump), DHW production and ventilation represented the bulk of energy demand, with the greatest room for improvement. Underdeveloped building services design, including the metering strategy, led to operational confusion and increased energy consumption. Energy consumption by end-use was compared to *ECON 19* benchmarks. Electricity consumption: 113.8 kWh/m² per annum (space heating 23.8 kWh/m² per annum, domestic hot water 10 kWh/m² per annum).

Occupant survey	**Survey sample**	**Response rate**
BUS (unknown type)	Not reported	Not reported

Blue Bell performed well overall. Occupants were generally comfortable in summer and winter. However during the winter some felt too cool and experienced the building temperature as variable. During the summer, Blue Bell was experienced as too warm by a high number of respondents. Findings from the interviews supported the results of the BUS survey. The occupants interviewed liked the building in many respects (except for temperature), and the layout, openness and levels of natural light.

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

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

This report details the findings of a Phase 2 Building Performance Evaluation (BPE) project that investigated the in-use performance of the Blue Bell Centre in Huyton, Merseyside. Causes and effects of different building related issues found during the BPE programme are examined, and where possible the report compares design intentions with the as-built, in-use reality to see how differences between the two came about.

The Blue Bell Centre is approximately 2600m^2 and provides a range of primary healthcare services. The three-storey building accommodates a pharmacy and community healthcare services on the ground floor, with the first floor sublet to four individual General Practices (GPs), three of which are currently occupied. The fourth practice has been unoccupied since the building opened. Blue Bell was one of the first buildings to achieve BREEAM Healthcare Excellent. The main plant room is situated on the top floor, opening out to the roof.

Figure 1-1 Blue Bell along Bluebell Lane, east facing (l); Along Liverpool Road, north facing (r)

Figure 1-2 South west facade (left-hand section) and carpark; aerial view of Blue BellProject scope

1.1 Scope of the study

The BPE study began in February 2012 and ran to August 2014. During this study the following investigations were completed:

Table 1-1 Investigations during study

Investigation	*Description*
Energy analysis	TM22
	Half-hourly mains electricity daily profiling
	Monthly submeter energy analysis
	Half-hourly submeter energy analysis
Metering	Metering strategy investigation
Building services performance	Underfloor heating investigation
	Domestic hot water investigation, including solar thermal and electric immersion operation intervention
	Voltage optimiser claims examination
	Space heating investigation and intervention
	Space cooling investigation
	Air Handling Unit investigation and intervention
	Lighting operation investigation and intervention
Lighting	Daylight and illuminance investigation
Occupant satisfaction analysis	Building Use Studies survey
	Occupant interviews
Building procurement review	Procurement team interviews

Findings from these investigations are detailed in the following accompanying documentation:

Table 1-2 List of appendices

Appendix A	Energy Demand Profile
Appendix B	Performance of Building Services
Appendix C	Interventions
Appendix D	BUS Survey
Appendix E	BUS Survey Appendices
Appendix F	Occupant Interviews
Appendix G	Lighting Review
Appendix H	Walkthrough Report
Appendix I	Air Leakage Report
Appendix J	Building Regulations United Kingdom Part L Report and Energy Performance Certificate
Appendix K	Display Energy Certificates
Appendix L	TM22 report

1.2 Key findings

Many issues affecting energy efficient operation and occupant satisfaction were identified in the study. These problems have their origin in different phases of building procurement and occupation, from design through construction and operation.

Early energy analysis showed that space heating and cooling, DHW production and ventilation represented the bulk of energy demand, with the greatest room for improvement and energy savings, and thus this is where the focus of the evaluation has been. Key findings related to the building services operation and energy consumption include:

- Despite BREEAM Excellent and an EPC rating of ‘B’, the current DEC rating (2013) is ‘D’, at 81 (a score of 100 is “typical” on the DEC scale, which includes new and older buildings)

- Inefficient operation of the Air Handling Unit (AHU) during the first winter of this programme, leading to large energy increase

- Underdeveloped building services design including the metering strategy leading to operational confusion and increased energy consumption

- Widespread building services commissioning problems leading to increased energy consumption

- Difficulty controlling services due to BMS installation

When it was designed and built, Blue Bell represented a step-change in sustainability ambition for all those that contributed to its creation. In an effort to meet these ambitions, fairly sophisticated energy systems were installed, designed to be controlled by a central Building Management System (BMS). In this evaluation, it is BMS operation that has been identified as the central and most significant issue and remains the largest barrier to improving the efficiency of operation.

But while much of this report focuses on failings in the design and construction that affect energy and thermal comfort, it should be remembered that the building is very well liked by its occupants and generally meets their needs.

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

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

2.1 Building procurement

The scheme was conceived in 2007 as one of a series of projects in a Local Investment Financial Trust (LIFT) framework led by Renova in partnership with Knowsley Primary Care Trust and Community Health Partnerships. The building was designed by jmarchitects with TACE providing Mechanical and Electrical (M&E) design services. It was procured under a Design and Build (D&B) contract using a single framework contractor. Since building Blue Bell, and before it, Renova has engaged these same supply chain partners to develop similar healthcare buildings under the same framework.

2.2 Design and construction process

Facilities management (FM) is outsourced by Renova to a large specialised company, with day-to-day management provided by a part-time handyman on site. The FM provider attended design meetings as soon as the M&E design started to be discussed. There was an item on most design review meeting agendas for FM related issues. The FM provider sent a representative, but this wasn't the person who was going to be responsible for operation of the building as they were not in their post at this point.

During the design phase, the Primary Care Trust (PCT) was also involved, representing the tenants. The PCT liaised with the GPs (and other tenants) during the process and passed information on, getting their input, and fed it back into design discussions. The PCT had a separate group which ran alongside the design meetings, attended by doctors and staff.

Blue Bell was one of the first buildings to achieve BREEAM Healthcare Excellent. Domestic Hot Water (DHW) is partially provided by an evacuated tube solar thermal system on the roof. The inclusion of this technology was driven by the need to meet a 10% renewable energy planning requirement. A wind turbine was included in the original design to help meet this target, but the Air Source Heat Pumps (ASHPs), already included in the design, became classified as an allowable renewable energy technology, obviating the planned onsite wind turbine.

The building is in a high profile location in Merseyside, built on the site of a former public house on the junction of Bluebell Lane and Liverpool Road, a main dual carriageway into Liverpool. The location at a busy, traffic-light controlled junction meant that its design needed to address protection from noise and pollution.

2.2.1 Building fabric

According to the architect, Blue Bell was designed with a “fabric-first” approach. The air permeability was set at $5m^3m^{-2}hr^{-1}$ @50Pa, half the requirement in 2006 (as-built it achieved an air permeability of $4.41m^3m^{-2}h^{-1}$ @50Pa when tested in May 2010 - see Appendix I for details).

The building construction is steel frame with a composite concrete floor, and concrete block external walls, with insulated cavities. The exterior is partly rendered and partly clad with timber boarding, which is used to form deep window reveals to provide solar shading.

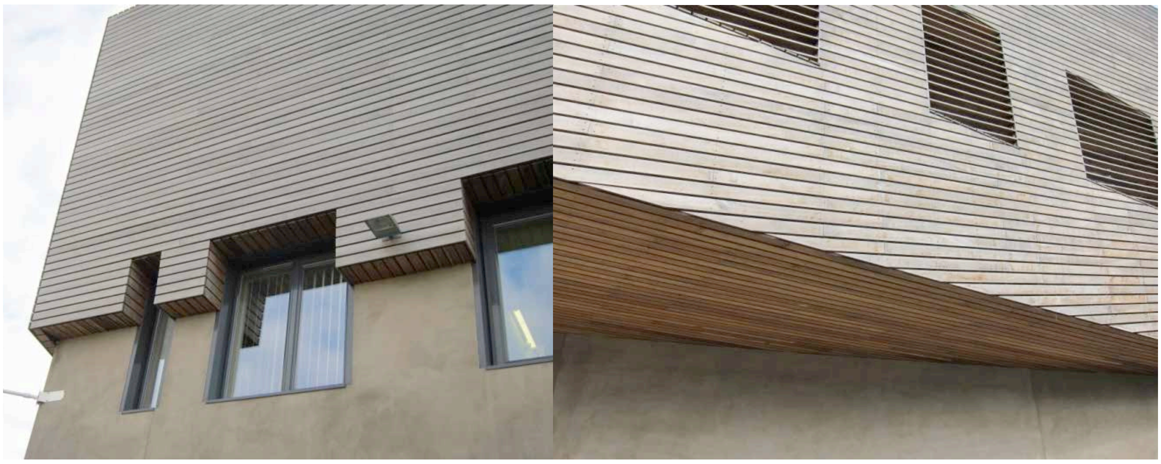


Figure 2-1 Timber cladding structure

Figure 2-2 Deep window reveals created by the timber cladding

Triple glazed windows sizes are designed to admit good levels of daylight to reduce the need for artificial lighting.

Figure 2-3 Triple glazed windows

As-built U-values (but unmeasured) and tested air permeability is shown in the Table below. Overall, it can be seen that the building should be free from significant draughts and has good thermal properties. Note that thermal coherence (thermal bridging) has not been examined in this programme however.

Table 2-1 As-built U-values (not tested however) and air permeability

Average U-value (as-built BRUKL)	0.32 W/m^2K
Air permeability (test certificate)	4.41 $m^3h^{-1}m^{-2}$ @ 50Pa, depressurisation only
U-value: roof, area weighted (as-built BRUKL)	0.20 W/m^2K
U-value: walls, area weighted (as-built BRUKL)	0.20 W/m^2K

U-value: ground floor, area weighted (as-built BRUKL)	0.22 W/m^2K
U-value: windows, area weighted (as-built BRUKL)	1.64 W/m^2K

2.2.2 Building services

The building is all electric, with ASHPs on the roof providing space heating needs. Domestic hot water is provided by a combination of a dedicated heat pump unit, the solar thermal system, and electric immersion heaters. Most building services are controlled by a central Building Management System (BMS), designed to optimise 'intelligent' heating, cooling and ventilation.

Accommodation is wrapped around a central two-storey atrium, with waiting areas on both floors. The central atrium is naturally ventilated, designed to maximise the stack effect, with low level windows and roof-mounted outlets with actuated louvres. Rooms off the central core are mechanically ventilated and some rooms have openable windows and trickle vents.

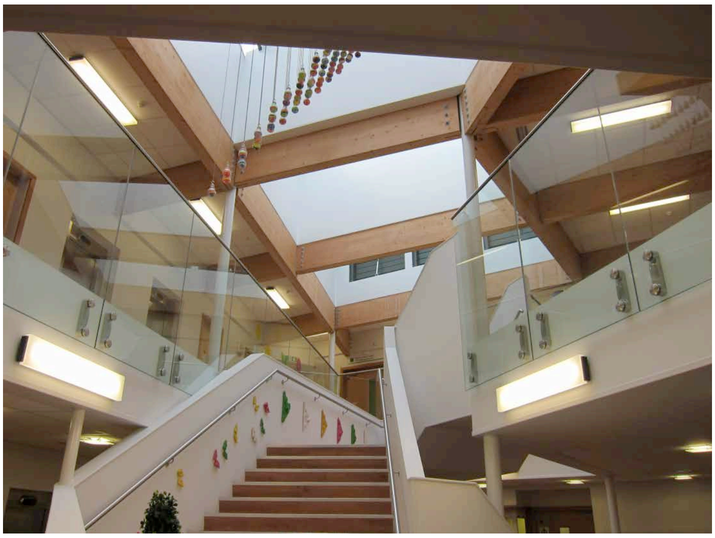


Figure 2-4 Staircase in atrium in building core

All lighting is low energy, which in most spaces off the central core is controlled by PIR occupancy sensors. Rainwater harvested from the roof, and stored underground, is used for flushing toilets and for cleaning in the bin store. Low flow fittings and appliances have been installed throughout the building.

3 Review of building services and energy systems.

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

3.1 BMS

The central BMS is a Trend system with IQ series controllers. The BMS supervisor is a Trend 963 Lite. The interface provides schematics, and allows the FM to change some set-point temperatures and timeclocks.

3.2 Lighting

All lighting is low energy, mostly a mix of T5 fluorescent tubes and Compact Fluorescent bulbs (CFLs), with feature lighting as well in some locations. Daylight sensing was originally in the design, but did not make it through to tendering (according to the M&E designers it was Value Engineered out). In many rooms off the central core, lighting is controlled by occupancy sensing; there are also manual switches for most lighting circuits. Additionally in some rooms, such as meeting rooms, lights can be dimmed. In the main ground and first floor waiting areas (the building core), lights are manually turned on each morning by the FM, and off each night by the cleaners.

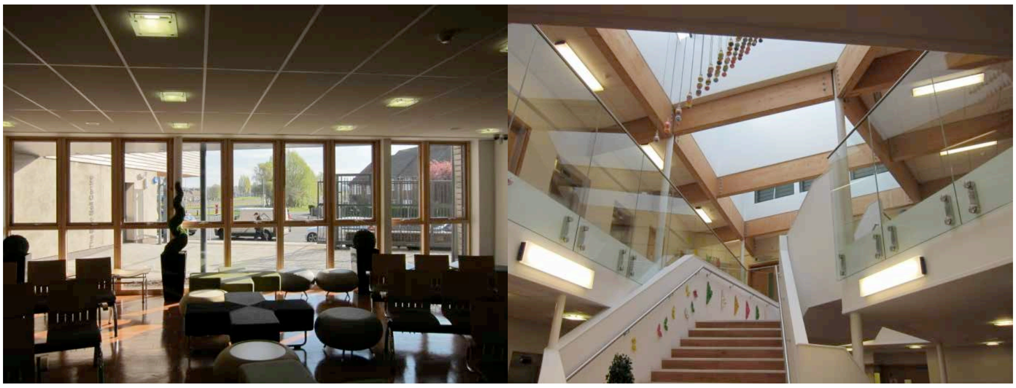


Figure 3-1 Ground floor waiting area; atrium and staircase to first floor waiting area

Figure 3-2 T5 lamps in decorative design luminaires with matt-opal diffuser in GF44

Figure 3-3 T5 lighting; PIR sensor; typical light switch

3.3 Ventilation

3.3.1 Natural ventilation

Fresh air is provided by both mechanical and natural ventilation - mechanical ventilation around the building in the treatment and consulting rooms, and natural ventilation in the core ground and first floor waiting areas.

Mechanically actuated louvres provide some control over the natural ventilation system, encouraging the stack effect and enabling hot air purge ventilation for the ground floor and first floor waiting rooms. These louvres are BMS controlled and open and close based on sensed internal CO_2 (the sensor is on the first floor near the atrium), indoor and outdoor temperature, and wind speed.

Figure 3-4 Mechanically actuated louvres; wind speed and external temperature sensors

Windows in naturally ventilated areas on the first floor can only be opened 100 mm in accordance with an H&S requirement – see Section 2.3). In mechanically ventilated areas there is a mix of openable and unopenable windows. During the summer, surgery staff stated that they (or the cleaners) open windows around the first floor waiting room to provide fresh air for the patients and cool the space down.

Many windows, in both naturally and mechanically ventilated areas have been installed with trickle vents. Most appear to be left closed however, including trickle vents in naturally ventilated areas, where they should actually be open. However, it is possible that some fresh air is provided into the waiting rooms through the main entrance doors opening when occupants enter and leave the building. This is unlikely to be sufficient however, and the natural ventilation strategy was designed such that the trickle vents would provide all the fresh air requirements.

Figure 3-5 Window trickle vents in first floor waiting area; trickle vent in first floor surgery

3.3.2 Mechanical ventilation

Mechanical ventilation is provided by an Air Handling Unit (AHU) located in the second floor plant room (supply and extract). The AHU contains the following components: supply and extract fans, electric resistance frost coil, heating & cooling DX coils, heat exchanger, and recirculation damper.

The AHU was supplied as a package, complete with separate controls. Operational temperatures, and component status and faults were only made visible on the BMS supervisor during this evaluation programme (in 2012), but it is still not possible to make many changes to its operation from the BMS (only from the AHU’s own control system, for which there is no purpose-built screen).

Temperature sensors provide control for the heating, cooling and frost coils. The system operates at a constant volume, and so is either “On” or “Off” (the fans operate at a constant speed).

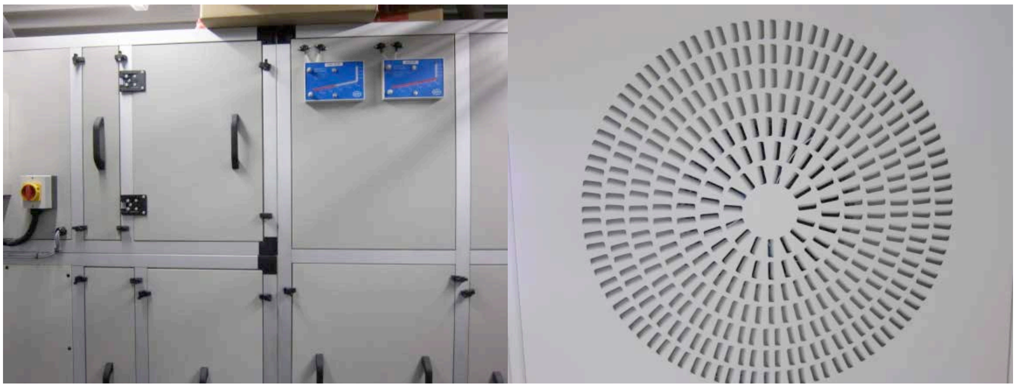


Figure 3-6 AHU plant (l); fresh air supply diffuser (r)

3.4 Space heating and cooling

Mitsubishi Multi-city outdoor heat pump units provide space heating and cooling to most areas in the buildings (in practice the underfloor distribution system does not provide much cooling – this was confirmed through energy analysis). All these units are housed together on the roof. Four heat pumps provide heating for the underfloor heating circuits, one heat pump provides comfort cooling and heating to treatment rooms and the ground floor open plan office, one heat pump provides heating to an overdoor heater at the main entrance of the building, one heat pump provides cooling to the Comms room (for the server), and another provides space heating and cooling to the pharmacy.

Outdoor units supplying heating and cooling to the underfloor system and treatment rooms utilise proprietary control boxes (BC controllers), which have the ability to transfer waste heat from one zone to another, if one zone is calling for cooling and another heating.

Figure 3-7 Comms heat pump; Outdoor units for underfloor distribution system

The underfloor heating system indoor units connect to a pumped hydraulic circuit which distributes heat and coolth to underfloor heating manifolds and circuits. All other heat pump systems are split units.

Figure 3-8 Underfloor distribution pumps and indoor units; twin head distribution pump

The main heating system appears complex for what it is delivering, with hydraulic and VRF levels of heat and coolth sharing: the VRF system shares heat between zones, and the underfloor heating manifolds provide branch flow control (distribution pumps are variable speed) and according to manufacturer literature, they can also distribute heat from one room to another. In operation it is not possible to tell whether this is effectively distributing heat and saving energy or if it provides greater complexity without any discernible benefit.

The main benefit of this type of system is if one area of the building is heating, while another is cooling. With small temperature deadbands this is more likely to occur, and if functioning correctly, this system efficiently enables what is normally energy intensive close temperature control. However for energy efficiency, deadbands should normally be wide to reduce heating and cooling demands. Further the underfloor distribution system is under concrete screed, and thus contains considerable thermal mass. Heat and coolth sharing works best in reactive distribution systems without thermal mass – it is not clear it could work at all with the underfloor system.

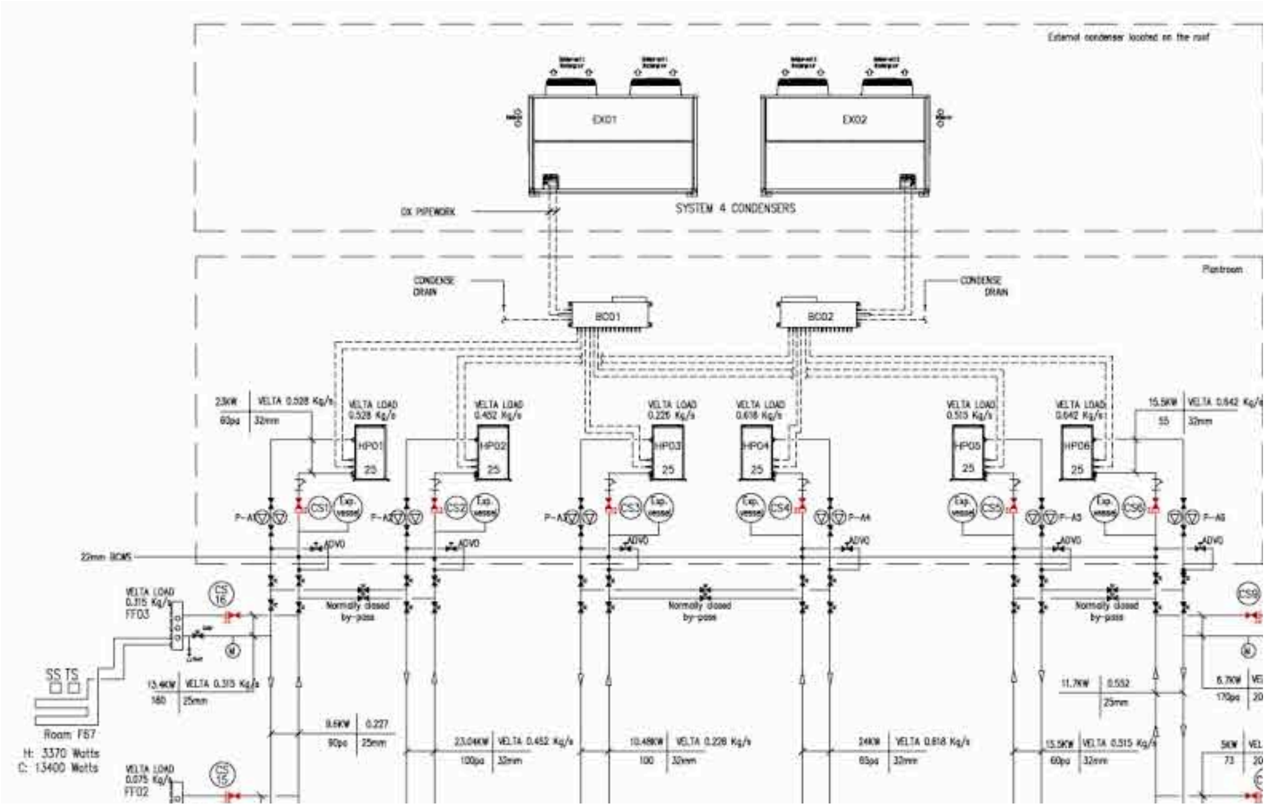
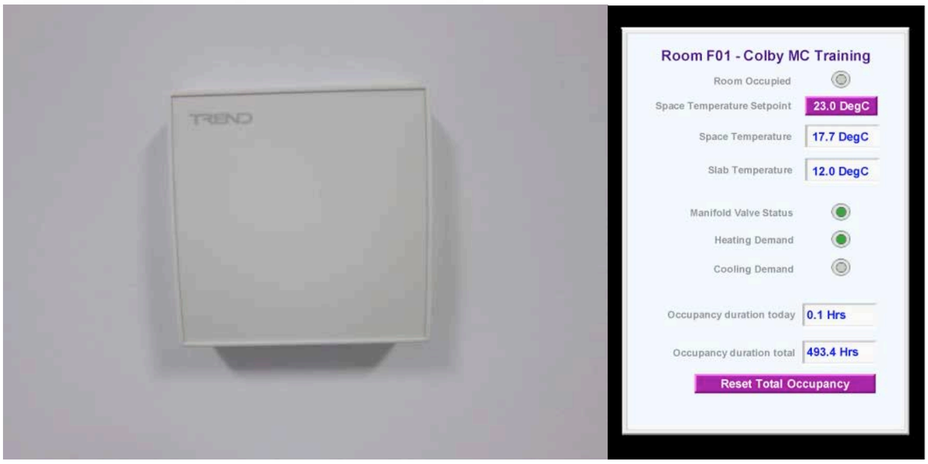


Figure 3-9 Underfloor distribution schematic [extracted]

Space temperature for most areas in the building is controlled via the BMS; occupants do not have direct control over the temperature in underfloor heated zones as thermostats are not provided in these areas. To change the temperature, occupants must contact reception, who then sends a request to the FM. The FM will often manually check temperature in a space to see if it conforms to design/operational requirements for both summer and winter. If the occupant is still not satisfied, the FM can change temperature through the BMS. The maximum flow temperature through the UFH circuit is 45°C and flow temperature is automatically adjusted through a weather compensation optimiser on the BMS. The heat pumps also have their own weather compensation optimiser.



Room F01 - Colby MC Training

Room Occupied ○
Space Temperature Setpoint 23.0 DegC
Space Temperature 17.7 DegC
Slab Temperature 12.0 DegC
Manifold Valve Status ●
Heating Demand ●
Cooling Demand ○
Occupancy duration today 0.1 Hrs
Occupancy duration total 493.4 Hrs
Reset Total Occupancy

Figure 3-10 Trend temperature sensor (l); BMS room SPT control (r)

3.5 Comfort cooling

One of the Mitsubishi Multi-city outdoor heat pump units provides “comfort” cooling and heating to Treatment Rooms in the surgeries on the first floor and to the open plan office on the ground floor. This is a VRF system which utilises proprietary control boxes (BC controller), which have the ability to transfer waste heat from one zone to another, if one zone is calling for cooling and another heating. Simple thermostatic control over this system is provided using local remote controllers, which the occupants use to increase or decrease temperatures in these rooms.

Figure 3-11 Comfort cooling indoor unit; comfort cooling controller

3.6 Domestic Hot Water

This system is fairly complex, with 3 different heat inputs for electric immersion, solar thermal, and a dedicated heat pump, and also includes various circulation and shunt pumps. Two hot water storage cylinders are provided. It is unclear whether the large amount of storage (for a building with an estimated low hot water demand) was driven by healthcare requirements or by the size of the solar thermal array – no information about system sizing and estimated loads was provided for examination. The system was designed for the solar thermal to lead, with the heat pump to top-up DHW storage temperature to 60°C. Electric immersion was designed only for back-up, the occasional/seasonal top-up, and for legionella pasteurisation operation (where the storage temperature is raised above 60°C for a short period of time).

The solar thermal array is evacuated tube type. Instead of mounting an array on a south facing A-frame, with a tilt angle of 30 degrees, the tubes are flat, running NE/SW to run parallel with the roof line, with most internal elements tilted 30 degrees. According to the manufacturer, the suboptimal orientation would have a very small reduction in overall output, and the tubes are designed to enable flat mounting.

There are five pumps for the DHW system: hot water circulation/return pump, solar pump, heat pump distribution pump, and shunt pumps for each cylinder to reduce stratification.

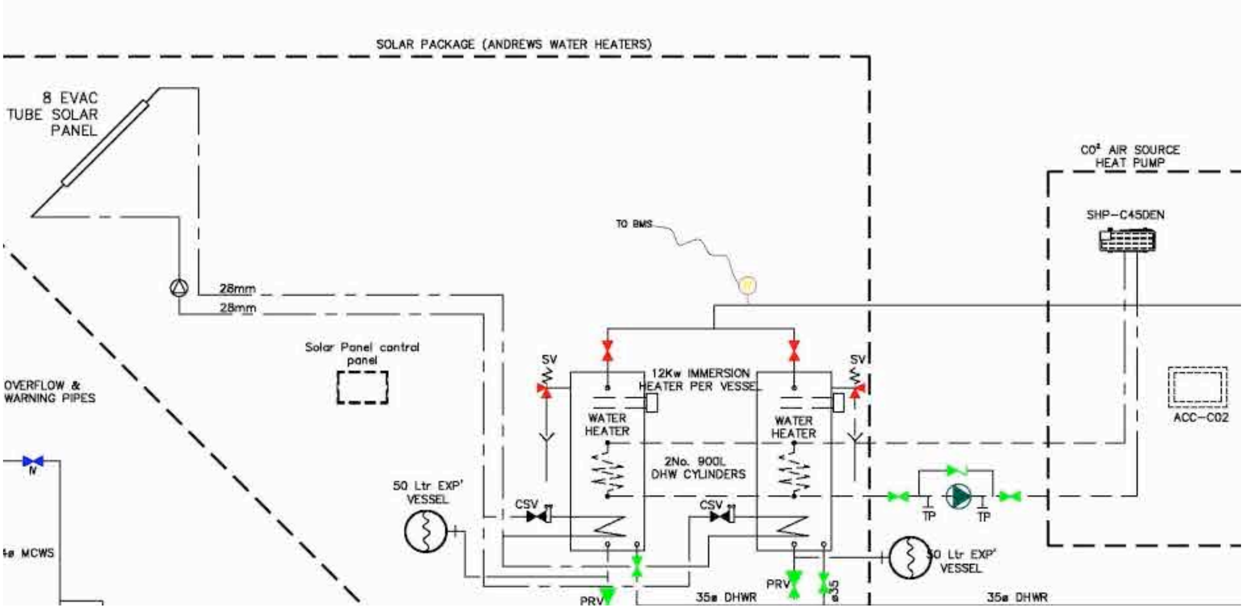


Figure 3-12 Hot water production schematic

Figure 3-13 DHW cylinder; electric immersion input; cylinder shunt pump

Figure 3-14 Dedicated DHW heat pump (l); Solar thermal installation

Figure 3-15 Analogue gauges with solar thermal pump; solar controller; heat pump controller

3.7 Cold and Rainwater systems

The building is provided with both mains cold water and a rainwater recovery system. Mains cold water is supplied into two storage break tanks in the second floor plant room. Cold water is then boosted around the building for domestic use, hot water production, and also for pressurisation closed loop heating and hot water production systems (no Pressurisation Unit was installed). Before mains cold water supplies the cold water storage tanks, some is diverted to the second floor plant room rainwater break tank for top up, if below ground rainwater storage levels are low.

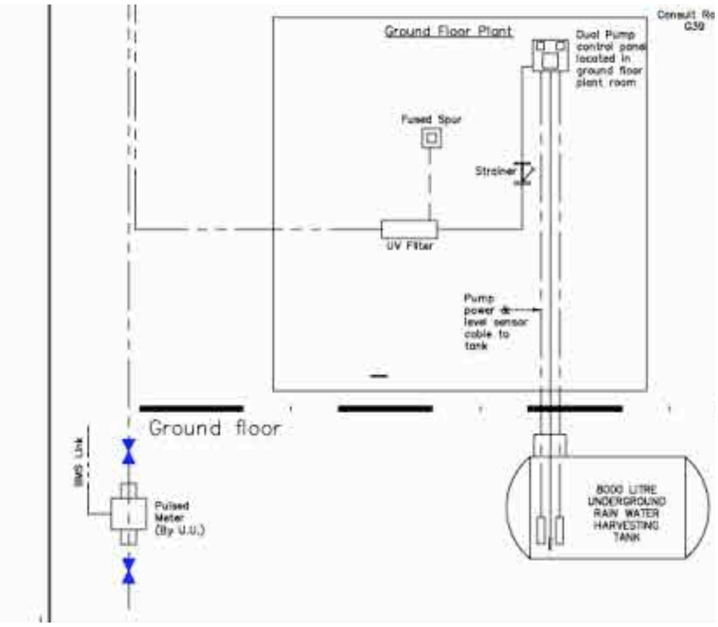


Figure 3-16 Rainwater harvesting system schematic, below plant room level

Figure 3-17 Cold water booster set; cold water storage; rainwater break tank

Rainwater is supplied around the building for use in toilets and the bin store. It is harvested on the roof and stored below ground. It is pumped through a UV purification tube and up to the second floor break tank.

Figure 3-18 Rainwater channel on roof; rooftop drain to below ground rainwater storage tank; rainwater UV purification

3.8 Metering

Blue Bell is an all electric building (although there is an unconnected incoming gas main), with a half-hourly mains meter. Mains half-hourly data is being picked up an external, contracted Automated Meter Reading and Tracking (AMR&T) service. Energy use can be viewed online, and half-hourly data downloaded.

An electrical submeter is provided on each electric Distribution Board (DB), with some DBs allowing the separation of small power and lighting. These provide a split between a top section load, and total load. Pulsed outputs from these submeters are linked to the BMS. In addition to electric submeters, the underfloor space heating system contains heat meters on every manifold which are also BMS linked, and water consumption and rainwater production is submetered (and BMS linked) as well.

Figure 3-19 Distribution Board submeter (l); rain water meter (r)

3.9 Voltage Optimisation

A voltage optimiser was installed at the Blue Bell after PC, in May 2012. Being a new building, the potential for traditional energy savings through a voltage optimiser from old technologies, such as incandescent lighting, is lower. However with other loads such as pumps and fans at Blue Bell, this technology could potentially reduce energy consumption. The product sold to Renova at Blue Bell guaranteed an energy savings of 7.9%. The original audit undertaken by the company to establish this figure was not available for review, so it is not clear what assumptions were made.

Shortly after installation, the manufacturer sent Renova a report detailing the energy savings provided by this device, which they had calculated to be 18.6%. Review of this report is found in Appendix B. A few significant issues were identified with the supplier's analysis, and it is thought that the energy savings claim is much too high and does not hold up to scrutiny.

4 Key findings from occupant survey

Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the BPE process and in particular with cross-reference to the BUS surveys, semi-structured interviews and walkthrough surveys. This section should draw on the BPE team's forensic investigations to reveal the root causes and effects which are leading to certain results in the BUS survey; why are occupants uncomfortable; why isn't there adequate daylighting etc. Graphs, images and data could be included in this section where it supports the background to developing a view of causes and effects.

4.1 Building Use Studies (BUS) survey

This section discusses the findings from the Building Use Studies (BUS) survey. For further details please refer to Appendices D and E.

Generally Blue Bell is very well perceived by occupants, scoring either close to or better than benchmark values. However many respondents did not fully complete the survey, leaving sections blank, and very few shared comments (although the Domestics, as a group, did tend to provide comments). Some respondents appeared to be "ticking down", not fully reading the questions, while others appeared to see key words, such as "Dry" or "Fresh" and tick the maximum value next to that word, leaving the other questions in that section blank. As such, BUS findings at Blue Bell perhaps need to be treated as less statistically relevant than in other surveys, and findings have been examined in conjunction with interviews and feedback from the FM.

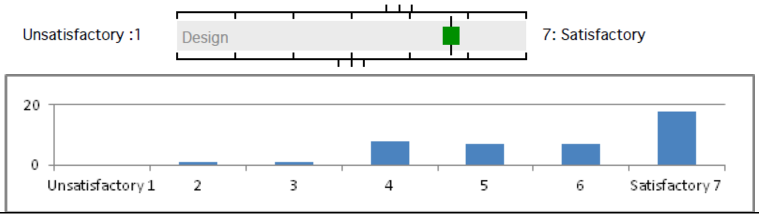
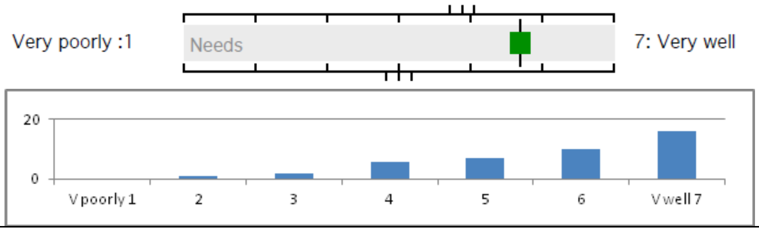
Keeping in mind the issues with survey completion, although the responses indicated Blue Bell is well perceived and generally scores well in relation to benchmark values, areas for improvement did stand out. In particular, thermal comfort, in both the winter but particularly the summer could be improved. It may be possible to improve thermal comfort by targeting particularly uncomfortable areas of the building, as from the distribution of responses, a few very low scores (uncomfortable) were bringing the otherwise very high scores (comfortable) down.

Other possible issues identified or areas for improvement did not appear to be building wide, but concerned certain areas of the building or certain professions, such as the ground floor, or the District Nurses.

4.1.1 BUS responses by section

Blue Bell performed very well in the ‘Building Overall’ section, above 80th percentile in all categories except for Image, for which it scores just slightly above the mean benchmark (47th percentile). Image is perhaps the most subjective, aesthetic related question, and Blue Bell’s design is remarkable for its location (it is not keeping with local building architecture).

Table 4-1 “Design” and “Needs” scores from BUS and distribution of responses

Design	
Needs	

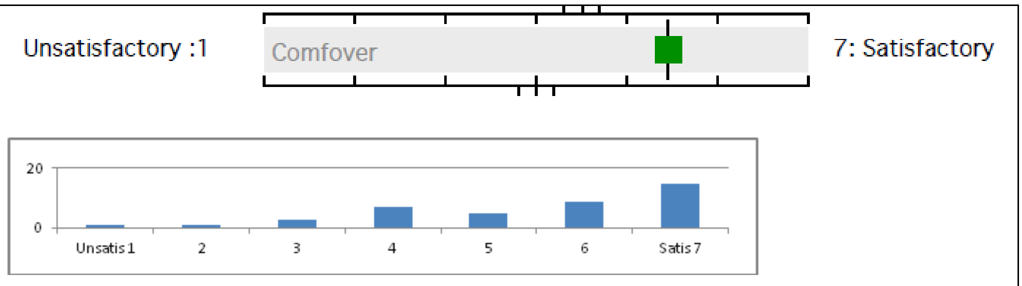
The results from the thermal comfort section indicate occupants are generally comfortable in the summer and winter. However during the winter some are feeling too cool and experiencing the building temperature as variable. The variability and relatively high number of occupants feeling too cold is surprising given that the building is well insulated and underfloor heated. Highly glazed areas tend to be in waiting rooms as well, away from working areas. Examining winter responses by working area, lower scores tended to come from staff working on the 1st floor. This chimes with FM feedback that some sections of the building were difficult to heat and some underfloor heating (UFH) data showing particularly low temperatures. An investigation ensued, examining thermal insulation continuity and effective space heating provision. The results found a commissioning problem with the UFH, with some rooms not receiving adequate heating from the main distribution system (the thermal investigation proved inconclusive). This is discussed in Section 7.

During the summer, Blue Bell is experienced as too warm by a fairly high number of respondents. Variability of summertime temperature appears mixed with some respondents finding the temperature stable and others variable. Examining summer responses by working area, the 1st floor as a group tended to find the temperature as too warm. Many individual rooms on the 1st floor are mechanically ventilated. Issues with free-cooling (day and night-time) and the delivery of warm air were identified with the AHU. Improving AHU operation and possibly pre-cooling these rooms before building operating hours could potentially improve summertime conditions. This is discussed in Section 7 as well.

Blue Bell scores very well in the ‘Noise’ section. Given that Blue Bell is located beside a very busy road, *Noise from outside* scored very close to the optimal midpoint. This indicates that triple glazed windows and other noise reduction strategies have been effective. Responses did indicate when occupants open windows, traffic noise becomes too loud. Traffic noise is difficult to avoid, but satisfying comfort needs through the improvement of the mechanical ventilation and “Comfort cooling” systems operation in the summer could help, as occupants may be less likely to have to open windows to get comfortable.

Blue Bell scored highly (92nd percentile) in the ‘Overall comfort’ section as well. The maximum score was the most commonly ticked value. Although not stated, it is implicit that the occupant is expected to rate the overall comfort considering thermal, aural, and visual factors.

Table 4-2 Overall comfort score from BUS

Overall comfort	

In regards to building management, Blue Bell scores excellently on the *Speed and Effectiveness of response* compared to benchmarks, showing that the facilities management team are providing a good service. Mean values are however only slightly above the midpoint, so it is clear that improvements could be made. It may be that difficulties experienced in winter in the inability of the heating system to deliver comfortable conditions to some areas are bringing the score down. A few comments appear to confirm this, with occupants requesting higher winter temperatures but not getting them.

4.2 Occupant interviews

This section discusses the findings from the occupant interviews. Additional information is found in Appendix F.

5 occupants were interviewed with each of the 3 occupied surgeries represented, as well as the PCT. Interviewees included 2 Practice Nurses and Nurse Clinician from the surgeries, and a Community Matron, and a clerical officer from the PCT.

Findings from the interviews supported the results of the BUS survey. The occupants interviewed like the building in many respects (except for the temperature). In particular they mentioned they like: how they are not responsible for cleaning or maintenance; the multi-tenanted set-up as it allows them to talk face to face with NHS professionals from different medical fields; and the layout, openness and natural light.

However, it appears that there is a significantly different building experience in terms of thermal comfort from one floor to the next, with the ground floor interviewees very satisfied with thermal conditions but the first floor interviewees all expressing strong views about their (and colleagues') thermal discomfort in both the summer and winter (but worse in the winter). Two surgeries stated that they had already begun using electric fan heaters in many rooms (the interviews took place in mid November 2013). Additionally one interviewee stated that patients had found summer temperatures too high in the first floor waiting room.

Occupants interviewed generally didn't like the light switches. They all found them initially confusing and didn't understand why there needed to be different kinds (they especially disliked the rocker switches which require the user to hold them down to turn off, on, and dim). All but one interviewed did not know that some lights could be dimmed. In the ground floor open plan office, the presence detection lighting installed is always on and thus the interviewee stated that they never just open blinds for 100% natural light and she did not know where the manual switch for the lights was.

Only a couple of the occupants used the controllers for the “Comfort cooling” system (the VRF system provided in Treatment rooms and the open plan ground floor office which actually provides space heating and cooling). They stated that they only adjust the temperature setting of the controller. One occupant expressed concern that the system never turned off and that it didn’t need to be on as often as it was. As installed, temperatures are set by the controllers in the different rooms but the timer is set by overarching central control, which the FM does not have access to – thus temperatures cannot be capped or collared. This is discussed further in Section 7.

First floor interviewees stated that they had difficulties with opening the windows (issues with the catches) and were unsure about leaving windows and doors open to get a cross-flow of air during the summer from a Health and Safety perspective. A couple of interviewees stated that would like to be able to open windows more fully and felt this would improve summer conditions. On the ground floor this was not an issue and the occupant in the open plan office stated she had never needed to open any windows.

While some occupants had done a kind of tour of the building when first occupying it, others had not, and it is unclear to what extent the tour demonstrated the use of the services. Further, some occupants had seen the user guide (the only one was housed at the ground floor reception), while others hadn’t. But generally the occupants had been in the building for over a year and now felt they were familiar with most features.

4.3 Conclusions and key findings for this section

4.3.1 Survey completion

While the response rate for the BUS survey was fairly high, most respondents did not complete all questions. Additionally very few respondents included comments. Reasons for the low completion rates are unknown and not uncovered during the occupant interviews. It may have been due to NHS staff work load, some occupants not aware that the survey was going to take place, NHS staff survey and form fatigue, or perhaps the BUS survey could be improved as well, as some respondents appeared not to understand how the survey is intended to be completed (or perhaps took the time to understand).

4.3.2 General perception

In the BUS survey Blue Bell generally performs very well compared to the benchmarks, scoring in a high percentile in many categories. Occupants generally are comfortable, like the building, and feel that their needs are satisfied by the facilities provided.

However the building is perceived differently by staff in different locations. Targeting problem areas and improving some staff needs could improve the score significantly. For example, improving the provision of space heating to some spaces and the mechanical ventilation system operation in the summer could improve conditions and thus possibly improve scores.

4.3.3 Travel

Almost all occupants drive to work. A car sharing scheme, or getting occupants to walk, bicycle, or take the bus (as most live fairly close to Blue Bell), could be an effective way to reduce carbon emissions.

4.3.4 Winter comfort

Winter responses chime with FM feedback – most occupants on the ground floor are comfortable, but there are a few hard to heat areas in the building, particularly on the first floor. Two surgeries stated that they had already begun using electric fan heaters in many rooms in mid November. These areas should be targeted to improve building user comfort.

Although the air temperature may have been 21°C in the winter in rooms on the first floor, occupants were still finding the space much too cold. While thermal comfort is related to more than just air temperature, the building is fairly airtight (no significant draughts), well insulated (higher surface temperatures), and one occupant interviewed who was complaining of the cold was wearing a scarf. A commissioning problem with the heating distribution was found and at the time of writing this (June 2014) being fixed. It is thought that this is primarily responsible for the discomfort during the winter.

4.3.5 Summer comfort

In the summer the majority of occupants are comfortable, but some are experiencing overheating, especially on the 1st floor. Better AHU operation, using free-cooling, both at night and during operational hours, should be examined. To improve conditions further, the operation of the mechanical louvres in the building core (currently operating on CO_2 and temperature sensing) could be changed so that they open at a lower internal temperature during the summer.

4.3.6 Occupant controls

Despite occupants only using the temperature setting, the “comfort cooling” controllers actually have a lot more functionality and many other features such as heating or cooling only, fan control, and a timer. However, the limited use (temperature up and down only) also calls into question why the controllers have been designed with so many other features.

Interviewees were not certain of whether they were supposed to open windows, the dimming function on some light switches and didn’t fully understand how to use the “Comfort cooling” controller. These things should be in a user guide and demonstrated to occupants.

First floor occupants stated that they had difficulties with opening the windows (issues with the restrictors) and were unsure about leaving windows and doors open to get a cross-flow of air during the summer from a Health and Safety perspective. A couple interviewees stated that would like to be able to open windows more fully and felt this would improve summer conditions. However on the ground floor this was not an issue and the occupant in the open plan office stated she had never needed to open any windows.

The use of restrictors to limit the opening of windows comes from the H&S ‘best practice’ recommendation in *Health Building Note 00-10 Part D: Windows and associated hardware.* From this, restrictors should limit window openings to 100mm. This opening size is generally too small to provide good airflow for heat purging. Following on from a TSB team meeting where the findings from the occupant interviews were discussed, Renova met with a NHS Property Services H&S officer. In this meeting, the officer stated that they were happy to relax this restriction in staff areas and other areas deemed to be low risk from falls. The FM is now looking to source longer restrictors.

4.3.7 Lighting

The good lighting scores related to glare and natural light validate design decisions to optimise natural night through the atrium above the central core staircase and the use of the timber cladding structure to create deep reveals to prevent glare. As overheating appears to occur in all surgeries, it does not appear that solar gains are the underlying factor for this – thus the reveals appear to be adequately providing solar gain control as well. However, as discussed in Section 7, the electric lighting installation does not take advantage of good daylighting design to enable energy savings. To utilise natural light in ground floor office space, daylight sensing with dimming should have been installed in conjunction with the presence detection.

4.3.8 Noise

Although Blue Bell is located along a busy A-road, the building scores well in the noise category in the BUS survey. Design features to minimise external noise include triple glazed windows and mechanical ventilation in cellular rooms off of the building core (occupants are not reliant on opening windows or window trickle vents for fresh air) - the timber cladding may be helping to absorb sound somewhat as well. Thus it appears that these design choices are validated from a noise reduction perspective. However occupants are opening windows to cope with summer time conditions, but when they open windows, traffic noise does become too loud.

4.3.9 User needs

Cleaning staff as a group were the most critical of the building and commonly indicated that a lack of well placed electrical sockets and sufficient storage was hindering their work. It should be investigated whether this can be improved through the addition of some well placed sockets and making available more room for Domestic’s storage needs. Designers need to address the needs of all building users where possible.

5 Details of aftercare, operation, maintenance & management

Technology Strategy Board guidance on section requirements:	This section should provide a summary of building operation, maintenance and management – particularly in relation to energy efficiency, metering strategy, reliability, building operations, the approach to maintenance i.e. proactive or reactive, and building management issues. This section should also include some discussion of the aftercare plans and issues arising from operation and management processes. Avoid long schedules of maintenance processes and try to keep to areas relevant to energy and comfort i.e. avoid minor issues of cleaning routines unless they are affecting energy/comfort.

5.1 Introduction

Facilities Management (FM) is outsourced to a large FM provider contracted to look after multiple new buildings for Renova, including Blue Bell. Day to day management is provided by an onsite, part-time handyman. The FM provider's Accounts Manager also provides support at Blue Bell, in addition to other buildings in the region.

From Renova's side, their Operations team works with Community Health Partnerships (CHP), to whom the building is leased, to provide support as their landlord in a Lease Plus agreement. Blue Bell provides a pharmacy, community healthcare facilities, but also is currently (as of May 2014) occupied by three (with space for four) GPs.

At Blue Bell most M&E systems are linked to a Trend BMS, which was designed to provide optimised, "intelligent" heating, cooling, and ventilation. Building services are fairly complex in Blue Bell, with multiple heat inputs for hot water production, a heat pump system connected to a hydraulic underfloor heating system, designed with waste heat utilisation at the VRF and hydraulic levels, and an AHU with heat recovery.

5.2 Building usage

Blue Bell is a multi-purpose healthcare building, providing different primary care services and a pharmacy under one roof. There are multiple reception areas, two large waiting rooms, a large daylit central core with an atrium, and proportionally large areas of the ground floor are devoted to meeting spaces and an open plan office. It was not designed like more traditional healthcare buildings, which many staff would have been more familiar working in.

Cycle storage is provided onsite, but most occupants drive themselves to work. Additionally, although showers are provided, according to the FM and speaking to occupants, these are seldom used.

Figure 5-1 Unused cycle parking

5.3 Operation

The FM begins each day by checking all systems on the BMS and then the maintenance logbook, to see if any faults have been recorded. The FM has a set of planned maintenance schedules, and for all maintenance activities, time spent, materials, and whether the problem is a defect or caused by damage or normal wear and tear is recorded.

If a fault shows up on the BMS, the FM first sees if it can be fixed in house, either by Blue Bell's FM or by another member of the FM provider team. There are several service contracts with manufacturers and suppliers of equipment at Blue Bell that they can call for repair as well.

Occupant concerns are never directed straight to the FM provider but to main reception. If something requires maintenance, a call is made to the helpdesk and a log is filled in which the FM examines each day. Maintenance issues could be related to anything in the building, from plumbing to electrics to woodwork.

For occupant complaints related to temperature, the FM checks the temperature with a portable thermometer to see if it is 21°C in the space, which is the design and operational temperature. If the temperature in the space is 21°C, occupants are shown this and according to the FM, usually accept this. However, most GP surgeries have brought in portable electric heaters that are used throughout the winter. In the underfloor heated areas, temperatures can only be changed through the BMS.

All occupant interviewees stated that they had reported problems with the building, ranging from cosmetic damage to building temperature, but all gave a glowing review of the FM service in the building.

As discussed in previous sections, the FM has had difficulty with the BMS since first taking over the building. This came to a head during the first winter, when it was felt that systems could not cope with extreme cold conditions and the BMS was hindering the operation of the heating system. The FM subsequently turned off the optimised start and stop.

At the time of the conclusion of this evaluation programme, the BMS continues to provide difficulty for the FM. Although the FM was never trained in its use, it is the poor commissioning of the BMS that prevents the building from being operated more efficiently.

The Building Logbook was produced by Blue Bell's M&E consultants (who are also involved in the design of Renova's larger framework of new developments) and given to the current FM provider at handover. The Building Logbook has not been used by the FM nor do they consider it to be useful. Examining the Logbook, it gives a good introduction to the building and building services, although some information is omitted and the drawings are not legible and don't appear to be final construction issue. One key section "Overview of Controls/BMS" gives a very basic overview and does not relate controls back to overarching energy strategy. Additionally mechanical ventilation and heat pump control operation is not mentioned. Further, some system descriptions refer to earlier design features that were not installed, such as daylight sensing. Other issues found include: the "Metering, Monitoring, and Targeting" section has not been completed; and energy information given in the "Building Performance Records" section cannot be traced or examined (requests for design calculations have not been answered, target energy use bears little resemblance to actual energy consumption - much lower in the Logbook - nor can the end-uses be targeted as they are not broken down in relation to installed submetering in the building).

5.4 Aftercare

Once the building was handed over there was a 20-day snagging period. Items outstanding at the end of this period were logged on the FM provider's list. After handover there was a 12 month defects liability period (which had passed prior to the beginning of this study). Once that had passed, the building entered into a 12 year period (which in principle covers latent defects or those already identified but not resolved within the initial defects liability period). However, in the 12 year defects period it has become more difficult to get contractors back to the building.

Renova have not always been satisfied with the main contractor's response to raised defects. In particular, they feel that the aftercare individual from the main contractor, who looks after all the contractor's projects in the region, lack sufficient technical understanding to provide a helpful response. As a result, such as with the issue with electric immersion heater at Blue Bell, the aftercare team often issues a standard reply, "as per design".

With some problems, it is difficult for Renova to prove something is a defect. In the case of the solar thermal system, Renova had the suppliers come out to site to examine the system and issue a report with recommendations. For other items of M&E equipment, Renova have the FM provider produce a report. Sometimes the FM provider can fix a defect and have this charged on to the main contractor, but this sometimes proves difficult because there is the possibility of voiding warranties. For this reason in the first 12 month defects period the FM is instructed not to fix anything as many warranties last a year. However, warranties last considerably longer for large items of equipment, and fixing defects discovered past this period becomes more difficult contractually. Renova often have to spend considerable resource proving something is a defect.

5.5 Occupant Induction

A building user guide had not been done originally during first occupation. According to Renova, this was mainly due to the fact that the PCT managed and controlled the tenant decanting phase. Although it was felt they did a good job, Renova felt it would have been beneficial if they had been more involved. Renova went back and put the user guide together and had a demonstration with the GP practice managers – this was done twelve months after occupation. Renova now take a more active role in occupation.

The production of the user guide was required to achieve BREEAM "Excellent", and is available for GPs for reference. Some sections appear to have never been completed (such as Materials and Waste Policy), while all other sections are very sparse, providing little information related to the building beyond listing building services equipment. There is little instructive information related to staff operation, with the exception being the following, from the "Building Services Information" section:

> *Heating & Cooling: There is a computer controlled Building Management System which aims to keep the temperature in the occupied rooms at 21^{o}C during operational hours. To keep the rooms at optimum temperature turn the thermostat to '4'.*
>
> *Ventilation: Ventilation is provided in a number of ways: 1) some outer offices are fitted with openable windows which should be opened early in the day in summer months. 2) main supply and extract serves all areas. 3) 6 x separate extraction fans for dirty areas – WCs and Dirty/Clean Utility Rooms. The ventilation is controlled via the Building Management System*

There are a few inaccuracies with this. First, there are no thermostats except in treatment rooms and the large open plan office, and these don't have the temperature settings as described in this document. Also there is no mention of the comfort cooling equipment. From discussions with the FM, building users in the treatment rooms, where the comfort cooling equipment is supplied, have had questions as to the operation of the controls for this system.

Renova have greatly improved on these documents for newer developments, providing a more thorough and illustrated guide, with detailed operational guidance for all systems, for different times of the year, pitched at a good level for all staff. Although not done at Blue Bell, according to Renova's Facilities Contract Administrator the induction is now much more extensive, with a walkthrough and explanation of all building systems, including comparing the tenants' old building to the new one.

Based on interviews with occupants, some had done a kind of tour of the building when first occupying it, but others had not, and it is unclear to what extent the tour demonstrated the use of the services. Further, some occupants had seen the guide (the only one was housed at the ground floor reception), while others hadn't. Generally the occupants interviewed had been in the building for over a year, and now felt they were familiar with most features and would not benefit from a tour.

Renova are now updating the user guide at Blue Bell, issuing one per tenant, and plan to hold meetings with tenants to review it.

5.6 Occupant Engagement

Renova engages tenants in regular customer satisfaction meetings. Renova also used to be able to engage with tenants via the tenant led user group meetings. The user group meetings were stopped as a result of the abolition of PCTs in 2013 but they have been recently re-launched and according to Renova, they hope to use these as a forum to share the findings of this BPE study.

They regularly produce an End User Energy Fact Sheets in which each of Renova’s buildings are compared. This contains a copy of the DEC, a building comparison table which compares current seasonal energy use with the previous year, and a “top ten tips” list for ways building users can save energy.

5.7 Conclusions and key findings for this section

5.7.1 Building Management

As discussed further in Section 7, the BMS is largest barrier to improving the operation of the building. Mechanical systems at Blue Bell are fairly complex and were designed with the intention that they be almost fully BMS controlled, without the need for much FM involvement beyond changing some set-points here and there. However the BMS was not installed to do this, many systems are not BMS linked, and some that are BMS linked have operational information and control (some of them detrimental to efficient operation) hidden from FM by not being visible on the Supervisor. ‘A’ type buildings dependent on BMS operation need to make sure the BMS has been well designed and installed correctly or they will end up as ‘C’ type buildings, with performance penalties (see Figure below). In operation, the BMS was not providing optimised heating and cooling, and hot water production and mechanical ventilation operations are not sufficiently manageable through the BMS.

Below are two diagrams based on a Usable Buildings Trust categorisation of services in buildings. Blue Bell was designed with fairly complex technologies, but with a BMS to act as an intelligent and low-cost operator, basically serving to increase management of the building (Type A). In operation Blue Bell maintains its technological complexity, but as installed the BMS does not provide sufficient management for most building services - thus becoming a Type C in operation.

[redacted]

Figure 5-2 Usable Buildings Trust building strategy types, adapted for Blue Bell illustration

Greater thought into how the building is likely to be operated needs to happen in M&E design. This partly needs to be facilitated by the developer, with a sober look at actual building management resources (human and machine) to run and maintain the building and fix problems.

5.7.2 FM training

The amount of building specific FM training needs to increase, especially the case with buildings with new and innovative technologies. The same applies to FM involvement in design and commissioning, particularly around the look of the Supervisor and capability of the BMS.

5.7.3 Occupant induction

It could be of benefit to formalise a demonstration for each new occupant, go into greater depth about how to get the best out of the services (from a comfort and efficiency perspective), and keep copies of the guide in different locations. Interviewees were not certain of whether they were supposed to open windows, the dimming function on some light switches and didn't fully understand how to use the "Comfort cooling" controller. These things should be in a guide and demonstrated to occupants. Note that Renova is planning on addressing this point through the updated user guide and meetings.

5.7.4 Aftercare

Renova have not always been satisfied with the main contractor’s response to raised defects and with some problems it has been difficult for Renova to prove something is a defect. This was feedback to the contractor, however they are now no longer engaged in the building of new healthcare buildings for the client (projects have completed and the pipeline has ended). Thus potentially renegotiating aftercare terms in their contract to improve things like response time is now not likely. This could potentially have had a positive effect on commissioning and the selection of products as it encourages the selection of quality products, installed right the first time.

6 Energy use by source

Technology Strategy Board guidance on section requirements:	This section provides a summary breakdown of where the energy is being consumed, based around the outputs of the TM22 analysis process. This breakdown will include all renewables and the resulting CO_2 emissions. The section should provide a review of any differences between intended performance (e.g. log book and EPC), initial performance in-use, and longer-term performance (e.g. after fine-tuning and DEC – provide rating here). A commentary should be included on the approach to air leakage tests (details recorded elsewhere) and how the findings may be affecting overall results. If interventions or adjustments were made during the BPE process itself (part of TM22 (process), these should be explained here and any savings (or increases) highlighted. The results should be compared with other buildings from within the BPE programme and from the wider benchmark database of CarbonBuzz.

6.1 Metering strategy

Although there are heat, electrical, and flow (for cold and rainwater consumption) submeters, the installed submetering at Blue Bell doesn’t lend itself to completeTM39 (and TM22) end-use separation (space heating, hot water, refrigeration, fans, pumps, controls, internal lighting, external lighting, small power, ICT equipment, vertical transport, distributed catering) – complete separation is not an explicit Part L requirement, but can be useful for energy management. At Blue Bell, energy for the electric immersion elements for DHW production, all pumps and controls for heating and cooling distribution, and hot and cold water production and distribution are submetered together on the MCCP in the plant room, and the heat pumps for space heating, cooling, and also DHW production are submetered together on a separate DB in the plant room. Further, energy demand for the AHU, which includes the fans and heating and cooling elements, is submetered on a separate DB. In many areas of the building, lighting and small power are separated, but this is not the case everywhere. Finally, although there is a large solar thermal array, no heat meter was installed to measure its energy contribution.

Table 6-1 Installed submeters and end-use separation

End-use	*Submeter designation*	*Equipment*
Ventilation	AHU	Supply and extract fans, ventilation heating and cooling equipment (electric frost coil and DX unit)
Small power & lighting	DB1, DB2, DB3, DB4, DB5, DB7, DB8, DBEX	Medical equipment, desktop computers, kitchenette equipment, some cleaning equipment and other small power loads, in addition to some security and extract fans; most lighting in the building, including external lighting (on DBEX)

Space heating and cooling; domestic hot water	DB Plant, MCCP	All heat pumps except Pharmacy (DB Plant); electric immersion heaters, pumps and ancillary equipment, CWS booster pumps, BMS (MCCP)
Lifts	Lift01, Lift02	Lifts
Comms	COMMS	Local server; a small amount of lighting; and local indoor split cooling unit
Pharmacy	DBPharmacy	All pharmacy electricity, including pharmacy heat pump

6.2 Design targets

In practice, complete end-use separation following TM39 or TM22 would likely be difficult and costly - and unnecessary, if benchmarks/targets were provided which reflect the installed submetering arrangement of the building. This is not the case at Blue Bell. Examining the Logbook, the *Metering, Monitoring and Targeting Strategy* section was not completed and no TM39 meter tree schematics were found. In the *Building Performance Records* section, the end-use breakdowns included are: lighting, fans and pumps, small power, and mechanical heating. These end-use breakdowns are not easily comparable with the installed submeter configuration, nor with TM39 end-uses, and some end-uses have not been included (and no explanation is given). According to the M&E engineer, these values were taken from TAS SBEM software outputs. From the worksheet provided for examination, these include: heating, domestic hot water, cooling, auxiliary, and lighting. SBEM does not consider all end-uses such as all small power loads (and associated unregulated emissions). Note that “Auxiliary” energy consists of fans, pumps and controls.

The dissimilarity between the breakdown in the Logbook, TAS SBEM, and the actual metering arrangement creates confusion and in particular detracts from the relevance and usability of the Logbook meter recording section. The TAS SBEM breakdown of end-uses is shown below.

Table 6-2 TAS SBEM anticipated energy consumption by end-use

Consumption kWh/m^2	*Actual*	*Notional*	*Reference*	*Typical*
Heating	5.66	36.13	37.50	70.68
DHW	3.46	5.64	5.64	5.64
Cooling	0.23	0.66	2.59	0.59
Auxiliary	3.09	4.01	1.75	6.60
Lighting	19.76	32.73	33.19	38.93
Displaced Electricity	0.00	0.00	0.00	0.00

Total	*32.21*	*79.17*	*80.67*	*122.44*

The end use breakdown taken from the Building Logbook is shown below. The empty "Actual" columns are intended for the FM to fill in. It can be seen that no DHW or space cooling energy has been included, although DHW could possibly be included with "Mech heating".

Table 6-3 Building Logbook anticipated energy consumption by end-use

Building energy performance for period from *[date]* to *[date]* Based on a gross floor area of *2271* m^2					
Fuel type	**Main end use**	**Actual** kWh/m^2/yr	**Actual** kWh/m^2/yr	**Design estimates** kWh/m^2/yr	**Good practice benchmark** kWh/m^2/yr
Electricity	*Lighting*			70114.26	
	Fans and pumps			6679	
	Small power			49171.74	
	Mech heating			47064.66	
Total electricity				173029.66	

Anticipated building energy consumption by end-use found in both the TAS SBEM output and in the Logbook are shown in Figures 6-1 and 6-2 below. In both Figures it can be seen that lighting represents the highest area of energy consumption.

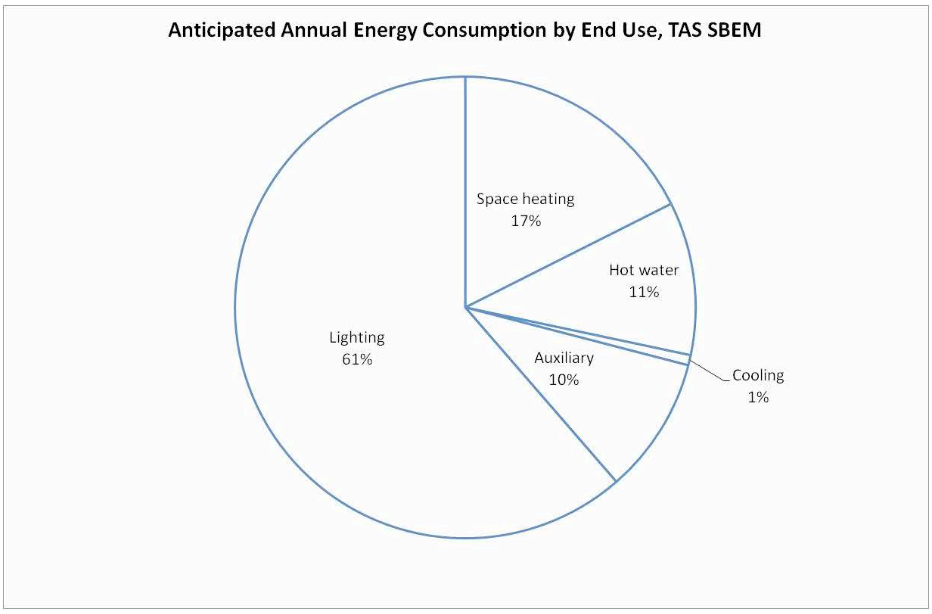


Figure 6-1 Anticipated proportional energy consumption by end-use, TAS SBEM

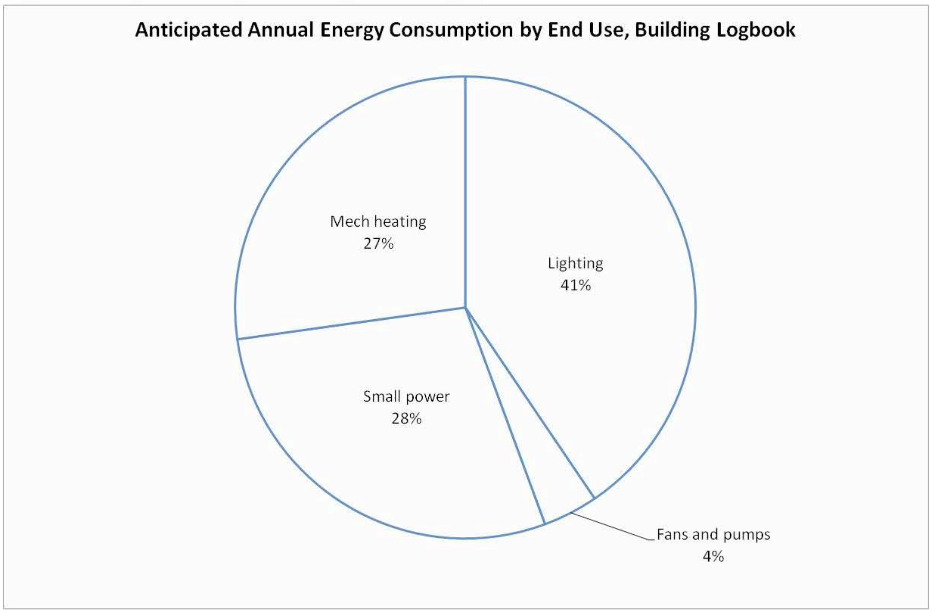


Figure 6-2 Anticipated proportional energy consumption by end-use, Building Logbook

It was not possible to obtain other design energy targets. For example, although there is a large solar thermal array, no figures estimating solar thermal energy production or even hot water demand were found. Additionally no assumptions, inputs or calculations that were used in TAS or the Logbook were provided by the M&E engineer.

6.3 Energy consumption

Early energy analysis showed that space heating and cooling, DHW production and ventilation represented the bulk of energy demand, with the greatest room for improvement and energy savings, and thus this is where the focus of the evaluation has been. Although there is a central server with a dedicated chiller, the building is not particularly IT heavy, and catering demands are very small, with only local tea points and kitchenettes around the building. Lifts consume less than 1% of total energy. Further information regarding in-use energy consumption and energy performance can be found in Appendices A and B.

Examining half-hourly electricity for the first year of Bluebell's operation, it also immediately became apparent that there was a significant performance gap between predicted and in-use energy consumption: the energy benchmarks presented in the Logbook and in planning documentations are about ½ the building's current annual consumption. Although a "settling-in" period is expected at first when the energy consumption is sometimes higher than predicted, the discrepancy found is much larger than just accounting for a "settling-in" period. This is illustrated in Figure 6-2 below.

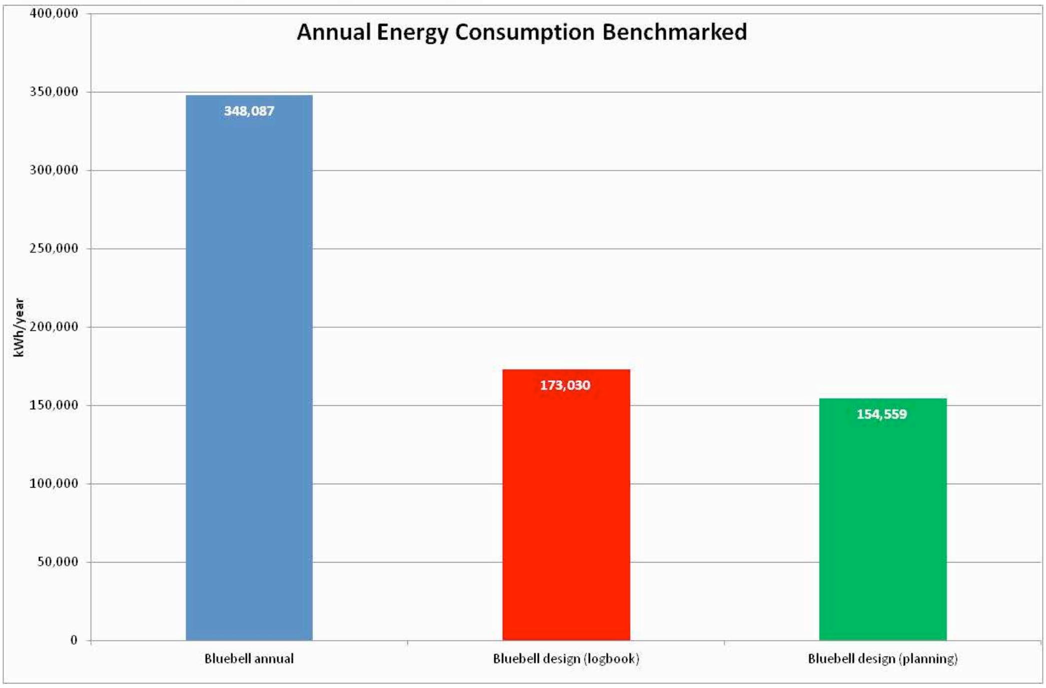


Figure 6-3 Annual energy consumption compared to design targets

Resulting annual CO_2 emissions from metered energy consumption is presented below in Figure 6-4. This value is compared to the Blue Bell “as-designed” (taken from the Building Logbook); the “as-designed” value used for planning stages; and the DEC “Typical” values. Floor areas have been normalised using Blue Bell’s actual floor area (the floor area in the Logbook is off slightly). It can be seen that Blue Bell’s emissions are lower than the DEC benchmark, but twice as high as the Logbook value. Reasons for this discrepancy are discussed in other sections in this report, but it likely has more to do with the calculation for the projected energy consumption in the Logbook than inefficiencies in the “as-built” building and its operation (although significant operational inefficiencies are still present). However as no assumptions used in anticipated energy calculations were provided, this cannot be examined in further detail.

Note that for the purposes of comparison the NCM 2010 carbon factor of 0.517 kg CO_2/kWh for grid electricity has been used throughout and benchmarks adjusted accordingly – thus the “as-designed” values may differ from their original publications.

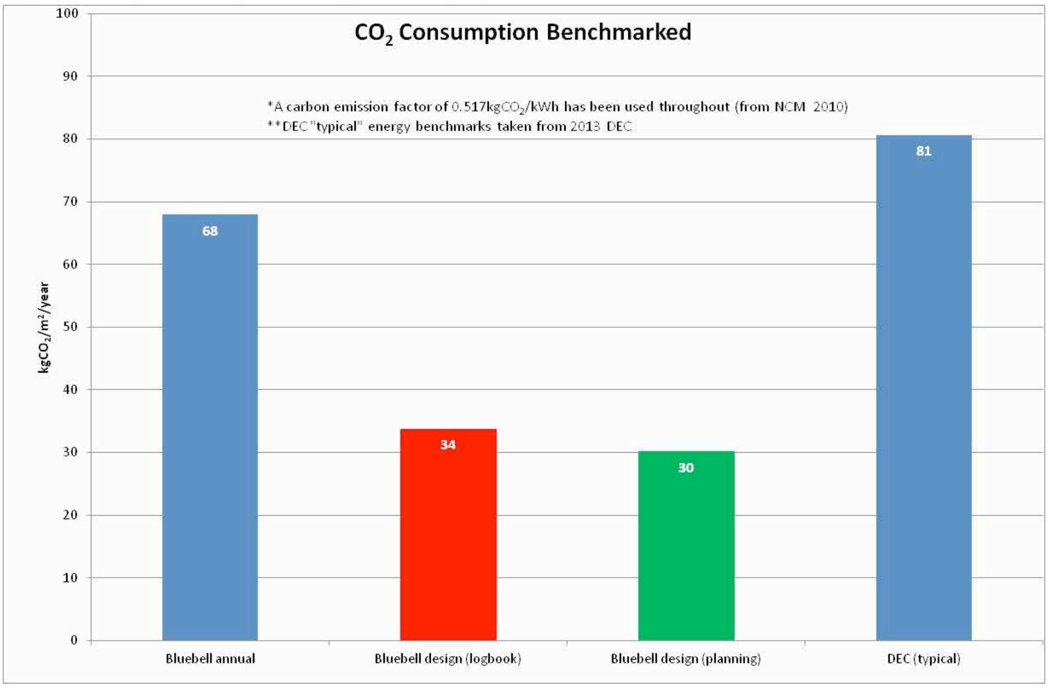
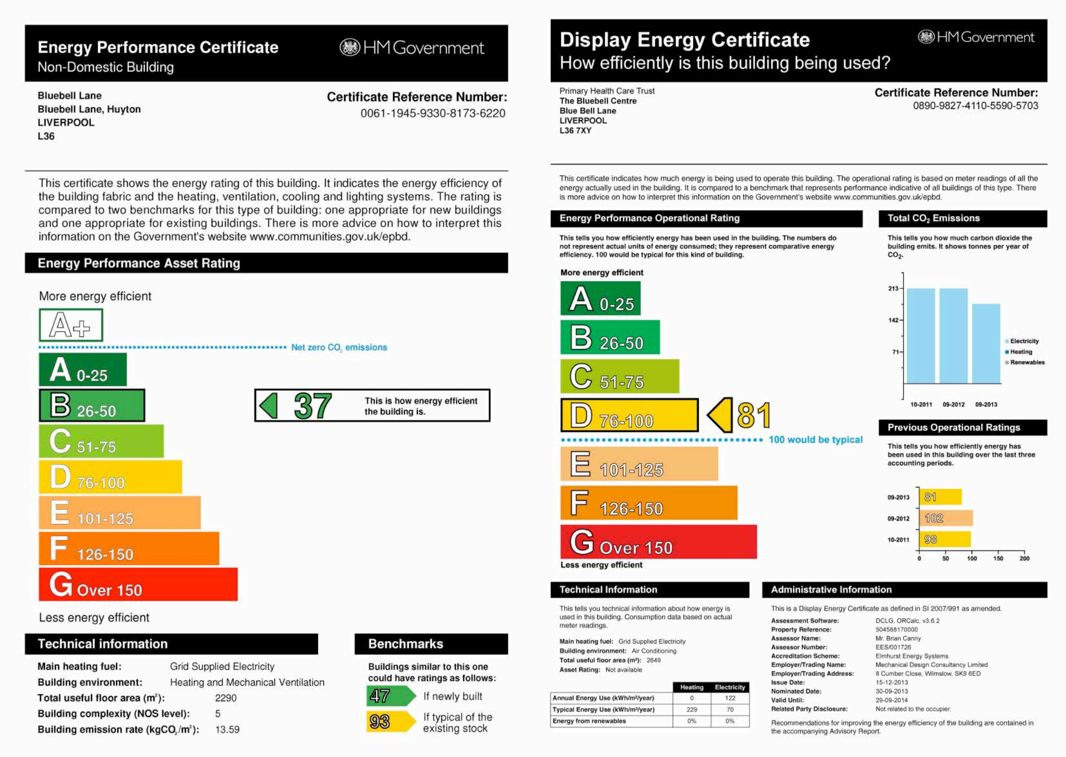


Figure 6-4 CO_2 consumption benchmarked

The discrepancy between real and anticipated is further illustrated in Figure 6-5, which compares the EPC to the DEC (2013). It can be seen that the EPC builds expectation for a high scoring, energy efficient building (B). The reality shown in the DEC was disappointing to the client and design team (D).



Energy Performance Certificate
Non-Domestic Building

HM Government

Bluebell Lane
Bluebell Lane, Huyton
LIVERPOOL
L36

Certificate Reference Number:
0061-1945-9330-8173-6220

This certificate shows the energy rating of this building. It indicates the energy efficiency of the building fabric and the heating, ventilation, cooling and lighting systems. The rating is compared to two benchmarks for this type of building: one appropriate for new buildings and one appropriate for existing buildings. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Asset Rating

Technical information

Main heating fuel:	Grid Supplied Electricity
Building environment:	Heating and Mechanical Ventilation
Total useful floor area (m²):	2290
Building complexity (NOS level):	5
Building emission rate (kgCO$_2$/m²):	13.59

Benchmarks

Buildings similar to this one could have ratings as follows:

47 If newly built
93 If typical of the existing stock

Display Energy Certificate
How efficiently is this building being used?

HM Government

Primary Health Care Trust
The Bluebell Centre
Blue Bell Lane
LIVERPOOL
L36 7XY

Certificate Reference Number:
0890-9827-4110-5590-5703

This certificate indicates how much energy is being used to operate this building. The operational rating is based on meter readings of all the energy actually used in the building. It is compared to a benchmark that represents performance indicative of all buildings of this type. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Operational Rating

This tells you how efficiently energy has been used in the building. The numbers do not represent actual units of energy consumed; they represent comparative energy efficiency. 100 would be typical for this kind of building.

Total CO_2 Emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO_2.

Previous Operational Ratings

This tells you how efficiently energy has been used in this building over the last three accounting periods.

Technical Information

This tells you technical information about how energy is used in this building. Consumption data based on actual meter readings.

Main heating fuel: Grid Supplied Electricity
Building environment: Air Conditioning
Total useful floor area (m²): 2649
Asset Rating: Not available

	Heating	Electricity
Annual Energy Use (kWh/m²/year)	0	122
Typical Energy Use (kWh/m²/year)	229	70
Energy from renewables	0%	0%

Administrative Information

This is a Display Energy Certificate as defined in SI 2007/991 as amended.

Assessment Software:	DCLG, ORCalc, v3.6.2
Property Reference:	504588170000
Assessor Name:	Mr. Brian Canny
Assessor Number:	EES/001726
Accreditation Scheme:	Elmhurst Energy Systems
Employer/Trading Name:	Mechanical Design Consultancy Limited
Employer/Trading Address:	8 Cumber Close, Wilmslow, SK9 6ED
Issue Date:	15-12-2013
Nominated Date:	30-09-2013
Valid Until:	29-09-2014
Related Party Disclosure:	Not related to the occupier.

Recommendations for improving the energy efficiency of the building are contained in the accompanying Advisory Report.

Figure 6-5 Blue Bell EPC and DEC compared

The actual breakdown of energy consumption by end-use is shown in Figures 6-6 and 6-7 below. Figure 6-7 illustrates the difference the winter operation intervention made during this programme (ventilation energy went down significantly). These Figures can be compared with Figures 6-1 and 6-2, although note that with 6-1 non-regulatory small power loads are not included in TAS and this will skew the proportions. As previously discussed the breakdown shown in the Figure below was necessary due to the installed meter arrangement. These are purely measured values – no calculations or assumptions of usage have been made. It can be seen that in-use, the end-use energy consumption is very different from anticipated.

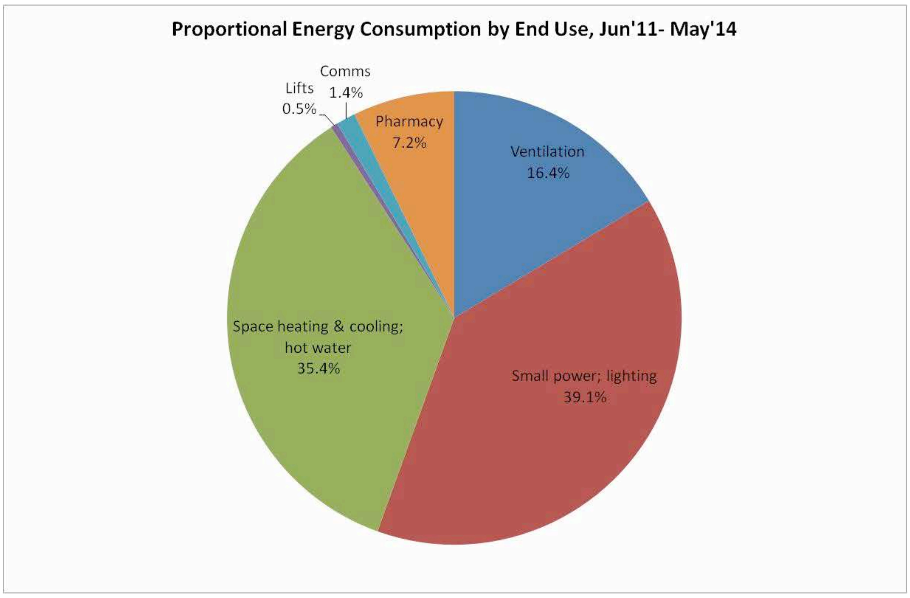


Figure 6-6 Proportional of building energy consumption Jun ’11 through May ‘14

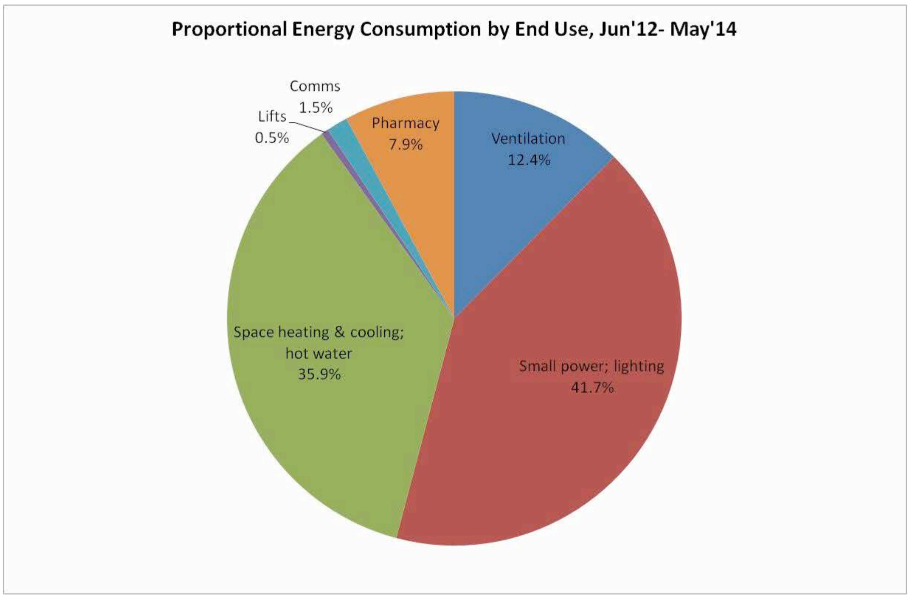


Figure 6-7 Proportional of building energy consumption Jun ’12 through May ‘14

6.4 Interventions

Results of the interventions can be found in more detail in Appendix C. Interventions primarily focused on winter operation. The performance of the DHW system was also examined (further details are found in Appendix B).

6.4.1 Winter operation intervention

Excessive energy consumption was identified between December 2011 and February 2012, which was traced to the heating and ventilation plant operation. Multiple reasons for this were identified, and a different operational regime was implemented the following year over the same months.

During the first winter the building was operational (2010-2011, before this study commenced) internal temperatures were difficult to maintain and the FM felt that the system simply did not have the necessary capacity, nor was the BMS-optimised heating up to the task. Some frustration with BMS-optimised heating may have also come from the lack of clear communication interfaces on the BMS Supervisor – the feeling was that the BMS is a black-box, and “smart” functions may really be detrimental. Additionally the FM questioned whether the heat pump units had sufficient capacity to maintain comfortable internal temperatures during very cold conditions, when the heat load requirement increases as the maximum output of the heat pumps decreases.

During this winter the heat pumps consistently failed to automatically defrost and became iced (they had to be manually defrosted). After the first winter the FM provider was told by the manufacturer that the heat pumps could not operate in external temperatures below -3°C.

Thus in reaction to the first winter, and taking on board the discussion with the manufacturer, during the winter of 2011-2012 (Dec – Feb) the underfloor heating system was operational 22 hours per day, every day, at constant room air Set Point Temperatures (SPTs), typically 21°C. Further, the ventilation system was also run 22 hours per day in an effort to maintain adequate room temperatures, as the FM did not believe the underfloor heating system was capable of solely providing the space heating requirements (note the ventilation is not designed to provide space heating).

The obelisk shape in Figure 6-8 illustrates the increase in energy consumption over this period.

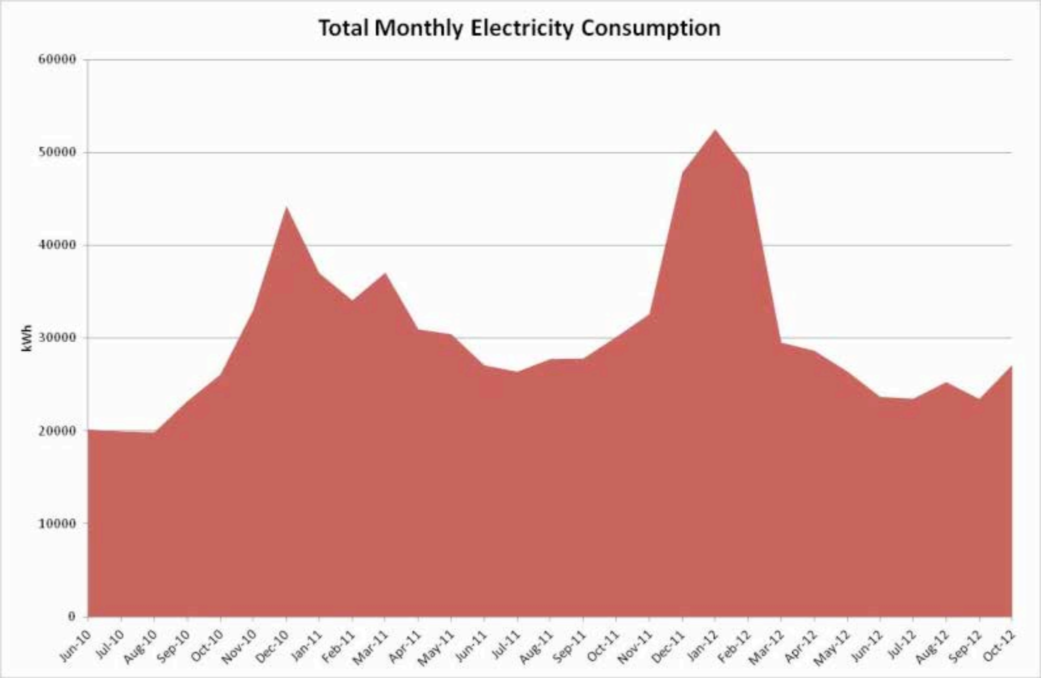


Figure 6-8 Total energy consumption at Blue Bell

Figure 6-9 compares energy consumption and external temperature across different months during the heating season. Comparing December 2010 and 2011, it can be seen that despite an average increase in external temperature by 6°C, energy consumption increased by around 8%. For January, nearly a 2°C increase in average temperature corresponds to an increase in energy consumption by over 40%, and for February, although the average temperature drops by almost 2°C, there is a disproportionate increase in energy consumption by 40%. Looking at these three months, it can be seen that despite conditions being generally milder during the winter of 2011-2012, energy consumption increases considerably.

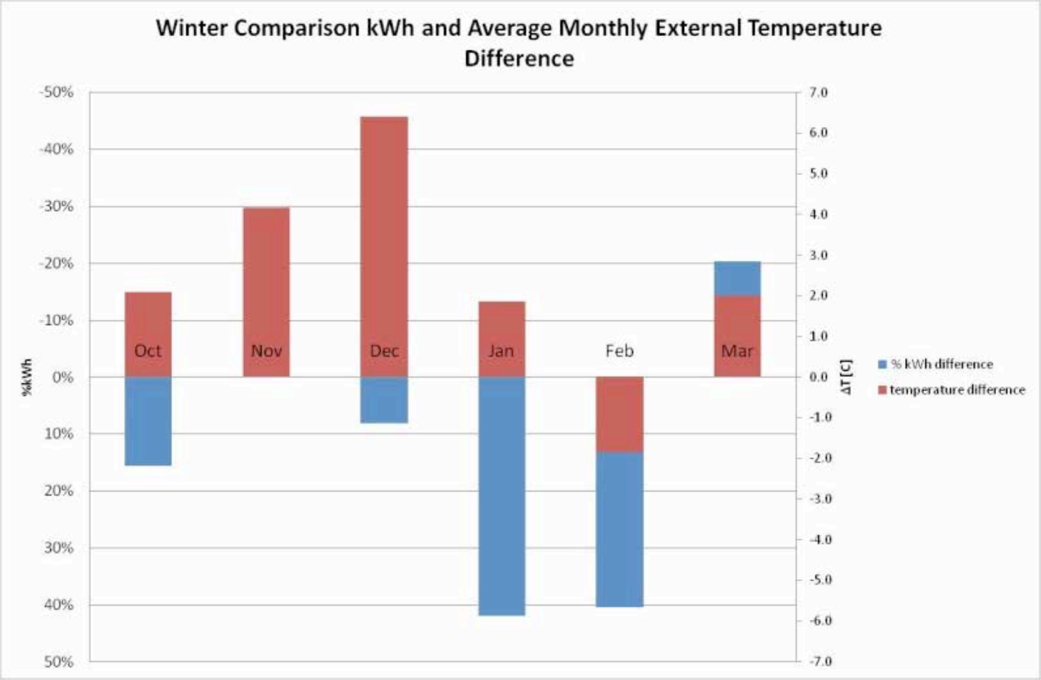


Figure 6-9 Difference in energy and external temperature across two heating seasons

Figure 6-10 below illustrates how this difference in energy consumption across the heating seasons is due to changes in operation. It can be seen that the average daily profile for December 2011, compared to the December 2010, increases substantially at an earlier hour and takes longer to decrease out-of-hours.

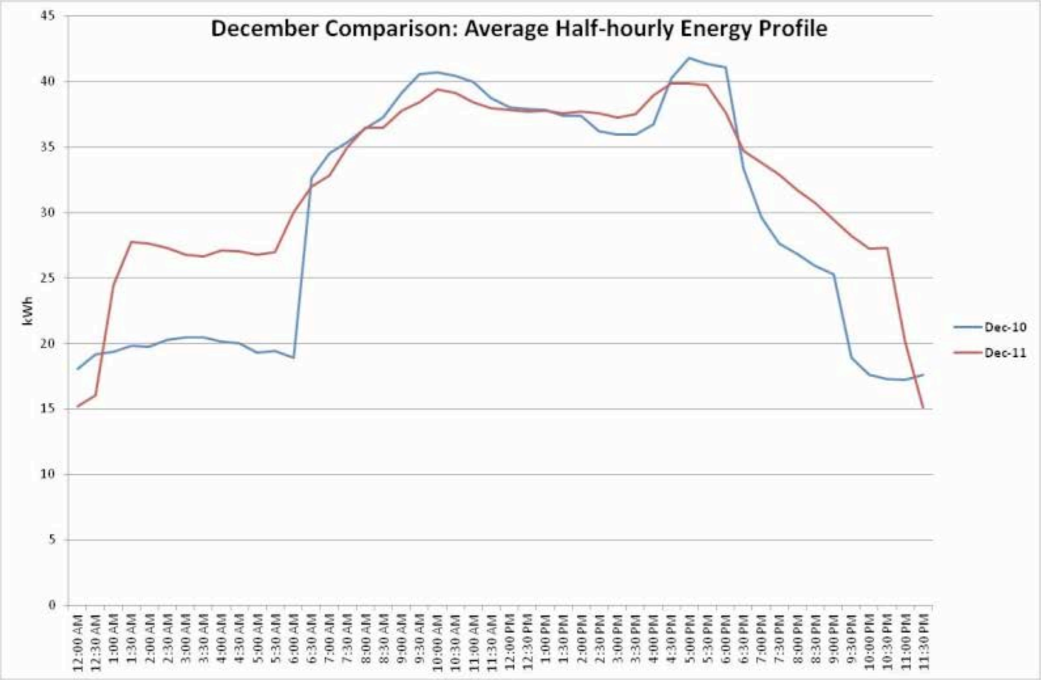


Figure 6-10 December 2010, December 2011 average daily electricity profile comparison

From submeter data manually taken by the FM shown in Figure 6-11 below, it can be seen that “Ventilation”, which is all energy consumed by the AHU, gives the shape to the total building energy use during this period. From June 2011 through May 2012, the yearly electricity consumption attributable to the AHU (submetered from the Ventilation submeter) was 89,411 kWh. AHU winter operation (December, January, and February) accounted for 50,651 kWh - 56.6% of the yearly energy, for just one season.

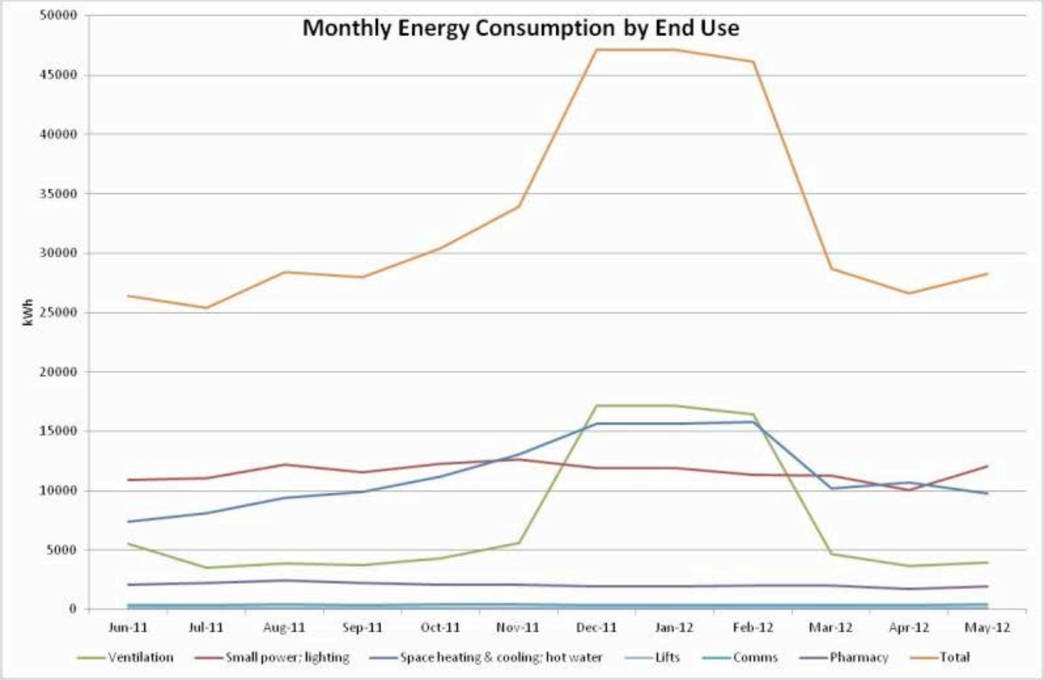


Figure 6-11 Energy consumption by submetered end-uses

Estimated energy consumption for the AHU fans is given in Table 6-4.

Table 6-4 AHU energy consumption from TM22 analysis

Component	**Yearly kWh**	**Winter ‘11-‘12 kWh**	**% Winter**
Supply fan	23,900	11,273	47%
Extract fan	14,497	6,838	47%

The following recommendations in Table 2.7 for changing the winter heating regime were discussed at the quarterly project meeting in November 2012.

Table 6-5 Winter Operation recommendations

	Recommendation	*Possible actions*
1	Ensure ventilation equipment is operational, control strategy functioning to engage the heat exchanger to maximum potential.	1. Improve BMS Supervisor control of AHU. 2. Ensure dampers visible on Supervisor are the heat exchanger bypass dampers. 3. Check temperatures against heating and heat exchanger operation in AHU in different external and indoor conditions to ensure designed control strategy is in operation.
2	Ensure UFH distribution pumps are in correct setting. Essential for efficient UFH operation.	1. Check against commissioning sheets. 2. Make sure pumps are operating variable flow (based on demand), not constant flow. 3. Discuss with manufacturer and M&E designer.
3	Run AHU only around occupied hours.	1. Maintain current timeclock settings (as set April 2012) for AHU.
4	Contingency plan operation: should the heat pumps fail to deliver the required output (possible at very low external temperatures) have portable electric heater handy to bring the building up to temperature quickly.	1. Review existing heating contingency plan to ensure response is adequate should heat pumps fail. 2. Possibly examine potential of using increased AHU fresh air delivery temperature. 3. Speak with heat pump manufacturer about recommendations for operation during extreme temperatures to ensure max output without freezing. 4. Ensure plan is in place to reclaim portable heaters.
5	The building has the potential to retain heat with good insulation and thermal mass. UFH system is not reactive and requires low temperature heat input, but for longer than reactive systems. Keep UFH system operational for longer but at lower out-of-hours temperature.	1. Keep the UFH heating system activated for about 20-22 hours/day but set a night-time/weekend set back temperature (based on slab temperature) 4°C below normal operating temperature. 2. Ensure Sunday and early Monday operation sufficient to bring building up to temperature before occupied hours through increasing set-point temperatures.
6	Ensure “comfort” heated areas not overheated.	1. Ensure heating not at excessively high temperatures in these spaces.

7	Monitor and feedback.	1. Monitor internal and external temperatures, feedback to improve heating, keep record of conditions and operational changes.
8	Optimised start-up has been disengaged for some time due to past difficulties with heat pump output and the system has not been allowed to "learn" how to heat the building. After peak-heating season re-engaged optimised functions.	1. Re-engage optimised heating functions in March or April.

The intervention was successful and resulted in a significant energy reduction without any related occupant complaints. Discussing the operation during the peak winter period with the FM, the following has been observed.

Table 6-6 Operational and equipment changes

	Recommendation	*FM action*
1	Ensure ventilation equipment is operational, control strategy functioning to engage the heat exchanger to maximum potential.	The BMS Supervisor schematic was changed to include an AHU damper as well as SPT and heat exchange appeared to be operating during the winter 2012-2013. However control over the AHU is still not possible through the Supervisor. During the winter 2012-2013 the AHU heating & cooling DX compressors were not in operation – this was traced back to poor commissioning with them not being properly pressurised. Despite this, the AHU heat exchanger managed to bring the fresh air up to a reasonable temperature and there were no occupants complaints related to cold air delivery. The compressors were subsequently fixed and have been operating since March 2013.
2	Ensure UFH distribution pumps are in correct setting.	These were changed at the beginning of April 2013. According to the FM they are running at a lower speed and heat exchange has improved.
3	Run AHU only around occupied hours.	AHU operational times were changed as per Table 2.11
4	Create contingency plan	A contingency plan was drawn up but was not required, despite a more severe winter than the previous year.
5	Keep UFH system operational for longer but at lower out-of-hours	The time control for the heat pump and distribution pumps was changed as per Table 2.9. However due to optimisers which were

	temperature.	engaged unknown to the FM, space heating equipment was still coming on Saturday and Sunday evenings. This was changed in March 2013. No night-time set back was set during this winter as recommended - this is still not possible from the BMS. The optimisation control should be investigated to determine if it is ideally suited for UFH – typically a night-time set-back is programmed with this heat emitter system.
6	Ensure “comfort” heated areas not overheated heated.	As initially installed, heating and cooling in “comfort” areas is turned on and off through the BMS timeclock. However there is still no facility to cap and collar temperatures through the BMS. To try to address high thermostatic settings, the FM has made some stickers which state the recommended maximum is 24C.
7	Monitor and feedback temperatures.	Due to the difficulties with data access and storage this was not done over the peak heating season. However a new system was purchased in June 2013 through Trend which included an extra controller to revamp the data collection processes on the existing controllers which enabled historic data, including temperatures, to be stored and accessed.
8	After peak-heating season re-engage optimised functions.	This has been done. Through work with a Trend engineer, it was discovered that the parameters had been set incorrectly at original commissioning. Initially there was a warm up limit set at 10 hrs; this has been changed to 3hrs. A cool down time limit of 0hrs was changed to 1hr as well. Most notably, it was discovered that all BMS optimisers had been originally been set for cooling mode, which could have resulted in the heating difficulties during the first winter before they were turned off. Optimisation features have now been changed to heating.
9	Other enacted or discovered, not previously discussed	Through work with a Trend engineer, it was discovered that there was embedded (tamper proof) weather optimisation for all five heat pump zones. This has now been set and has been working. A housing system has been built (starting in Dec, completed before Christmas) to partially enclose the heat pumps on the roof to try to improve efficiency and prevent icing by increasing their surrounding temperature. Additionally a small volume of ventilation supply air is periodically blown over them during very cold weather (this is a manual operation and thus can only occur during operational hours.

Results show a significant reduction in energy consumption compared to the previous winter, despite a colder 2012-2013 heating season. Figure 6-12 shows overall energy consumption. It can be seen that the 2012-2013 peak heating season profile is greatly affected by the changes in operation, more closely resembling the first winter in energy consumption month by month.

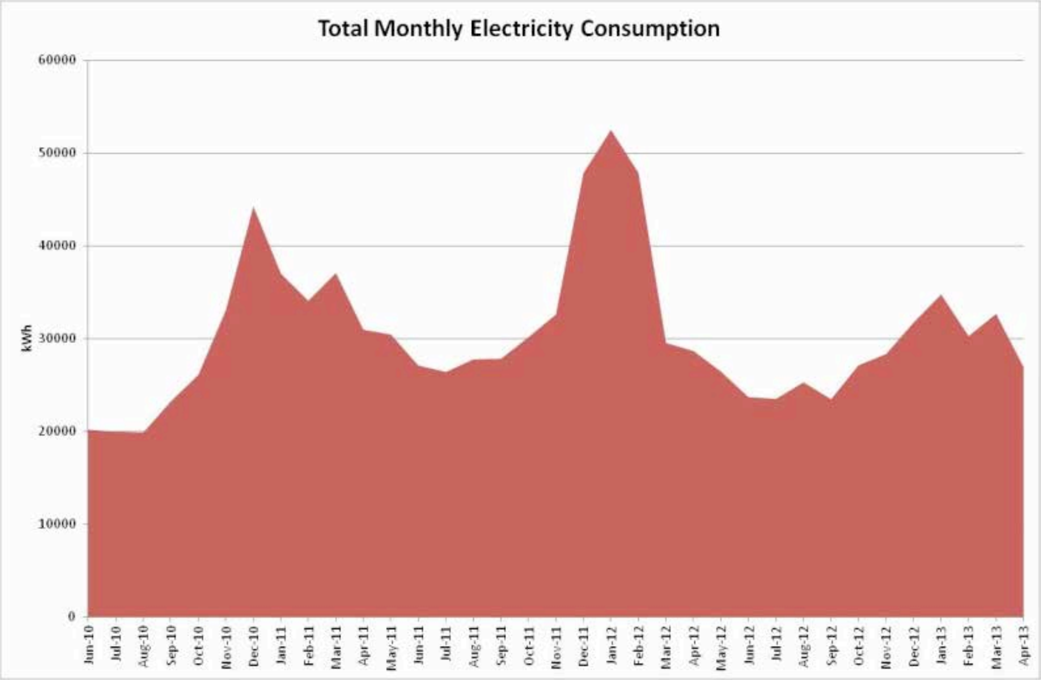


Figure 6-12 Total energy consumption

Figure 6-13 below illustrates the difference in operational profile from the previous two peak heating seasons. It can be seen that during the 2012-2013 season the average baseline has been reduced compared to both previous seasons, and shoulder periods of consumption have been reduced with reduced operational times.

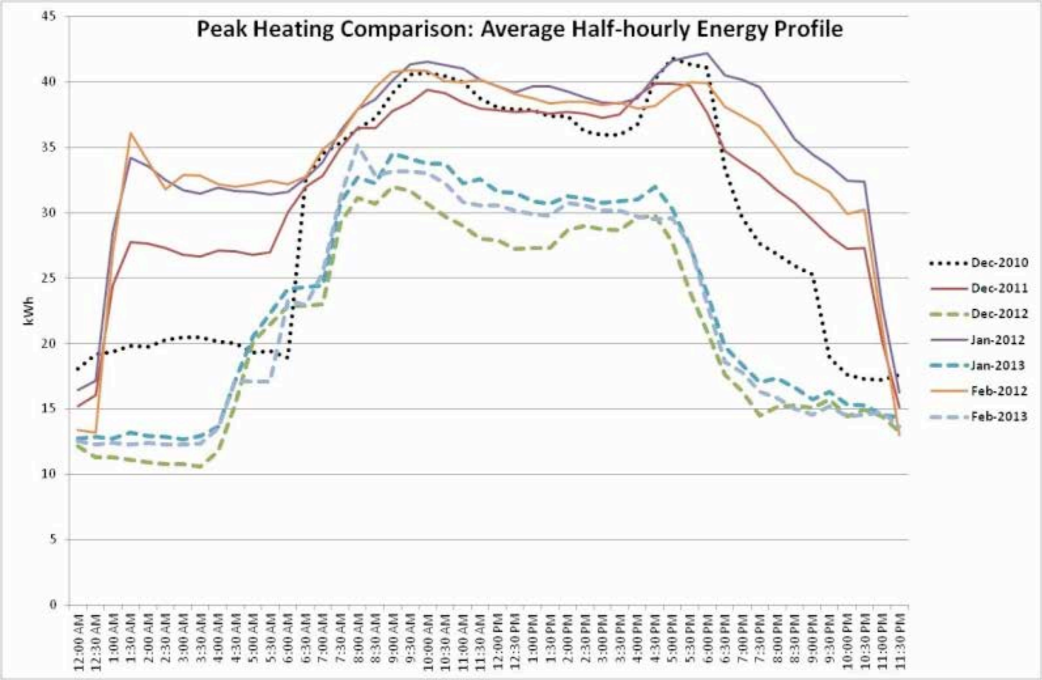


Figure 6-13 Peak heating season profile comparison

Figure 6-14 shows monthly energy consumption by submeter. The reduction in the AHU energy consumption during this heating season stands out. The small increase in AHU energy consumption likely corresponds to the DX heating coming back on line, controlling supply air temperatures. A large increase in heat pump energy (DB Plant) can be seen, as well as a reduction in UFH distribution pump energy (MCCP). Note that the reduction in both of these may in part be due to other operational changes, such as to the DHW system. However it is clear that overall the 2012-2013 season space heating was primarily provided by the heat pumps, in line with the design intention (over the previous season the AHU may have been doing much of the space heating).

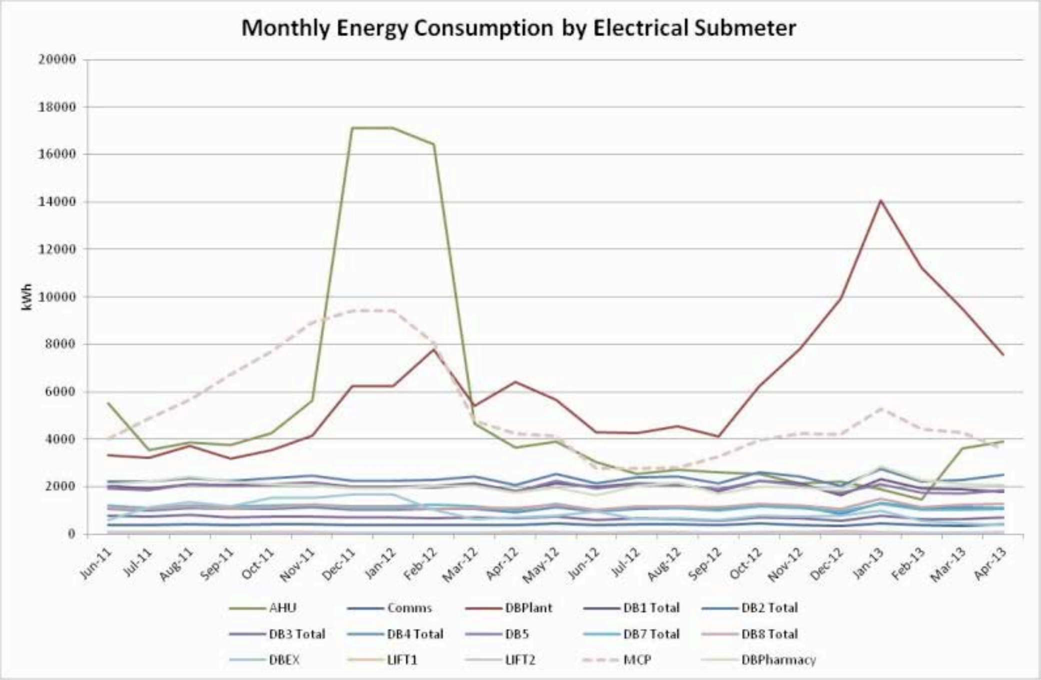


Figure 6-14 Monthly energy consumption by submeter

Energy consumption over 2011-2012 and 2012-2013 (December, January, February) is compared in Table 6-7 and Figure 6-15 below.

Table 6-7 AHU and heat pump energy consumption comparison

Peak heating months *(Dec, Jan, Feb)*	*Air Handling Unit [AHU]* *(kWh)*	*Heat pumps [DB Plant]* *(kWh)*	*Total* *(kWh)*
2011-2012	50,651	20,222	70,873
2012-2013	5,556	35,247	40,803
Difference	*45,095 reduction*	*15,026 increase*	*30,070 reduction*

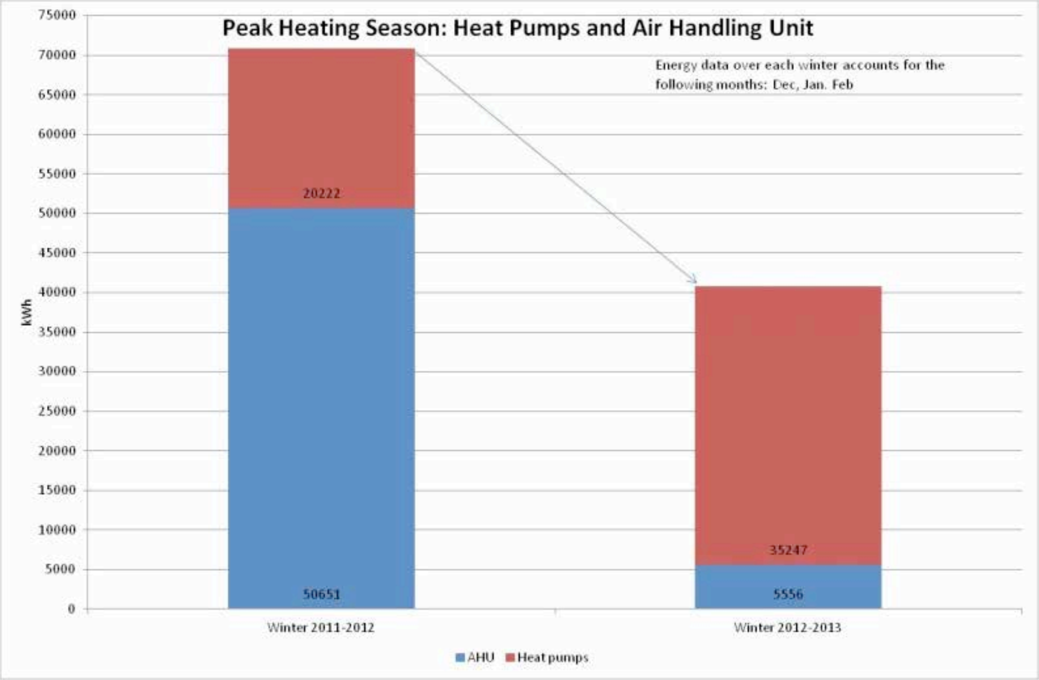


Figure 6-15 AHU and heat pump energy consumption comparison

However without factoring in heating demand it cannot be determined if this reduction is mainly due to warmer external conditions. Table 6-8 compares HDDs over the past two peak heating seasons. It can be seen that there has been a substantial increase in heating demand in 2012-2013. Thus despite colder weather and corresponding increased heating demand, the operational changes have resulted in a decrease in energy consumption. This is examined further in Figure 6-16. This graph plots HDD and heat pump (DB Plant submeter) energy consumption by month. It can be seen that the increase in HDD corresponds to an increase in heat pump energy consumption. Past February 2013, of note is March 2013, which actually had the highest HDD shown in this graph. Despite this, heat pump energy consumption has decreased from the previous 2 months.

Table 6-8 HDD comparison

Peak heating months (Dec, Jan, Feb)	*Heating Degree Days at 15.5°C, Liverpool*
2011-2012	832.1
2012-2013	983.6
Difference	**152**

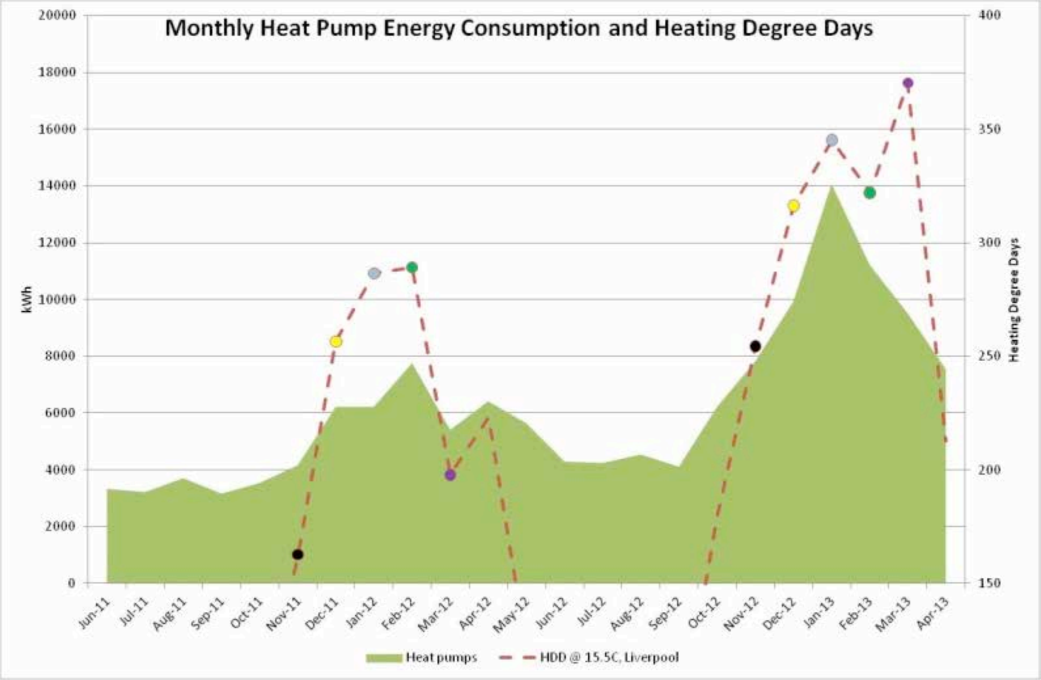


Figure 6-16 HDD and heat pump (DB Plant submeter) energy consumption

Finally, Figure 6-17 examines the correlation between total monthly energy consumption and HDD. A fairly strong correlation can be seen. Note that the peak heating season 2011-2012 has been excluded from the trendline. These data points can be seen as an abberation from normal building operation, as these months had a particularly high energy consumption to HDD ratio.

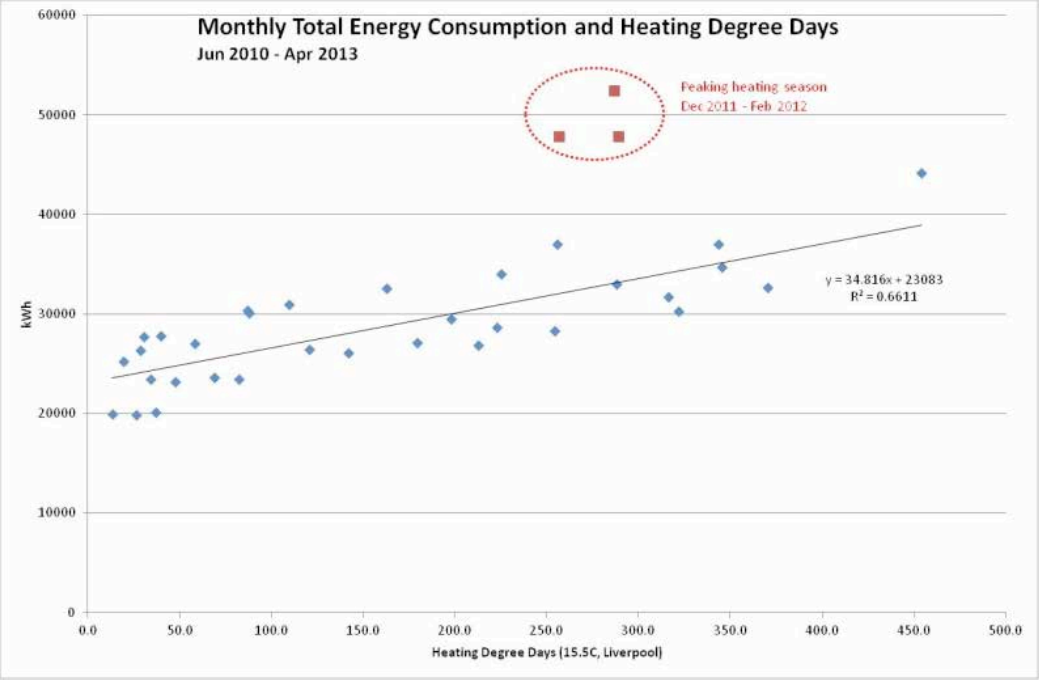


Figure 6-17 Linear regression: HDD and total monthly energy consumption

6.4.2 DHW energy

It was initially thought that some additional submeters and sensors could be purchased to better enable the monitoring of the DHW system. While additional equipment was bought for the solar thermal system, expectations were scaled back as the available budget was consumed with the purchase of the energy management software and resolving the BMS energy data issue. Further, the installation of the heat meter for the solar thermal system proved difficult, as the temperature sensors, ultrasonic flow meter and datalogger have been incompatible with one another and became dysfunctional. In the end, just the surface mounted temperature sensors were installed successfully. These proved useful to better understand how the system was operating, but due to inaccuracies associated with surface mounted sensors, and that no flow meter was also installed, heat input was not quantified.

In Figure 6-18 below, the estimated energy for hot water production at Blue Bell (the calculation is based on the system as-designed, not as-operated) is compared against the following: the TAS calculated demand (note that no TAS inputs were provided to the BPE evaluator); the calculated energy consumed from the electric immersion heaters; the theoretical solar thermal system heat output (calculated using the SAP algorithm); and two hot water energy requirement benchmarks from ECON 19 Type 3 offices (cellular, mechanically ventilated). The calculation for DHW demand assumes the hot water demand is 40% of metered mains cold water, not including months with extraordinarily high demand (see Appendix A), where high consumption is thought to be the result of either leakage or flushing and filling building services systems.

Note as there is not a flow meter installed to record hot water demand it is quite possible that 40% DHW assumption is higher or lower than the actual demand.

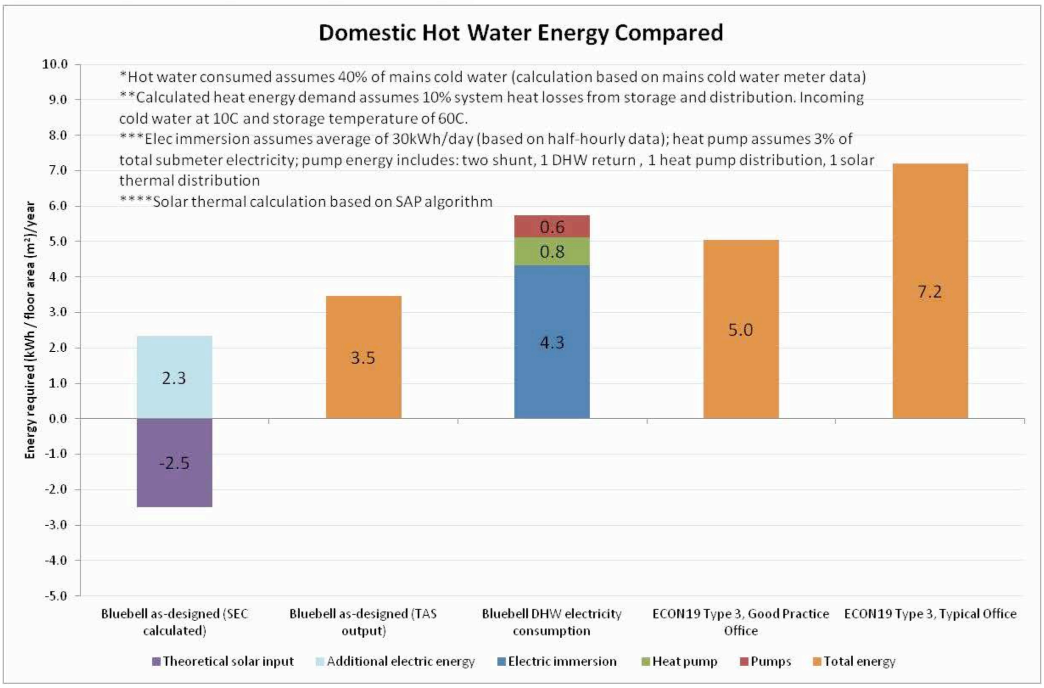


Figure 6-18 DHW benchmarked

Comparing the estimated values in Figure 6-18, it can be seen that the energy currently being used from just the electric immersion elements alone would almost cover the entire as-designed DHW energy demand, including any contributing solar thermal heat. This operation is not as-designed, which was the solar thermal as the lead, followed by the heat pump, and the electric immersion for legionella pasteurisation.

Also interesting to note is the added energy consumption required for centralised hot water storage. The as-designed system electricity requirement at Blue Bell is compared to the in-use requirement and also an instantaneous point-of-use system in Figure 6-19. It can be seen that the energy required to meet the building’s hot water demand (again assuming 40% of mains cold water) using the instantaneous heaters is about equal to the as-designed system (SEC calculated) and less than the as-designed TAS output, while the in-use system is consuming close to 2.5 and over 1.5 times more energy than the as-designed systems, SEC calculated and TAS respectively. This Figure presents a strong argument for the use of de-centralised, instantaneous hot water production, as these systems are much easier to install and operate, from an energy efficiency perspective (thus there is unlikely to be such an extreme performance gap).

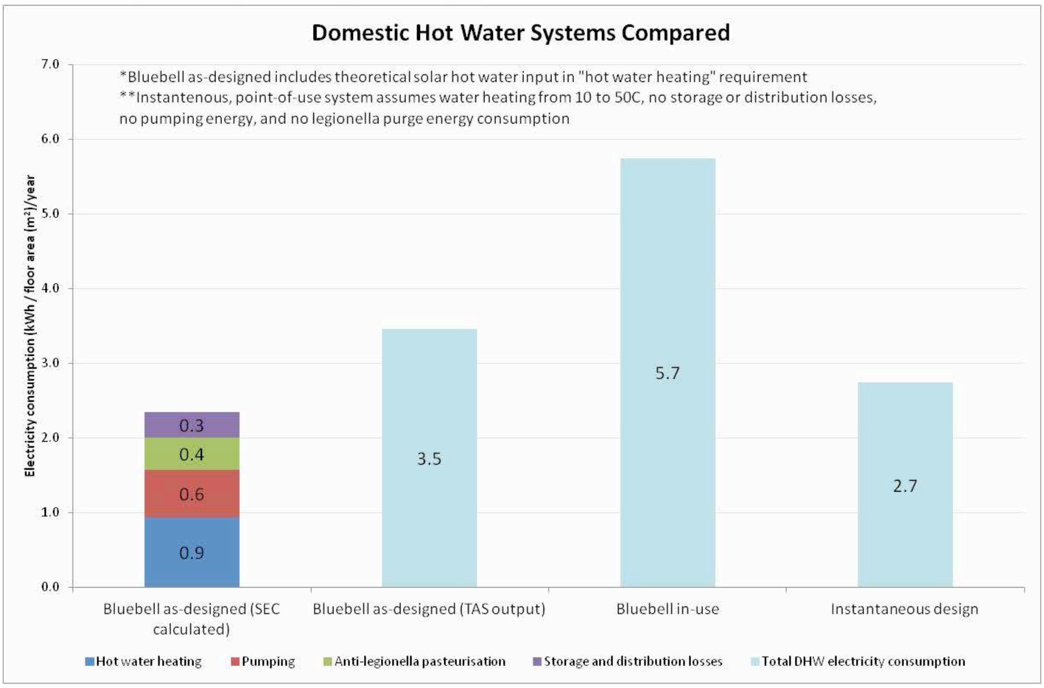


Figure 6-19 DHW systems compared

As previously stated, the design intention was for the electric immersion heaters to be seldom used, primarily for legionella pasteurisation of the 2 no. 900 litre storage tanks. The theoretical energy required for this has been calculated to be approximately 1000 kWh/year, and assumes that the pasteurisation is performed once a week, heating the tanks up from 60°C to 70°C, as is often recommended (and indeed was at one point set-up by the solar thermal suppliers – every Sunday from midnight to 2AM). However half-hourly electricity consumption profiles indicate that the electric immersion heaters are operating each day (including weekends), not just once a week. From the profiles, it would seem that the electric immersion heaters are actually functioning as the primary means of DHW heating.

Energy consumed by the electric immersion heaters on the weekends, when there is no building user demand for hot water, is shown in Figure 6-21. This energy consumed is compared to the energy required for boiling water for making tea.

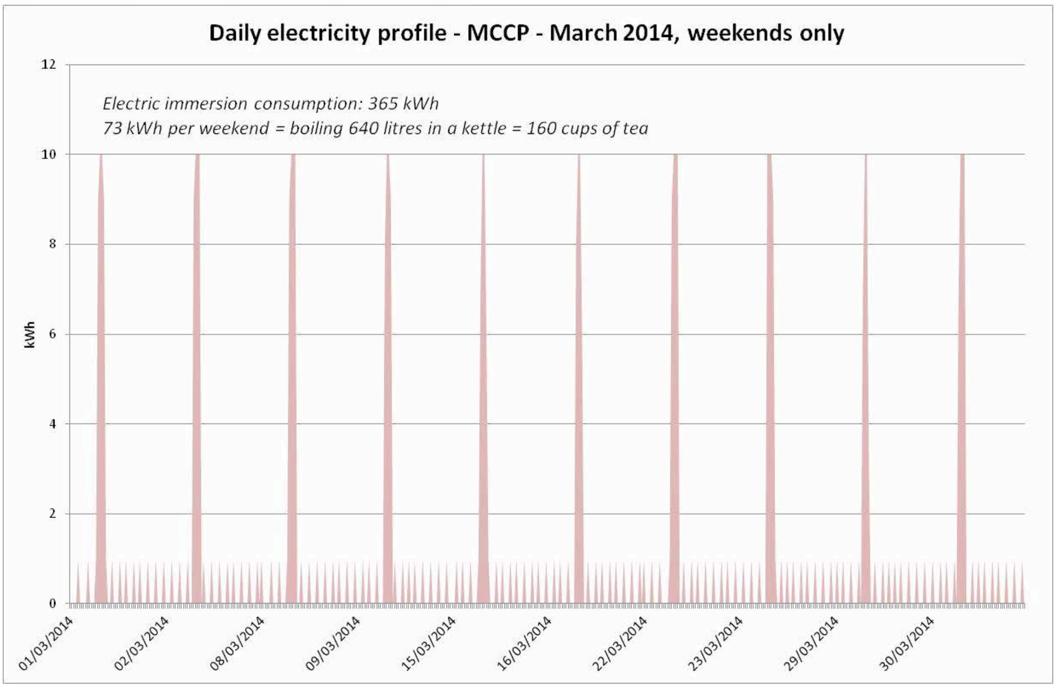


Figure 6-20 MCCP energy consumption, March 2014

As previously stated, surface mounted temperature probes were used to gain a better understanding of how the DHW system, in particular the solar thermal input, was being operated. The solar system was installed as stand-alone, and the FM has no time control over it. The FM has very limited control over the other system components as well, such as the electric immersion heaters and heat pump.

Figure 6-22 shows solar thermal operation with MCCP energy consumption over a week during March 2014. The high morning spikes in energy on the MCCP will be entirely due to electric immersion energy consumption during this month. Figure 6-23 shows operation over a weekend day, where the spike in energy consumption due to the electric immersion elements can be more clearly seen.

It can be seen that the electric immersion heaters come on before the solar thermal system becomes active. This will have the effect of preventing the solar thermal system from contributing much heat to the storage vessels. In fact, looking at the day profiles, it can be seen in the morning that the return temperature to the panels is higher than the solar flow to the vessels – this shows that the solar thermal system is effectively cooling the hot water stores, which have recently been heated by the electric immersion heaters. From these graphs, solar heat contribution can be seen to be minimal (as shown by the limited temperature difference, which is sometimes negative), mitigated by the cooling effect they are having in the morning. This demonstrates the need to change the electric immersion heating times to give the solar system a chance to provide some heat to the system.

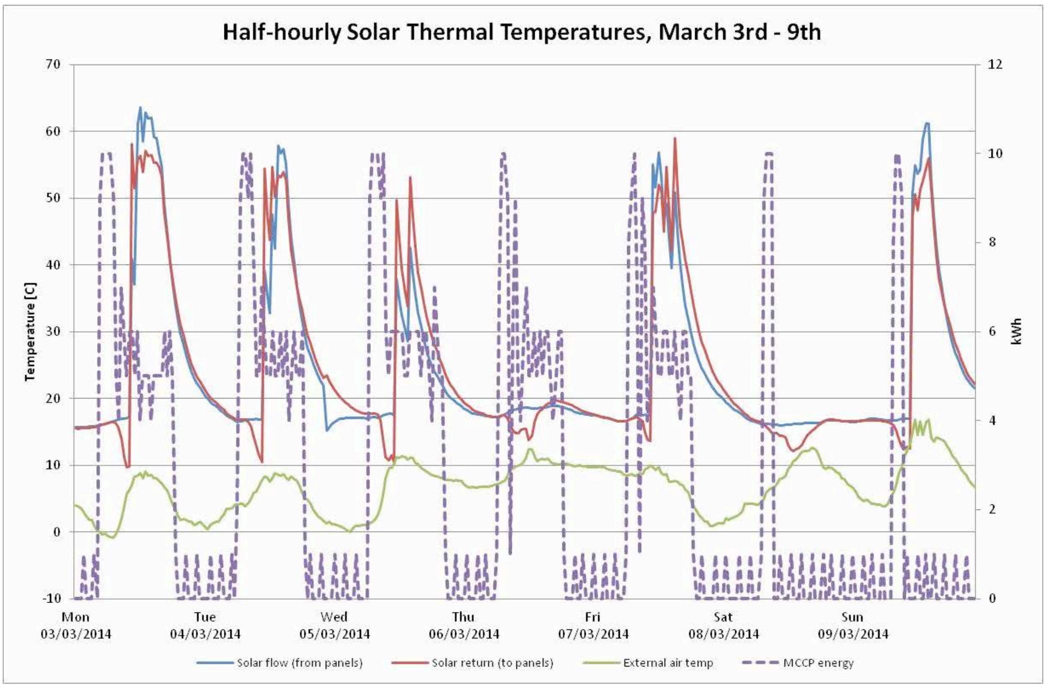


Figure 6-21 Solar thermal system temperatures and MCCP energy in March 2013

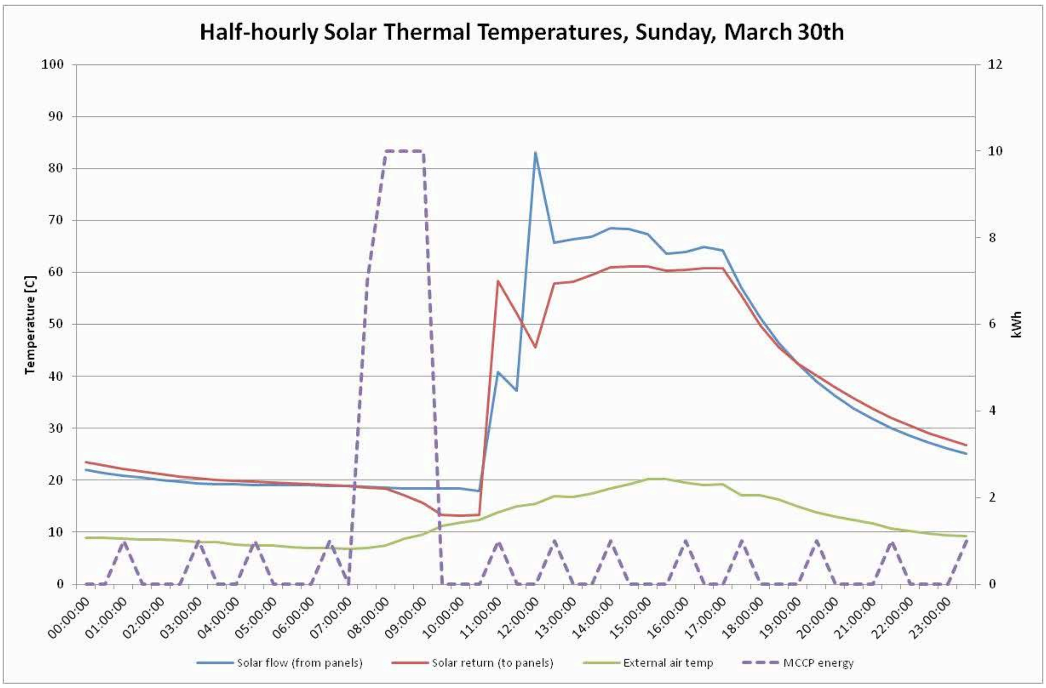


Figure 6-22 Solar thermal system temperatures and MCCP energy over March 30th 2014

These findings were presented to the FM and evaluation project team. A trial of changing the electric immersion operation time to later in the day was agreed. The results can be seen in Figures 6-23 and 6-24 below.

From Figure 6-23 (a Saturday), it can be seen that there is an improvement in the morning operation of the solar system, with the electric immersion not coming on until 14.30. After this the solar return can be seen to increase and surpass the flow temperature at around 17.00. However in Figure 6-24 (a Tuesday), it appears that the timeclock was not changed for this day.

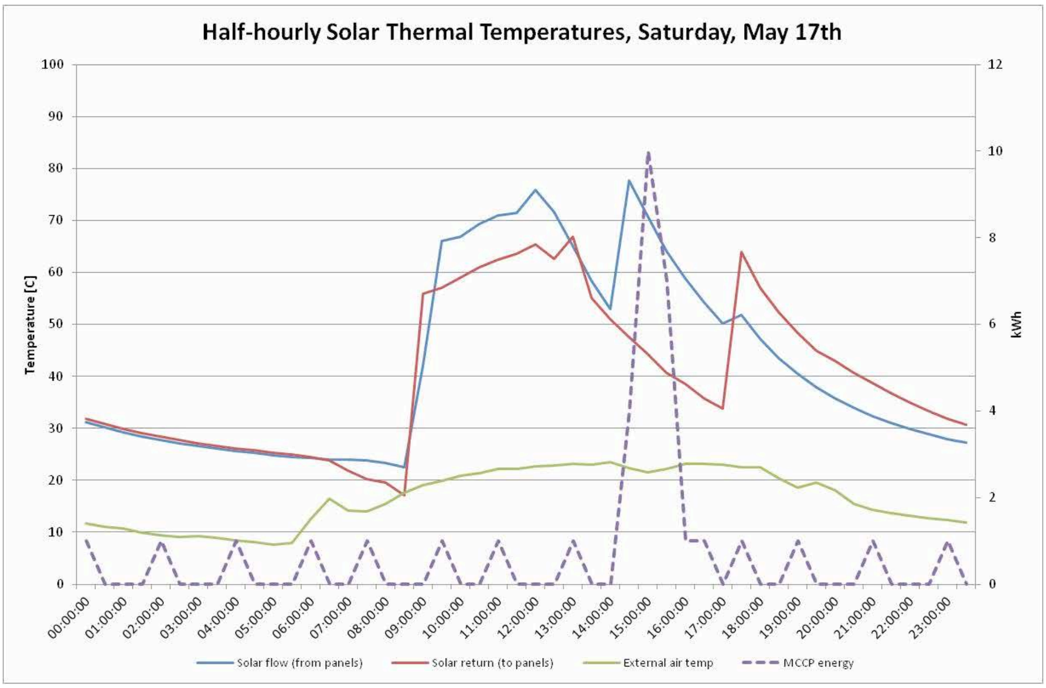


Figure 6-23 Solar thermal system temperatures and MCCP energy over May 17th 2014

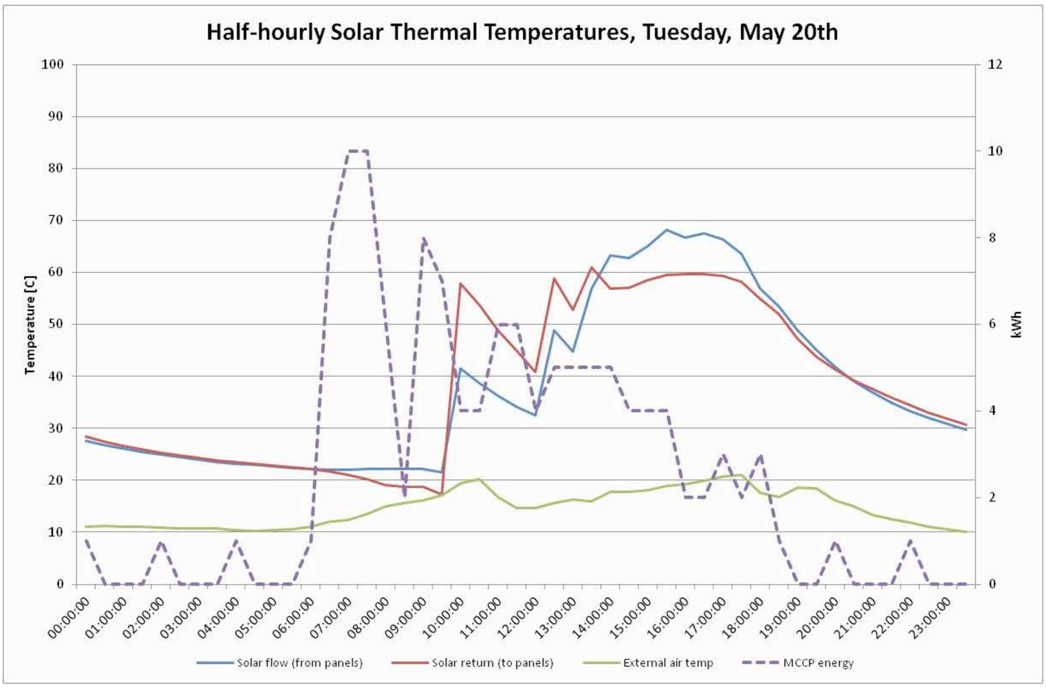


Figure 6-24 Solar thermal system temperatures and MCCP energy over May 20th 2014

In commercial solar thermal systems, maximising the potential of the solar thermal energy while still operating legionella pastuerisation cycles (where the storage temperature typically exceeds 70°C for a short period) requires careful design and control. Requirements for mitigating legionella are found in the HSE Code of Practice and Guidance L8, 'The control of legionella bacteria in water systems'. However, it is not clear from this document how frequently the anti-legionella cycle should be operated. In practice, this often occurs at least once a week for an hour. From the data collected, it seems that this is happening once a day at Blue Bell, although it is not clear what temperature the storage cylinders are being heated to. Even heating up the cylinder to a storage temperature of 60°C could negate a considerable amount of possible solar heat. As the FM stated that the supplied heat pump struggled to get the cylinder up to 60°C it seems that the electric immersion element is required for operation.

Some operational guidance for commercial solar hot water systems recommends operating the legionella pasteurisation at the peak of hot daily hot water demand. Figure 6-25 shows a typical daily mains water consumption profile for Blue Bell. Although this is for mains and rainwater, the hot water demand should be very similar. Unfortunately there were issues with the half-hourly mains data during the months of the solar thermal analysis so they could not be overlayed together. However, it appears that the peak is close to building opening time – this was when the electric immersion was being operated. Commercial buildings often require a stricter legionella control and have a different demand profile to domestic buildings. In Blue Bell, hot water demand is occurring at the same time as peak solar thermal production. This is not the case with domestic profiles, with demand occurring before and after peak hours of solar thermal production.

It is not clear how to get the most out of the solar thermal system given the twin coil set-up with electric immersion heaters in each cylinder. As discussed in Appendix H, the solar system manufacturer attended site and produced some recommendations, although this was not seen as providing a clear way forward by the team. Potentially a different installation, utilising a dedicated solar thermal store could provide better control and maximise solar thermal contribution. However given the theoretical limitations discussed above, a stronger case needs to be made if this technology is to be utilised again in health care premises. Further, in similar buildings with low hot water demand, de-centralised, instantaneous point-of-use heaters should be the favoured option.

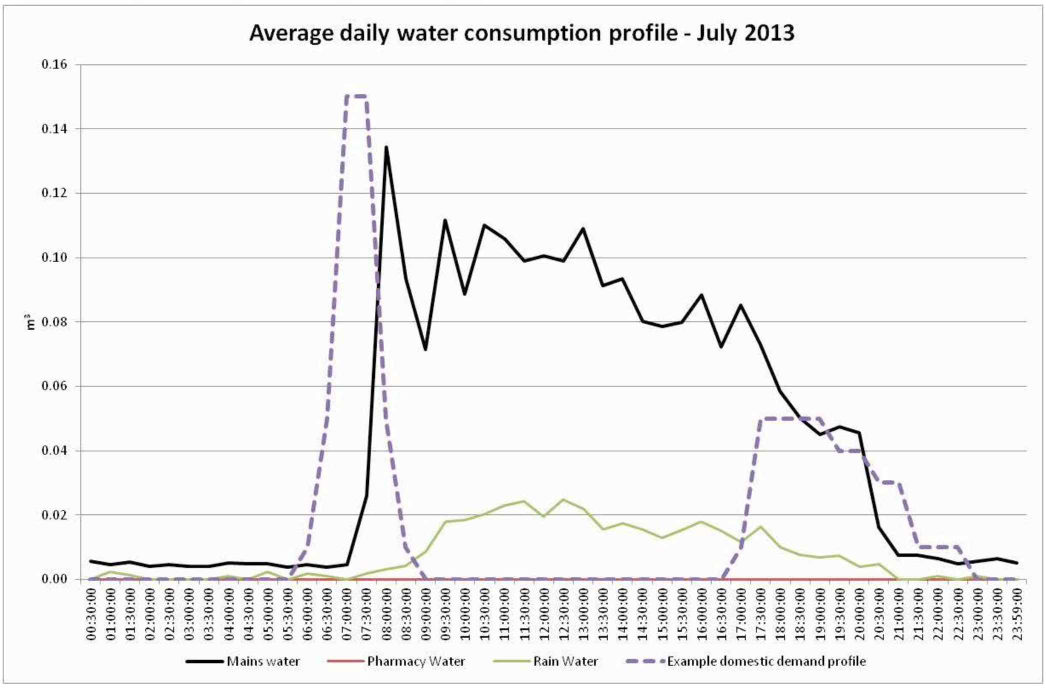


Figure 6-25 Water demand profile

6.5 TM22 Outputs

Summary TM22 outputs are shown in this section. More information can be found in Appendix L. Energy data used in TM22 is a combination of half-hourly mains data and manually recorded monthly energy consumption by submeter (by the FM), used to populate the Detailed Assessment section. Energy data used is from the period 01/06/2013 through 31/05/2014.

The Figure below compares energy supplied to Blue Bell to the DEC and Logbook (user specified) values. As Blue Bell is all electric, the benchmark for the DEC energy is somewhat limited – a better comparator therefore is CO_2 emissions, shown in Figure 6-27. It can be seen that Blue Bell betters the DEC Typical benchmark but is considerably larger than Logbook benchmark.

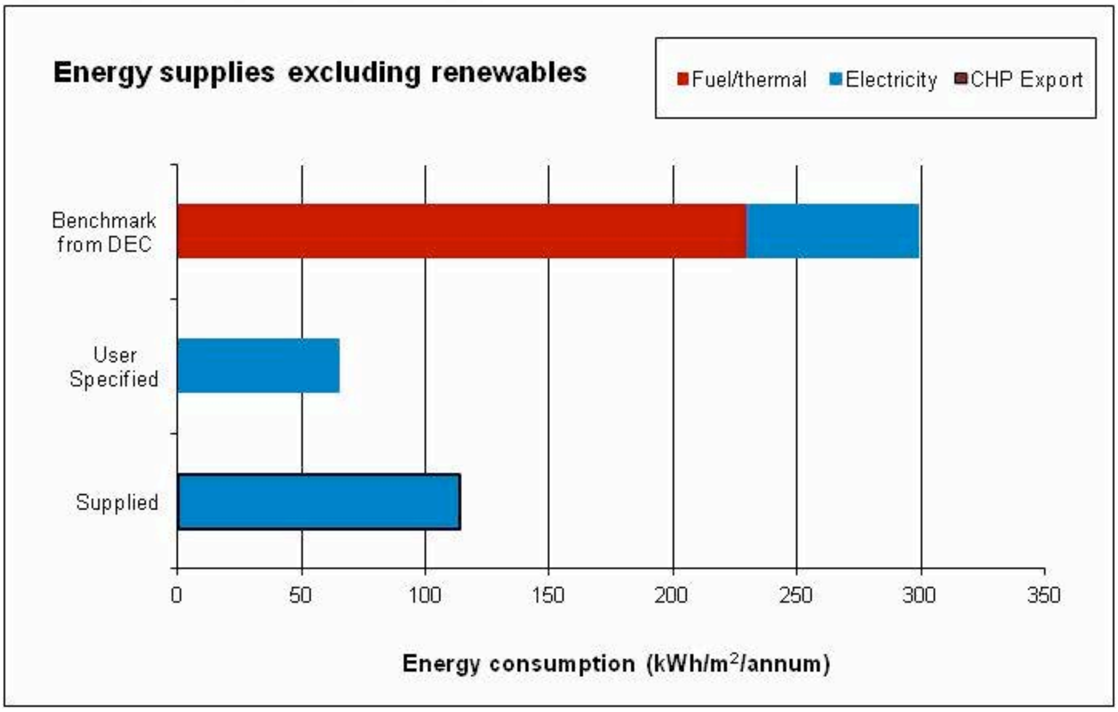
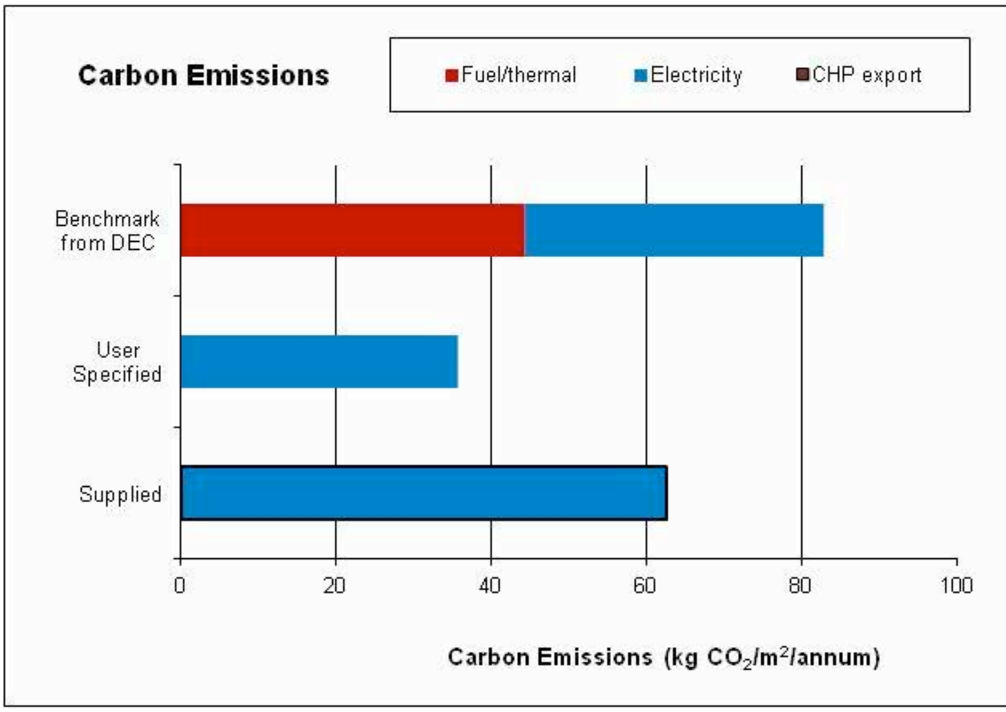


Figure 6-26 Energy supplies benchmarked against the Logbook and DEC



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

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

Figure 6-27 CO_2 emissions benchmarked against the Logbook and DEC

Energy consumption at Blue Bell is examined by ECON 19 end-uses and compared to a Type 3 office (air conditioned, standard). Note that this is the most appropriate Type available, even though Blue Bell has mixed mode ventilation and a combination of open plan and cellular rooms.

Energy consumption by end-use is compared to ECON 19 benchmarks in the Table below. In the Table, where in-use energy at Blue Bell is better than the 'Good Practice' benchmark, these end-uses have been highlighted green. It can be seen that space cooling, air movement, lighting, household/office appliances and cooking all better the 'Good Practice' benchmarks. As discussed in the Final Report, inefficiencies with the use of the pumps and controls were identified.

Table 6-9 ECON 19 end-use energy benchmarked

System	**Electricity demand (kWh/m2/year)**		
	In-use electricity (kWh/m^2/year)	**Typical benchmark (kWh/m2/year)**	**Good practice benchmark (kWh/m2/year)**
Space Heating	23.8		
Domestic hot water	10.0		
Space cooling	4.7	27.9	12.6
Air movement	11.3	37.8	19.8
Pumps and Controls	10.1	16.2	7.2
Lighting	20.7	48.6	24.3
Household/office appliances	13.6	27.9	20.7
ICT Equipment/computer room	5.8	5.8	5.8
Indoor transportation	0.6		
Cooking	3.1	5.4	4.5
Cooling Storage	0.0		
Other electricity	7.9	7.2	6.3
Total	**111.5**	**176.8**	**101.2**
Metered building energy use	113.8		
Variance TM22 versus metered total	-2.2		
Variance TM22 versus metered total	-2%		

Carbon emissions for Blue Bell is compared to ECON 19 benchmarks in the Figure below. It can be seen that although Blue Bell betters the 'Typical' benchmark, it still exceeds the 'Good Practice' benchmark.

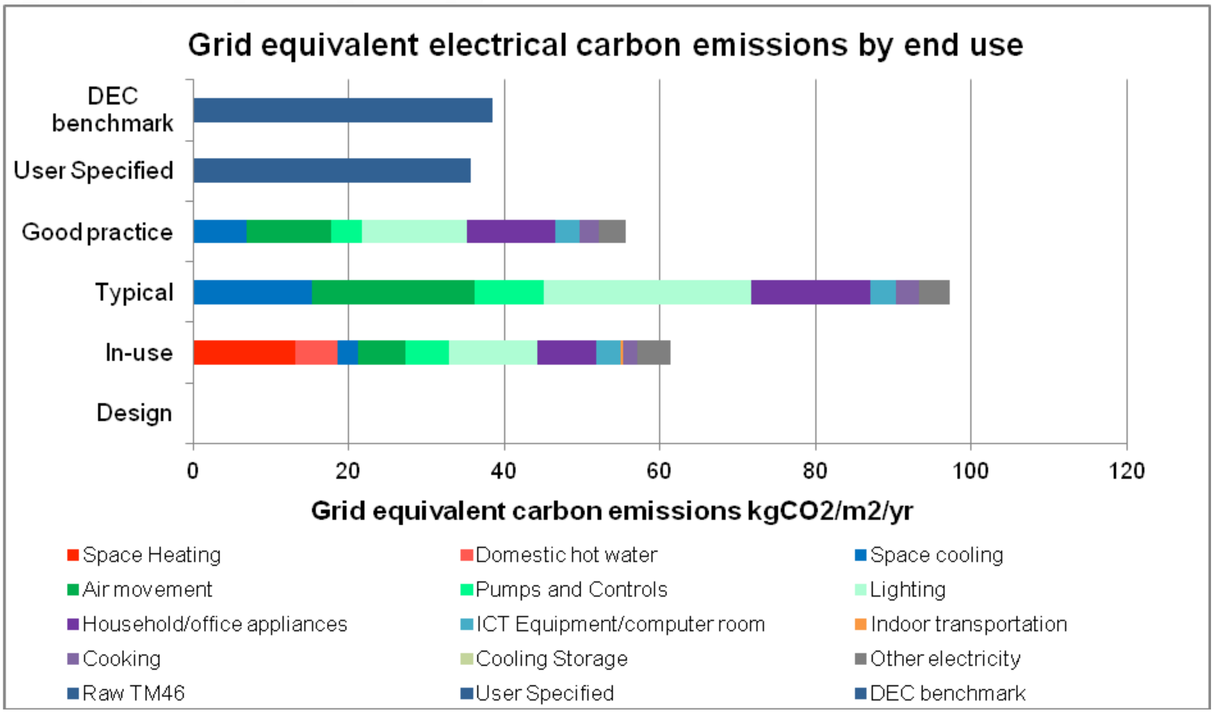


Figure 6-28 ECON 19 CO2 emissions benchmarked

7 Technical Issues

Technology Strategy Board guidance on section requirements:	This section should review the underlying issues relating to the performance of the building and its systems. What are the technical issues that are leading to efficiency results achieved to date? Are the automated or manual controls effective, and do the users get the best from them? Are there design related technical issues which either need correcting/modifying or have been improved during the BPE process? Did the commissioning process actually setup the systems correctly and, if not, what is this leading to?

7.1 Introduction

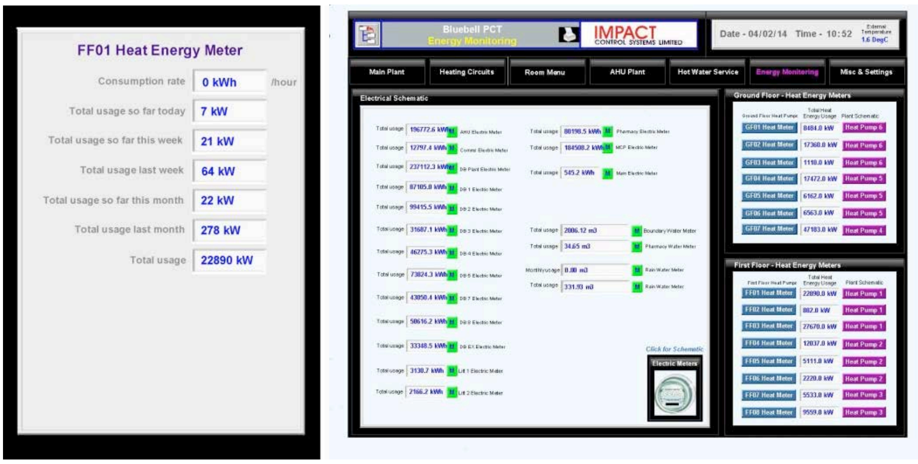
Throughout this programme many issues have been identified which have negatively impacted energy consumption and occupant comfort, some much more significantly than others. Some of these issues were addressed through interventions, which are detailed in Appendix C. However there remain ongoing problems, primarily related to the BMS and mechanical ventilation and DHW services. While these problems are multi-causal, common themes emerge which include: lack of detail in design documentation, poor installation, confusing or unusable interfaces, and a lack of understanding of how the building was intended to be operated.

7.2 BMS

The FM has had some difficulty using the BMS interface. Some of this stems from lack of formal training, but much actually is a combination of factors such as: frequent system log-off; the PC running the Supervisor was not up to the task (very slow); many system components were not (as originally installed) visible, such as the ventilation recuperator, while some system components are visible but not controllable; and the BMS has some command over some systems, like the “Comfort” and Comms heating/cooling systems, but this is not visible or accessible by the FM over the Supervisor, and thus it is not known how the BMS is actually controlling these systems, and in some cases it appears that the BMS is overriding desired local controls.

Figure 7-1 BMS controller screen (L); BMS Supervisor schematic, DHW screen shown (R)

The BMS Supervisor was installed on a PC with inadequate memory to operate the software. As such, the system stalls frequently and operates very slowly, making operation frustrating for the FM. Additionally no other software programs, such as Energy Management programmes, could be installed without upgrading or replacing the PC.



FF01 Heat Energy Meter

Consumption rate: 0 kWh /hour
Total usage so far today: 7 kW
Total usage so far this week: 21 kW
Total usage last week: 64 kW
Total usage so far this month: 22 kW
Total usage last month: 278 kW
Total usage: 22890 kW

Bluebell PCT Energy Monitoring
IMPACT CONTROL SYSTEMS LIMITED
Date - 04/02/14 Time - 10:52 External Temperature 1.6 DegC

Electrical Schematic

Total usage 196772.6 kWh AHU Electric Meter
Total usage 12797.4 kWh Control Electric Meter
Total usage 237112.3 kWh DB Plant Electric Meter
Total usage 87105.0 kWh DB 1 Electric Meter
Total usage 99415.5 kWh DB 2 Electric Meter
Total usage 31687.1 kWh DB 3 Electric Meter
Total usage 46275.3 kWh DB 4 Electric Meter
Total usage 73824.3 kWh DB 5 Electric Meter
Total usage 43050.4 kWh DB 7 Electric Meter
Total usage 50616.2 kWh DB 8 Electric Meter
Total usage 33348.5 kWh DB EX Electric Meter
Total usage 3130.7 kWh Lift 1 Electric Meter
Total usage 2166.2 kWh Lift 2 Electric Meter
Total usage 80198.5 kWh Pharmacy Electric Meter
Total usage 184508.2 kWh MCP Electric Meter
Total usage 545.2 kWh Main Electric Meter
Total usage 2006.12 m3 Boundary Water Meter
Total usage 34.65 m3 Pharmacy Water Meter
Monthly usage 0.00 m3 Rain Water Meter
Total usage 331.93 m3 Rain Water Meter

Ground Floor - Heat Energy Meters

Ground Floor Heat Pumps	Total Heat Energy Usage	Plant Schematic
GF01 Heat Meter	8484.0 kW	Heat Pump 6
GF02 Heat Meter	17360.0 kW	Heat Pump 6
GF03 Heat Meter	1110.0 kW	Heat Pump 6
GF04 Heat Meter	17472.0 kW	Heat Pump 5
GF05 Heat Meter	6162.0 kW	Heat Pump 5
GF06 Heat Meter	6563.0 kW	Heat Pump 5
GF07 Heat Meter	47183.0 kW	Heat Pump 4

First Floor - Heat Energy Meters

First Floor Heat Pumps	Total Heat Energy Usage	Plant Schematic
FF01 Heat Meter	22890.0 kW	Heat Pump 1
FF02 Heat Meter	882.0 kW	Heat Pump 1
FF03 Heat Meter	27670.0 kW	Heat Pump 1
FF04 Heat Meter	12037.0 kW	Heat Pump 2
FF05 Heat Meter	5111.0 kW	Heat Pump 2
FF06 Heat Meter	2220.0 kW	Heat Pump 2
FF07 Heat Meter	5533.0 kW	Heat Pump 3
FF08 Heat Meter	9559.0 kW	Heat Pump 3

Figure 7-2 BMS energy metering displays (fixed during this evaluation)

Although a separate screen for energy and water meters was provided on the BMS Supervisor, accessing and viewing energy data, both current and historical, has been problematic. Through investigations and discussion with controls specialists, prompted by the TSB evaluation programme, many problems with the original set-up came to light. These included:

- The BMS Supervisor had not been set-up to provide useful display of energy data. The graphical outputs available (which had been set-up by the installer) presented energy consumption as a continuously increasing straight line (energy consumption increasing over time), providing no useful information as to daily profiles or even daily consumption.

- Energy data was not set-up to be stored on the desktop computer. This can be done without a BMS engineer present, but doing it is not straight forward, nor is finding the data file. Eventually the BMS engineer (from the manufacturer) sat down with the evaluator and FM to do this. Data can be recorded for other inputs as well, such as temperature. Subsequently we attempted to download the data, but it seems the system had not in fact begun recording. However, at this stage another software programme (purchased from the BMS manufacturers) had been installed.

- It was discovered that some historical energy information was available for only a few days. Additionally a few submeter readings remained static. To investigate why this was occurring, a BMS engineer was called out. It was determined that this issue stemmed from the way energy data was being recorded on the BMS controllers. The BMS controllers have a limited memory capacity, but instead of data being overwritten on some controllers, no new data was recorded. This was because multiple energy data acquisition routines had been programmed and had overloaded the controllers. Instead of each controller being set-up to record energy data every half-hour, and then re-write that data with new data after the data had been stored on the hard drive, each had been programmed to record data at multiple time increments: every half-hour, daily sum, weekly sum, monthly sum, yearly sum. It was these redundant routines that had overloaded the controllers.

- Although small power and indoor lighting is effectively split (but needs to be subtracted out) on many DB submeters throughout the building, by “Top section load” and “Total load”, it was found that only the “Total load” submeters were linked to the BMS. This means that small power and indoor lighting, individually, are not being directly submetered, and half-hourly energy data for these DBs thus includes the two added together. This was disappointing to discover, as the energy management software programmes can utilise ‘virtual’ meters to subtract the two.

Subsequently some ICQ controllers were wiped, energy data acquisition routines re-programmed, and the Trend Energy Management software purchased and installed on a PC at Renova’s HQ. This software now enables the recording and analysis of submetered data at Blue Bell.

7.3 Energy management software

An energy management software programme was purchased from Trend, the suppliers of the BMS, called Trend Energy Manager (TEM). This software periodically takes data from the BMS controllers storing it. It has great capabilities for energy management, having built in graphical functions, and emailed alerts when energy consumption on a submeter exceeds the set profile. These alerts provide a great check that the BMS controlled systems are behaving as expected.

However there have been installation problems with this programme. These include:

- When the computer on which TEM was installed would hibernate or was shut down it resulted in data loss. It is unclear why this should be the case as the data would still be stored on the BMS controllers. For this evaluation, this has resulted in three significant periods of data loss, which has somewhat limited energy analysis.
- Initially the Trend engineer sent to Renova's head office to install the software had received no instructions and did not know what to do when he arrived. He thus did not set up the system as specified: some data was taken every 15 minutes while some every 30 min; daily sums were unnecessarily recorded for each time interval; alerts were not set up; and no report templates were set up.

The above issues were eventually resolved with further on-site call-outs. Alerts were also set-up – however one for each submeter has proved excessive, generating copious 'exception' emails. This is being changed so alerts are only generated on submeters with larger building services plant. In the end, manual monthly submeter readings and the half-hourly mains AMR&T software proved to be the most reliable source for energy consumption information.

7.4 Lighting

There have been issues with PIR sensors. In one location, a PIR sensor was being set off by car lights from nearby road. The FM resolved this problem by setting up a shield to block road light. In another area, in the hallway of the unoccupied surgery, movement in the neighbouring surgery often sets this light off.

Occupancy sensing seems to be a mix of presence and absence detection not only for different spaces, but in many spaces a hybrid has been installed. Looking at construction drawings and the M&E specifications, exact operation is not detailed (which spaces should be presence or absence, what the timeout should be). It was found in multiple consulting rooms that the opposite form of absence detection was actually commissioned: the lights automatically turn on upon entry, but the occupant must physically turn the lights off when leaving. The FM confirmed they had encountered this problem (lights were seen left on overnight) and building management ask cleaners to manually switch the lights off at the end of the day. As with some other equipment under warranty, the FM has not changed settings on any PIRs.

Another issue with lighting control involves the light switches. This was brought up both by Renova and the FM and seems to have caused confusion for some occupants. There are two types of switches around the building – physically they look very similar, but have slightly different functionality. One is a straight-forward switch, while the other requires that the switch is pushed and held to turn off the lights. Holding down the switch when turning the lights on allows some lights to dim as well.

From discussions with the occupants, this issue was confirmed. Occupants found the light switches frustrating, although this seemed to be more of an irritant than something that was impairing working (lights were not turning off when patients were still in the room, for example). However 4 out of 5 occupants interviewed did not know that some lights could be dimmed.

Although the building was carefully designed to optimise daylight penetration while avoiding excessive solar gains, as installed and operated, the electric lighting in most core areas was on throughout operational hours, regardless of the amount of natural light. As originally installed, lights in these areas did not have the capability to be dimmed, either manually or with daylighting control. Additionally, it was not possible to switch lights off closest to higher daylit areas as the installed lighting control boxes are linked to luminaires linked throughout these rooms, not parallel to glazed areas.

Further, in the ground floor office, the provision of occupancy sensing lighting (presence detection) without a manual switch has resulted in the occupants unable to use or maximise the use of natural light from the window - they do not use the blinds at all, and when occupied, the artificial lights are always on.

Through discussions with the project team the FM made the following changes: nearly half the type P luminaires on the ground floor (rooms G43 and G44) were unplugged and in some of these luminaires one of the 18W bulbs has been removed (most of these have subsequently been plugged back in due to lower natural light levels during the winter); half of the type N lights on the ground floor around the stairwell were unplugged; a daylight sensor was retrofitted on the ground floor and first floor on the row of lights closest to the windows which turns these lights on or off (no dimming). According to the FM, an additional control box was not required for this, and the intervention was inexpensive (under £50 parts for each floor).

Figure 7-3 Disconnected lights in GF43

7.5 Comfort cooling

Control over this system is very similar to other installed systems: the BMS has some hierarchal command, sometimes overriding local control, but the FM cannot get access to or examine what exactly the BMS has been programmed to do, as nothing is visible on the Supervisor. In the case of the “comfort” system, the FM is locked out from changing some local control settings, such as the timer and capping and collaring temperatures. So while there may be centralised temperature setting limitation, it has not been possible to determine what this is. Further, although there is an “OFF” button on the local controller, according to the FM, this button does not override the central BMS control.

From the BUS survey and occupant interviews, occupants on the first floor perceive summer conditions to be very hot and stuffy. As previously discussed in Section 4, first floor occupants stated that they had difficulties with opening the windows (issues with the restrictors) and were unsure about leaving windows and doors open to get a cross-flow of air during the summer from a Health & Safety perspective. The use of window restrictors that allow more than 100 mm opening is being explored by the FM. Further, the domestics have been requested to open the windows at the ends of the corridors at the start of each day.

7.6 Ventilation

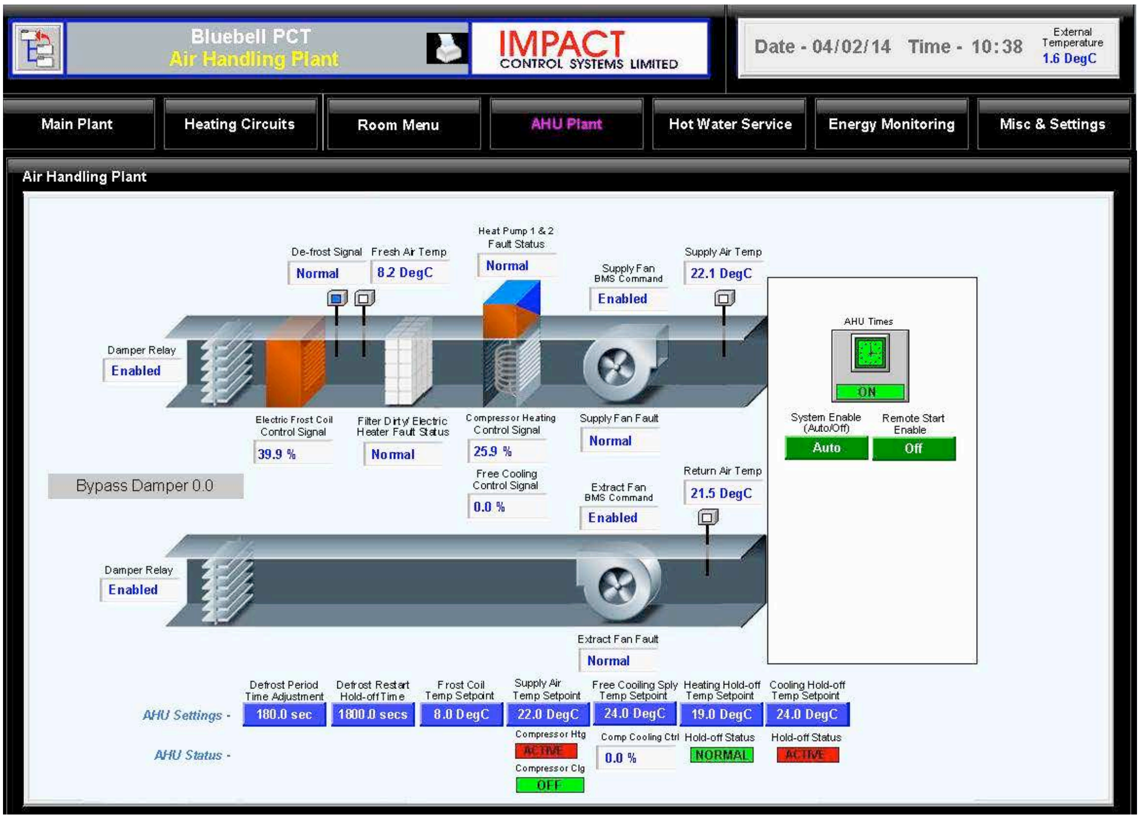
According to the control specification provided by the installers, fresh air supply temperature is controlled thus: the electric frost heater protects the filters, bringing the air up to 10°C. A temperature sensor, TS1, is positioned downstream of the frost heater. Another temperature sensor TS2, on the leaving supply air, signals the bypass damper and the DX heating/cooling coil to operate. If heating demand is recognised, the bypass should be fully closed, and will modulate open if the set-point temperature is exceeded (stage 1). The second stage of control involves the DX unit providing heating and cooling to the fresh air supply. During DX defrost mode, the recirculation damper is activated and a proportion of extract air is mixed with supply air.

There was considerable confusion among the TSB evaluation team about what components were actually installed in the AHU as it appeared that only one damper was functioning. In the Mechanical Services specification from the M&E designers and the control specification, there is a clearly written requirement for a heat exchanger bypass to enable free-cooling.

During the winter of 2011-2012 (Dec – Feb) the ventilation system was run 22 hours per day in an attempt by the FM to avoid the same under-heating issues encountered the previous winter. During this time, it was thought that the heat exchanger bypass damper motor had failed while in bypass mode (this was discovered 13/04/2012, after the peak heating season had passed), but as this was missing from the BMS Supervisor, this was not detected. It was thought therefore that the heat exchanger could have been bypassed during this whole period.

However once inspected and operational temperatures examined on the BMS (during the summer 2013) it became clear that a heat recovery bypass damper was never installed – only a recirculation damper.

Until May 2012 the damper status was not visible on the BMS Supervisor; it was subsequently made visible (and incorrectly) labelled as a “bypass damper” in April 2013. As originally installed, not only did the FM not have the capability to change AHU controls - he could not see how the AHU was operating. Full control is still not possible from the BMS.



Date - 04/02/14 Time - 10:38
External Temperature 1.6 DegC

De-frost Signal: Normal
Fresh Air Temp: 8.2 DegC
Heat Pump 1 & 2 Fault Status: Normal
Supply Fan BMS Command: Enabled
Supply Air Temp: 22.1 DegC
Damper Relay: Enabled
Electric Frost Coil Control Signal: 39.9 %
Filter Dirty/ Electric Heater Fault Status: Normal
Compressor Heating Control Signal: 25.9 %
Supply Fan Fault: Normal
System Enable (Auto/Off): Auto
Remote Start Enable: Off
Bypass Damper 0.0
Free Cooling Control Signal: 0.0 %
Extract Fan BMS Command: Enabled
Return Air Temp: 21.5 DegC
Damper Relay: Enabled
Extract Fan Fault: Normal

AHU Settings - Defrost Period Time Adjustment: 180.0 sec; Defrost Restart Hold-off Time: 1800.0 secs; Frost Coil Temp Setpoint: 8.0 DegC; Supply Air Temp Setpoint: 22.0 DegC; Free Cooling Sply Temp Setpoint: 24.0 DegC; Heating Hold-off Temp Setpoint: 19.0 DegC; Cooling Hold-off Temp Setpoint: 24.0 DegC

AHU Status - Compressor Htg: ACTIVE; Compressor Clg: OFF; Comp Cooling Ctrl: 0.0 %; Hold-off Status: NORMAL; Hold-off Status: ACTIVE

Figure 7-4 BMS Supervisor, AHU

While the specification clearly states a requirement for free-cooling, that capability has not been installed. During the summer of 2013 once AHU temperature sensors became visible on the AHU, these temperatures were examined to determine how the system was functioning. During this time there was a cooling demand in some comfort cooled rooms. It was found that no free-cooling was possible. While the fresh, outside air could have been introduced directly (bypassing the heat exchanger) without treatment and would have helped somewhat to improve working conditions (overheating is experienced in the summer), it instead passed through the heat exchanger, picked up a few degrees and was subsequently cooled back down by the integral DX unit (thus heating up to cool down). This is a waste of energy.

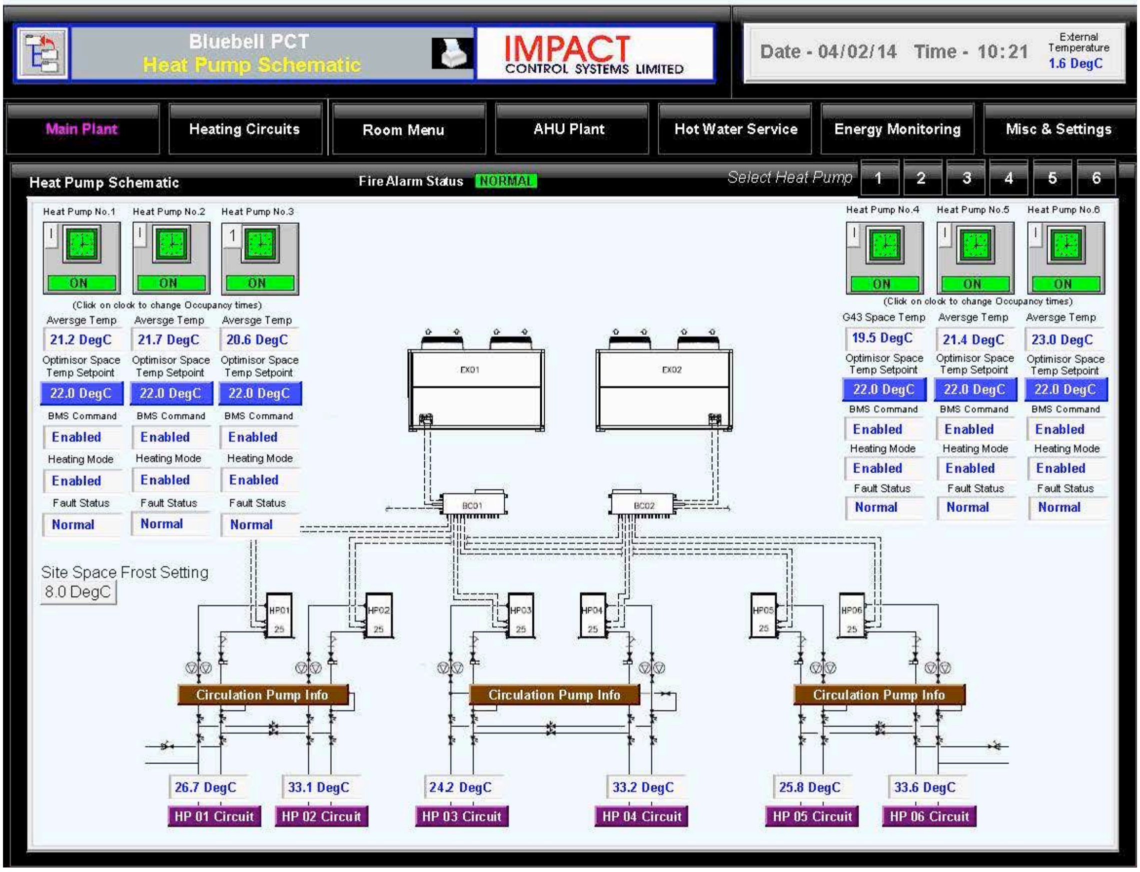
Finally, the intake and exhaust louvres from the AHU are placed within external timber cladding system, and are not visible from outside the building. This increases the likelihood of recirculation - it is very likely that fresh air is being mixed with exhaust air.

7.7 Space heating

Although the BMS was commissioned to provide optimised heating & cooling, in practice these services have been manually controlled by the FM, changing set-points and timeclock settings through the BMS.

As it was originally commissioned, it was not possible to examine whether the heat pumps themselves (refrigerant side) had any form of weather optimisation control – nothing was visible on the BMS. The BMS heating optimiser had not been allowed to “learn”; during the second heating season there was no optimised start or stop. This function was turned off by the FM following the difficulties they had with the first peak heating season, during which the heat pumps consistently failed to automatically defrost and became iced. Thus in reaction to the difficulties encountered during first winter, during the winter of 2011-2012 (Dec – Feb) the underfloor heating system was operational 22 hours per day, every day, at constant room air SPTs, typically 21°C. Mechanical ventilation was on during the same hours.

Through subsequent work with a Trend engineer, it was discovered that the parameters that had been set incorrectly at commissioning were not optimal for heating. Initially there was a warm up limit set at 10 hrs; this has been changed to 3 hrs. A cool down time limit of 0 hrs was changed to 1 hr as well. Most notably, it was discovered that an optimiser had been originally been set for cooling mode, which could have created or contributed to the heating difficulties during the first winter. Optimisation features have now been changed to heating and are operational again.



Bluebell PCT
Heat Pump Schematic
IMPACT CONTROL SYSTEMS LIMITED

Date - 04/02/14 Time - 10:21
External Temperature 1.6 DegC

Fire Alarm Status NORMAL

	Heat Pump No.1	Heat Pump No.2	Heat Pump No.3	Heat Pump No.4	Heat Pump No.5	Heat Pump No.6
	ON	ON	ON	ON	ON	ON
Aversge Temp	21.2 DegC	21.7 DegC	20.6 DegC	G43 Space Temp 19.5 DegC	21.4 DegC	23.0 DegC
Optimisor Space Temp Setpoint	22.0 DegC	22.0 DegC	22.0 DegC	22.0 DegC	22.0 DegC	22.0 DegC
BMS Command	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
Heating Mode	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
Fault Status	Normal	Normal	Normal	Normal	Normal	Normal

Site Space Frost Setting 8.0 DegC

HP 01 Circuit	HP 02 Circuit	HP 03 Circuit	HP 04 Circuit	HP 05 Circuit	HP 06 Circuit
26.7 DegC	33.1 DegC	24.2 DegC	33.2 DegC	25.8 DegC	33.6 DegC

Figure 7-5 BMS Supervisor, heat pump schematic

Serious commissioning problems associated with the BMS operation of the space heating system include:

- Cooling optimisation control was originally commissioned (which is likely to be one and/or the main reason the system had difficulty during the first winter 2010-2011).
- Key BMS controls features were not visible, with the FM unable to see what control had been embedded, such as weather compensation or cooling optimisation.
- The FM does not have the ability to manually set night-time set back SPTs, either for the building or for each zone. This is typically recommended in well insulated buildings with underfloor heating. Basically, there is no user-operated time and temperature control at Blue Bell - commonly installed domestic controllers have this capability. Perhaps this is because optimisation features are provided.
- It was found that an optimisation feature was overriding the weekend timeclock, causing space heating to come online Saturday and Sunday evenings.

Perceived inadequate space heating in some areas, especially around the building overhang has resulted in occupants using electric fan heaters. Low readings from underfloor heating slab temperature sensors were identified and an investigation ensued. An infrared thermographic survey was conducted but did not reveal any obvious issue with the underfloor heating circuit or identify any missing wall or floor insulation. However this is not conclusive, as the built form does not lend itself well to thermographic investigations - the air cavity between the concrete walls and the timber cladding could hide discontinuities in insulation and thermal bridges. Subsequently the FM began taking surface temperature readings in one room and comparing them with slab and space temperature readings (see Appendix C for further information). Recorded data showed very low floor surface temperatures, chiming with the slab temperature sensor readings on the BMS. This indicated that there may be a problem with distribution into some rooms. The FM examined this and found that some UFH manifold settings were incorrectly set, resulting in very little UFH system flow reaching some rooms. Changes were made and slab temperatures will be monitored this coming winter (2014-2015).

7.8 Domestic Hot Water

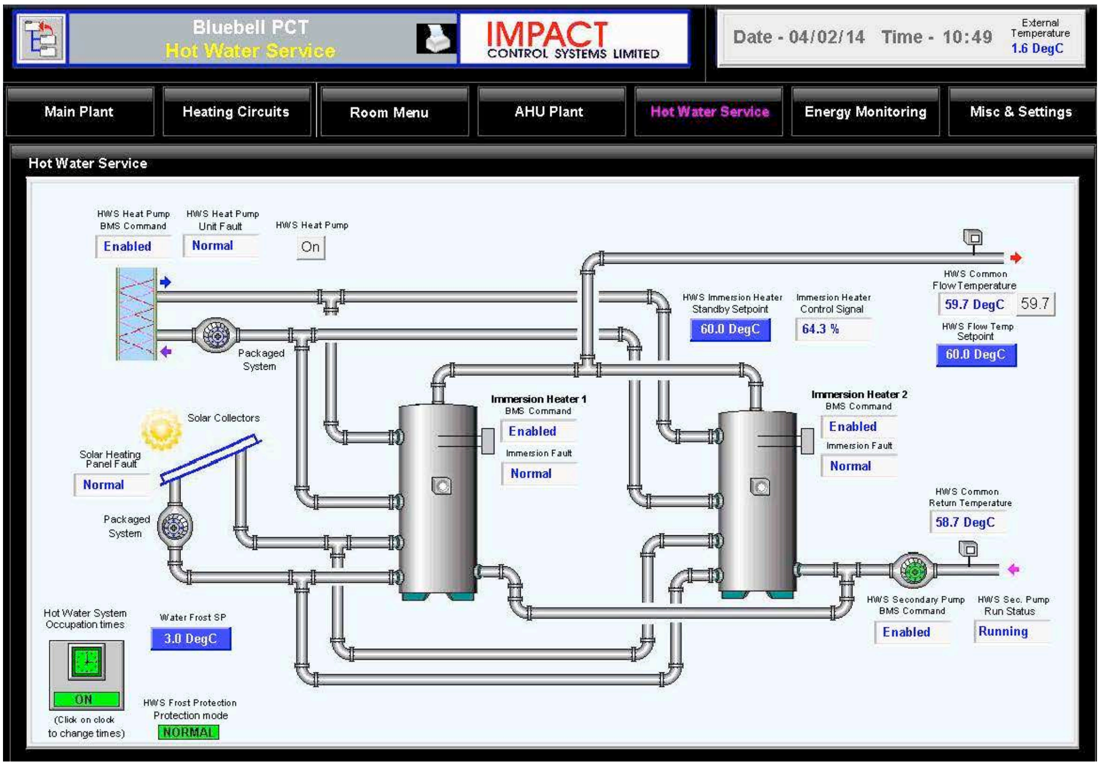
There have been issues maintaining adequate pressure in the DHW heat pump. No leaks were ever identified however. It was confirmed by TACE that the sub-optimal orientation was a decision made during construction for space concerns, with the orientation not significantly impacting output according to the manufacturer.

Correspondence with Baxi Commercial (suppliers of the Andrews SolarFlo solar thermal system) revealed that they have no record of calculations or design requirements – the system is a pre-configured package. According to Baxi Commercial, all information about the design requirements would sit with M&E consultant or main contractor. Design calculations have not been provided by the M&E consultant for examination.

Review of commissioning documentation revealed a potentially unresolved issue with the solar thermal system. According to a commissioning report, the location of the electric immersion element and its temperature sensor meant that the solar thermal system would never receive the call for heat – thus the electric immersion elements would be supplying 100% of the hot water requirement. Discussions with the client, design team, and commissioning specialist were not conclusive – they did not remember if this issue had been resolved or not.

To resolve this issue (these meetings took place during this evaluation programme), a meeting was called with Renova's external commissioning specialist and the M&E consultant. The result of the meeting was that we were still unable to determine the actual operation. Another meeting on site was held with the solar system supplier, Andrews Water Heaters. This meeting was also inconclusive. Andrews engineers stated that they had never seen a flat installation of that array product. Andrews subsequently provided a report concerning the hot water cylinder configuration, recommending the purchase of further equipment.

Almost no BMS control and very little monitoring capability was installed for the DHW system. A timeclock and storage and immersion set point temperatures can be adjusted through the Supervisor, but the FM has had difficulties controlling the immersion heater (unable to turn it off using the timeclock) and suspects some (invisible) BMS optimiser programming is overriding the time clock.



Date - 04/02/14 Time - 10:49
External Temperature 1.6 DegC
HWS Heat Pump BMS Command: Enabled
HWS Heat Pump Unit Fault: Normal
HWS Heat Pump: On
HWS Immersion Heater Standby Setpoint: 60.0 DegC
Immersion Heater Control Signal: 64.3 %
HWS Common Flow Temperature: 59.7 DegC 59.7
HWS Flow Temp Setpoint: 60.0 DegC
Immersion Heater 1 BMS Command: Enabled
Immersion Heater 1 Immersion Fault: Normal
Immersion Heater 2 BMS Command: Enabled
Immersion Heater 2 Immersion Fault: Normal
Solar Heating Panel Fault: Normal
HWS Common Return Temperature: 58.7 DegC
Hot Water System Occupation times
Water Frost SP: 3.0 DegC
HWS Frost Protection Protection mode: NORMAL
HWS Secondary Pump BMS Command: Enabled
HWS Sec. Pump Run Status: Running

Figure 7-6 BMS Supervisor, DHW schematic

There is no BMS link with solar system and no heat meter on it either – an analogue temperature gauge is provided and a digital temperature output on the solar controller, but these do not appear to always match up. Thus the FM could not tell when solar pump has been operating or what the solar contribution is. The heat pump controller is not BMS linked either and when directly queried does not provide much useful operational information.

This lack of control led to the suspicion that the electric immersion elements were indeed supplying a good deal, if not most heat for hot water production. Beginning in May 2012, the FM changed the hot water production routine, dropping the standing storage temperature to 55°C and turning off the electric immersion heaters. Solar thermal was then lead, supplying what solar energy is captured, the heat pumps provided top-up to 55°C, which they seemed to be able to cope with, and the electric immersion is only run daily to boost the cylinder from 55°C to 60°C. From energy demand profiles, it appeared that this had a beneficial effect on energy consumption. However, further experimentation with the system revealed that the heat pump was struggling to provide much if any temperature rise in the cylinders.

The FM subsequently installed surface mounted temperature sensors connected to a datalogger on the solar thermal flow and return to the hot water cylinders in order to better understand the operation. Examining these temperatures in conjunction with electric immersion energy consumption (using the MCCP submeter half-hourly data) revealed that the solar thermal system was indeed providing very little input to the system, and actually appeared to be cooling the DHW cylinders somewhat (see Appendix B for further details). Subsequently the FM attempted to delay the immersion heater daily input, as it was turning on before the solar thermal system could provide any useful heat input. From the data the results were mixed, as many days the electric immersion was still turning on early in the morning before the solar thermal system.

As the building is used, hot water demand is undoubtedly low – as the showers are seldom used, hot water will only be used at sinks and basins. The system appears oversized for hot water demand – however exact demand cannot be quantified without further metering.

7.9 Cold and Rainwater systems

The rainwater harvesting system has been periodically out of operation during this evaluation. For one period, the UV tube was broken and ordering a replacement took considerable time.

Given the overall low water demand, even when the rainwater harvesting was out of commission, and the relatively low number of installed appliance points, the inclusion of this technology seems difficult to justify beyond achieving a BREEAM point.

As discussed in Appendix B, if industry benchmarks are used for sizing the hot and cold water systems, storage requirements will be largely oversized. This is illustrated below for mains cold water. It can be seen that the actual demand is much less than the benchmark provided in the HTM guidance, and more closely resembles an office. Current industry benchmarks found in HTM guidance are for hospitals and this research was conducted in the 1960s. Note that in the Figure below, the lowest benchmark provided in the HTM guidance was used.

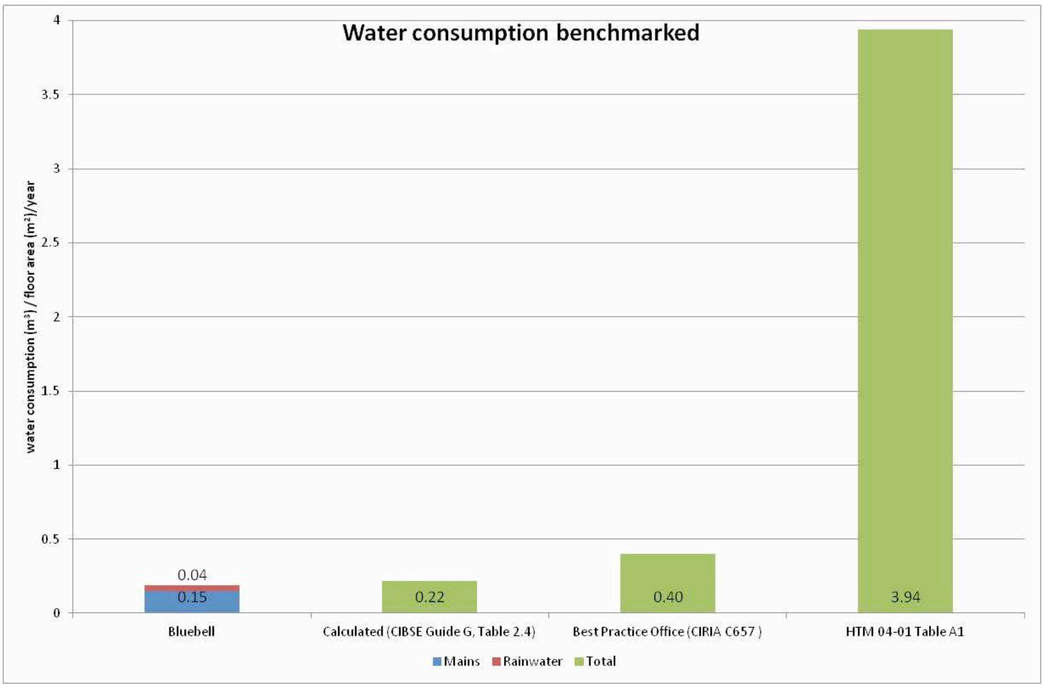


Figure 7-7 Water consumption benchmarked

7.10 Conclusions and key findings for this section

7.10.1 Process

A common story in many buildings, the consequences of Value Engineering during design to the operation of the building is not fully understood. In this case, Blue Bell was designed to optimise natural light with large east and north facing windows and extensive daylight through the roof lights in the atrium. Daylight sensing around the glazed areas and atrium would have helped to maintain good lux levels at the same time as reducing lighting energy consumption. As installed, without daylight sensing, all lights are fully on regardless of natural light levels.

So while the consequence of removing daylight sensing may have appeared to be minor during design and construction (say in SBEM or BREEAM), it can frustrate efficient operation and render careful design in related areas (good daylight) almost pointless.

Solar thermal technology was included to help satisfy a renewable energy contribution planning requirement. Thus it had been estimated at this stage, likely from benchmarks, that DHW production represented about 8% of the buildings total energy demand (the remaining 2% was originally going to be met with a wind turbine). In reality, the actual hot water demand in the building is very small, representing well under 8% of the total energy load (see Appendix B). The solar thermal system greatly complicates the provision of a building service in little demand (neither the actual hot water demand nor the output from the solar thermal system have been measured, as no meters were installed to do so). It is likely that a simpler, possibly decentralised system could have met this demand more efficiently – for example one that did not require large centralised hot water storage. Thus its inclusion does not appear to be justified.

7.10.2 Design

This building does not operate as a typical healthcare building – its services and energy requirements are more similar to an office. Benchmarks used in early stage design need to be developed to include newer healthcare buildings like Blue Bell, or calculations based on anticipated usage need to be done to inform design to achieve planning consent.

Air movement (or active cooling) to provide some thermal comfort relief in the summer in small, single aspect rooms needs to be considered in design, even where mechanical ventilation is provided. The rooms most affected by overheating are mechanically ventilated (and not necessarily south or west facing), and while windows are provided, they cannot be fully opened and there is not much of a possibility of cross ventilation unless the door is left fully opened. Relaxing window opening requirements (allowing occupants above ground floor to open windows more fully) could provide occupants with more fresh air.

The M&E Performance Specifications are very light on specifics around BMS and submetering requirements and design and construction drawings (and ultimately the installation) lack submeters in key locations, such as the cold water supply to the DHW system and the solar thermal system heat output. The Building Logbook does not adequately address energy management with unclear, inaccurate, and thus unusable benchmarks. Additionally no meter trees were found, and the metering arrangement does not lend itself to TM22 end-use separation (although it is acknowledged in practice this is likely to be expensive and potentially unfeasible).

7.10.3 Handover

Recommendations for system settings, such as for comfort cooling, including details of the commissioned settings (if factory settings are changed) were not provided by the M&E engineer or contractor and would have helped the FM.

7.10.4 BMS

At Blue Bell the perception is that the BMS is a black box – it is difficult to know what control routines have been programmed, what they are doing, and when they are operating. This led to distrust of the optimisation routines; some were subsequently disabled, and the space heating system manually configured. This in turn led to inefficient operation, especially concerning the AHU. However this distrust was confirmed to be well founded – a cooling optimisation routine had been programmed and selected, and another optimisation function was causing the heating system to come on during unoccupied hours, with little perceived benefit (for example to maintain stability with thermal mass).

Following meetings and call-outs with Trend and the BMS installers (at fairly considerable time and cost), system settings like the cooling optimisation and weekend operation were fixed/re-adjusted. However the FM still does not have the ability on the BMS Supervisor to operate night-time set back set-point temperature control. This further emphasises the need for more detailed specifications, more M&E designer input into the BMS installation, more extensive and staged/seasonal BMS demonstrations.

During design and construction an operational strategy was not sufficiently developed nor is any strategy documented. As found here, it is not good enough to just rely on the BMS, or specifically on the BMS optimisers, to operate a building effectively without understanding how the system is operating. Better controls descriptions, better BMS visualisation and accessibility are required for building management. A better description of the system in the O&M could potentially have prevented the use of the ventilation system for space heating in the winter 2011-2012, as it is not intended that it does this.

7.10.5 Controls

Throughout email discussions with the controls specialist to figure out what had actually been installed, there was difficultly communicating the concept of 'free-cooling' – what was understood by them was frost protection or defrosting (which is the function of the recirculation damper). The Mechanical specification only mentions free-cooling by name and does not provide an explanation of operation. It should not be taken for granted that control terminology is understood to mean the same thing by all design and construction team members. BMS specialists understood night-time setback to mean frost-protection for the underfloor heating system, and free-cooling in the AHU to mean defrost mode.

Occupants don't use the functions on the comfort controller beyond On/Off and increasing or decreasing temperatures. Most of these functions are really for the commissioning engineer or FM to set. However occupants should be shown how to make simple changes, like change of mode or fan speed. Additionally written instructions should be provided to occupants to guide them through the more simple function changes.

7.10.6 Metering strategy

Including energy use targets for end-uses which do not bear resemblance to the actual submetering in the building can create confusion and in particular detracts from the relevance and usability of the Logbook meter recording section (the FM stated that he never used the Logbook for reference or recording energy data). Further, the benchmarks figures included bear little resemblance to the in-use energy consumption – they are far too low.

No heat meter was installed in the solar thermal system, and thus it has not been possible to determine how much heat this system provides for DHW production. This not only prevents the monitoring and evaluation of this system to determine whether its inclusion has been worthwhile from an energy contribution perspective, but also precludes any direct financial benefits from heat generation available from the Renewable Heat Incentive (note that through this investigation it was determined that the system was not eligible anyway, as the installer was not MCS certified).

The inclusion of the solar thermal system to meet planning requirements for renewable energy contributions, DHW storage size, and distribution system design were all predicated on an anticipated hot water load for the building (it has not been possible to find any design calculations or load assumptions). As installed, it has not been possible to determine the building's actual DHW demand. A flow meter on the cold water supply to the DHW system could have adequately provided this.

Further, the other heat sources contributing to DHW production – a dedicated heat pump and electric immersion elements in each storage tank – have not been submetered. For the heat pump both a heat meter and an electrical submeter (the heat pump for DHW production is on the same DB submeter as the heat pumps for space heating) would have been necessary to quantify these, and from this the COP of the heat pump could have been determined. For the electric immersion heaters, an electrical submeter would have provided very useful information about energy consumption from these elements.

Submeter arrangements at Blue Bell, especially for heat meters, focus on submetering each branch or zone. While this can be useful if there is a supply problem or potentially for zonal billing, the installation of submeters further upstream, capturing the total heat output or electrical input of heat generation sources, is recommended for examining the efficiency of these sources. Heat meters closer to the energy generation source make energy management easier (unless examining distribution losses), are more accurate than summing each branch, and their installation potentially means that some submeters further downstream could be eliminated.

7.10.7 Energy management

Most submeters are linked to the BMS, but accessing energy information has been difficult. The system can provide a rudimentary level of energy and performance monitoring and analysis, but as installed, it could not be considered to be a functional Building Energy Management System (BEMS), as it is advertised. Many barriers to energy management were discovered, including controller data collection and storage, and Supervisor set-up and data logging. To better perform this function, another software programme was purchased, specifically for energy analysis.

The first Trend engineer sent to Renova's head office to install the TEM software did not install the system as specified nor to its full capability. All the failings around the BMS installation, support and associated software points to extremely poor customer service in this area and a generally dysfunctional relationship between client and provider. Clients are often not educated as to what they are purchasing, and control and building energy management companies need to work with building owners and managers to help them understand how to use their products better.

8 Key messages for the client, owner and occupier

Technology Strategy Board guidance on section requirements:	This section should investigate the main findings and draw out the key messages for communication to the client/developer, the building owner, the operator and the occupier. There may also be messages for designers and supply chain members to improve their future approaches to this kind of building. Drawing from the findings of the rest of the report, specifically required are: a summary of points raised in discussion with team members; recommendations for improving performance, with expected results or actual results where these have already been implemented; a summary of lessons learned: things to do, things to avoid, and things requiring further attention; a summary of comments made in discussions and what these could be indicating. Try to use layman's terms where possible so that the messages are understood correctly and so more likely to be acted upon.

8.1 Scoping and early stage design

This building does not operate as a typical healthcare building – its services and energy requirements are more similar to an office. Benchmarks used in early stage design need to be developed to include newer healthcare buildings like Blue Bell, or calculations based on anticipated usage need to be done to inform design to achieve planning consent. Renova should more thoroughly submeter their buildings so their own building benchmarks can be used by the designers they engage.

Many HTM requirements are derived from or possibly more relevant for traditional healthcare buildings or hospitals. Desired derogations from HTMs in regards to the provision of building services (for example hot and cold water storage, window opening aperture) should be identified during early design stages.

8.2 Product selection and supply chain control

Package systems, like the AHU and solar thermal systems at Blue Bell, either need to be fully integrated with the BMS, with control through the BMS supervisor, or a separate screen be provided which the FM can access.

The purchase of a new PC with a specification that exceeds the BMS Supervisor software requirements would have represented a very small cost compared to the overall BMS installation – this is not an area to find cost savings. To safeguard against this, in the future the M&E specification and Employer's Requirements need to include the requirement for the Supervisor's PC to be new, and far exceed software requirements.

The “comfort cooling” temperature settings for Auto need to be examined to ensure a wide deadband exists on each controller. Further, the Auto feature could be turned off so that only Cool and Heat settings are available. Different systems which employ better centralised control to change or maintain On/Off times and to cap and collar temperature settings should be considered in future projects.

8.3 Specifications and drawings

Throughout email discussions with the controls specialist to figure out what had actually been installed, there was difficultly communicating the concept of ‘free-cooling’ – what was understood by them was frost protection or defrosting (which is the function of the recirculation damper). The Mechanical specification only mentions free-cooling by name and does not provide an explanation of operation. Because free-cooling can refer to night-time and/or daytime operation, which in operation would use different inputs and logic, and because it seems that M&E designers and controls specialist contractors do not adhere to the same definitions, specifications (even Performance specifications) need to be much clearer about operation, and provide not only definitions for all control terminology but also logic diagrams with required inputs and outputs.

The type of occupancy sensing (presence or absence) needs to be more clearly communicated and defined in specifications, ERs and drawings, including details on time-out. Sensor locations need to be carefully planned to avoid unwanted (unintended) activation.

8.4 Operational documentation

During design and construction an operational strategy was not sufficiently developed nor is any strategy documented. As found here, it is not good enough to just rely on the BMS, or specifically on the BMS optimisers, to operate a building effectively without understanding how the system is operating. Better BMS visualisation and accessibility are required for building management. The O&M needs to have a more complete description of how systems are controlled, how they were set up (at which temperatures etc), how to change operation, and why and when this should or should not be done (a full description of the control “philosophy”). A better description of the system in the O&M could potentially have prevented the use of the ventilation system for space heating in the winter 2011-2012, as it is not intended that it does this.

8.5 Operation

It is not good enough to simply trust that the installed building controls (especially optimisation functions) are operating the building in the most efficient way possible. At Blue Bell the perception is that the BMS is a black box – it is difficult to know what control routines have been programmed, what they are doing, and when they are operating. This led to distrust of the optimisation routines; some were subsequently disabled, and the space heating system manually configured. This in turn led to inefficient operation, especially concerning the AHU. However this distrust was confirmed to be well founded – a cooling optimisation routine had been programmed and selected, and another optimisation function was causing the heating system to come on during unoccupied hours, with little perceived benefit (for example to maintain stability with thermal mass). To avoid these man vs. machine misunderstandings:

- Supervisor visualisations need to be more complete, and optimisation functions need to be detailed (and this description needs to be readily available to the FM).
- Any administrative level embedded routines that the installer but not the operator would have access to need to either be listed and detailed, or accessible to the operator.
- The O&Ms need to be improved, with detailed description of control “philosophies”.
- The BMS should be demonstrated to the FM; BMS control over each system needs to be demonstrated. This would need to be staged or seasonal (and thus before and after PC) to ensure that each system, like space heating and cooling is demonstrated.

Control over the comfort system either needs be mostly centralised on the BMS Supervisor, or control needs to be taken away from the BMS, and individual programmers need to be programmed. This includes On/Off times and temperature limitation.

Occupants don’t use the functions on the comfort controller beyond on/off and increasing or decreasing temperatures. Most of the available functions are really for the commissioning engineer or FM to set. However occupants should be shown how to make simple changes, like change of mode or fan speed. Additionally written instructions should be provided to occupants to guide them through the more simple function changes.

During the summer, surgery staff sometimes open windows around the first floor waiting room to provide fresh air for the patients and try to cool the space down. To improve conditions, the operation of the mechanical louvres in the building core (currently operating on CO_2 and temperature sensing) could be changed so that they open at a lower internal temperature during the summer. Night-time free-cooling using this system should also be investigated.

Rooms off the building core (the surgery rooms) are mechanically ventilated. It has already been identified that there is no free-cooling functionality on the AHU due to its design (thus all fresh air is passed through the heat exchanger). Free-cooling, both at night and during operational hours could have provided occupants in these spaces with some relief.

Trickle vents could be left open during the summer on the first floor in mechanically ventilated rooms off the core. In naturally ventilated areas, they should be left open as well. Trickle vent importance and use needs to be communicated to the occupants. Additionally it may be possible for surgery rooms to get some cross ventilation by opening room windows, the doors to corridor, and the windows at the end of corridors. [This is now being trialled.]

8.6 Metering strategy

Installed submetering at Blue Bell is fairly extensive, although meters are not always in the best locations for examining consumption and system efficiency. While energy meters are BMS linked, energy data was at first not accessible and analysis not possible. Because of this the FM began taking monthly readings for each electric and water submeter. Towards the completion of the BPE programme, an energy management software package was purchased and BMS linked energy data problems appeared to be resolved, although periodic data loss still occurred. In the end, manual monthly submeter readings and the half-hourly mains AMR&T software proved to be the most reliable source for energy consumption information. This is an important lesson – sometimes manual energy management may be more insightful and cost-effective than automated systems.

Including energy use targets for end-uses which do not bear resemblance to the actual submetering in the building can create confusion and in particular detracts from the relevance and usefulness of the Logbook meter recording section (the FM stated that he never used the Logbook for reference or recording energy data). Further, the benchmarks figures included bear little resemblance to the in-use energy consumption – they are far too low.

Submeters and sensors required to monitor system operation and performance have not been adequately installed. This applies to most systems, described in the subsections below. Energy monitoring and system evaluation is not purely academic, nor strictly for benchmarking or improving building procurement – it helps provide verification that the systems are actually behaving as programmed and envisaged.

8.7 Training

FMs should receive building specific training on energy management. Training and associated manuals should be written by the M&E designers with client input, and be sensitive to building management resources (human and AMR&T). Benchmarks (building specific energy calculations) for each installed meter and submeter need to be included. Potentially the Logbook could serve this function.

9 Wider lessons

TSB Guidance on Section Requirements:	This section should summarise the wider lessons for the industry, clients/developers, building operators/managers and the supply chain. These lessons need to be disseminated through trade bodies, professional Institutions, representation on standards bodies, best practice clubs etc. As well as recommendations on what should be done, this section should also reveal what not to do on similar projects. As far as possible these lessons should be put in layman's terms to ensure effective communication with a broad industry audience.

9.1 Complex building services and the consequences of sustainability requirements

Sustainability requirements from planning, Part L, and BREEAM can often result in more complex energy systems being installed in a new building, such as at Bluebell. Complexities (or even unfamiliar technologies) arising as a result of these requirements need to be identified, rationalised (in particular examining estimated energy loads), and if indeed required, additional resources need to applied to their design, installation, and commissioning to ensure their inclusion actually results in a reduction in energy and/or carbon. In particular, a special focus needs to be applied to their control and integration with other control systems.

9.2 Window openings and overheating

Relaxing window opening requirements (allowing occupants above ground floor to open windows more fully) could provide occupants with more fresh air. Alongside this, architects and developers should examine installing architectural features, such as window gratings, that are commonly used in warmer climates, which allow the windows to be opened more fully but still provide the required building safety. Sash windows are another possibility and effective for single-sided ventilated rooms.

9.3 Design and Build procurement

The M&E Performance specifications were very light on specifics around BMS and submetering requirements. This, along with other vague M&E descriptions, point to a general failure of setting out or emphasising design responsibilities in the D&B arrangement. Even in D&B contracts, designers need to provide more detailed specifications (and drawings) with clear definitions and specific performance requirements and not rely on contractors to design most of the detail; contracts between designers and developers need to give them the time and scope to do this effectively.

Products with appropriate (not necessarily many) control features need to be specified and installed to avoid confusion in operation. Developers should seek to exert more control over the supply chain than is typical in D&B procurement through very detailed performance requirements.

9.4 Dependencies and knock-on effects

Although the consequence of removing daylight sensing may have appeared to be minor during design and construction (say in SBEM or BREEAM), it can frustrate efficient operation and render careful design in related areas (good daylight) almost pointless. Dependencies and the knock-on effects of changes to design features need to be understood and communicated to the entire project team.

9.5 Building management

Design intention around what level the BMS should operate the building without human involvement needs to be fully communicated to the FM. Additionally, behind-the-scenes operation (functionality not visible on the Supervisor) either should not be programmed, or the FM should know exactly what has been included. Further, almost all system sensor points should be shown on the Supervisor. With less visibility and transparency, the FM is likely to distrust the BMS operation more, finding it comparable to a ‘black-box’, as at Blue Bell.

9.6 Energy management

Many operational issues, especially BMS ones, are virtually undetectable without energy management. Energy monitoring and system evaluation is not purely academic, nor strictly for benchmarking or improving building procurement – it helps provide verification that the systems are actually behaving as programmed and envisaged. New buildings need to include some programme of energy management. This goes way beyond installing submeters, which are often not read, and thus consumption is not analysed. An energy management programme needs to go beyond an AMR system as well – people need to look at the results from energy analysis and make operational changes accordingly.

Designing actual submetering to be able to separate end-uses to TM22 standard (or potentially ISO 12/ECON 19 or Carbon Buzz) with minimal calculation requirements may be unfeasible. If this is the case, TM22 should be used a design tool to estimate the predicted energy consumption for each submeter – these should then be included in the Logbook. The new CIBSE TM54 ‘Evaluating operational energy performance of buildings at the design stage’ may go some way to improve this and should be included as a contractual requirement, especially in D&B projects where responsibility for in-use energy efficient design may not be clear.

With all the difficulties experienced accessing energy data from the BMS, energy metering systems not linked to the BMS, on their own network, should be investigated in future projects.