Woodland Trust HQ

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Innovate UK project number	450028
Project lead and author	Bill Bordass Associates for Max Fordham and Feilden Clegg Bradley Studios
Report date	2014
InnovateUK Evaluator	Jason Palmer (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Offices	Grantham	Traditional	2010
Floor area (TFA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
2650 m^2	3	B / N/A	Excellent

Purpose of evaluation

The aims of the project included assessing how the technical systems were working and how energy predictions were being met, how the occupants find the building and its systems, an assessment of the lighting strategy, the dynamic thermal performance of the building, the thin client IT solution with centralised servers, and a comparison of the results with the National Trust's Heelis building (designed by the same architects and engineers).

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

Electricity use: 120 kWh/m^2 per annum; thermal (gas): 32.6 kWh/m^2 per annum. Energy use was similar to predictions. However, in spite of "thin clients" and other efforts, the electricity used by ICT systems was no lower than that at Heelis. The building's BMS and metering systems proved less effective at collecting useful data. Problems included missing data owing to incompatibilities with the building's thin client system, a main check meter that did not record accurately, meters with insufficient resolution to allow daily profiles to be determined, and difficulties interrogating data remotely.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	171 of 180	90%

For the BUS summary indicators the results were relatively good. Overall satisfaction levels were generally in the top quintile of the BUS reference dataset, though scores for summertime temperature and health were only average. The other summary indicators (air quality, winter temperature, lighting, design, meeting needs and perceived productivity) were all above average, at the 95% confidence level. The only summary indicator that was below average was for noise and unwanted interruptions.

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

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

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

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1.0 INTRODUCTION AND OVERVIEW

The Technology Strategy Board (TSB) has generously provided funding for a review of the performance in use of the Woodland Trust's head office by its design and building team, assisted and reviewed by an independent assessor, William Bordass Associates. The innovative low energy building was designed to meet the institutional requirements of the sector with no capital cost premium and without being too bespoke. The design evolved from a number of projects designed by the same architects and environmental engineers, and was influenced by Post Occupancy Evaluations (POEs) of previous buildings, particularly Heelis, the National Trust's award-winning central office in Swindon.

The aims of the project included improving the performance of the building in use; helping the design and building team and the construction industry as a whole to provide a better service to clients; and providing advice to clients and policymakers on how to ask for better buildings. A particular driver for TSB is to identify better ways to improve energy and carbon performance to satisfy stringent government targets, without compromising other aspects of in-use performance. Key benefits include learning and sharing lessons about:

- How the technical systems are working and how energy predictions are being met.
- How the occupants find the building and its systems.
- The lighting strategy, with a combination of natural lighting, ambient lighting, wall-washing and user-controlled task lighting.
- The dynamic thermal performance of the building, including the effects of the "concrete radiators" bolted to the underside of the cross-laminated timber structural floor and roof panels to provide stiffness and add thermal capacity.
- The thin client IT solution with centralised servers.
- A comparison of the results with the National Trust's Heelis building by the same architects and engineers, previously assessed in 2007 and on a brief revisit in 2013.

This final report is a review of the numerous feedback loops instigated through the Building Performance Evaluation (BPE) process. It reviews observation of inputs and outcomes and summarises recommendations fed back to the occupier and to the design and building team through meeting notes and newsletters produced at intervals throughout the project.

In summary, the building achieved many of its design objectives: good quality at a normal cost (£1800/m²), good levels of occupant satisfaction generally, though with shortcomings in relation to noise in particular. Initial problems with air quality and summertime temperature were tackled in 2013, with some success, and with further potential for fine-tuning.

Energy use was similar to predictions, with the objective of lower energy use than Heelis achieved for all building-related end-uses, especially heating. However, in spite of "thin clients" and other efforts, the electricity used by ICT systems was no lower than that at Heelis. Future projects may benefit from the services of an ICT energy efficiency consultant.

The sophisticated water chiller for the server room, with integrated waterside free cooling, was probably too complicated for this relatively small installation. It broke down on several occasions, leaving the Trust with no ICT services at all, and requiring the hire of emergency backup cooling until a dedicated standby system was installed in 2012.

2.0 DETAILS OF THE BUILDING, ITS DESIGN, AND ITS DELIVERY

2.1 Building design

The Woodland Trust's headquarters is a short distance from its previous rented offices in Grantham. In accordance with its charitable objectives, the Trust sought a low-cost but high quality building with a low environmental impact, both in construction and in use. The architects and engineers selected had previously designed Heelis – the National Trust's head office in Swindon - which had won twelve awards, including three for sustainability. The brief and design for the new headquarters incorporated lessons from a post-occupancy evaluation of Heelis in 2007.

Figure 2-1 View of construction from Grantham Station. 29 April 2010.

Figure 2-2 Aerial view of Grantham showing location off Dysart Road, west of the town centre

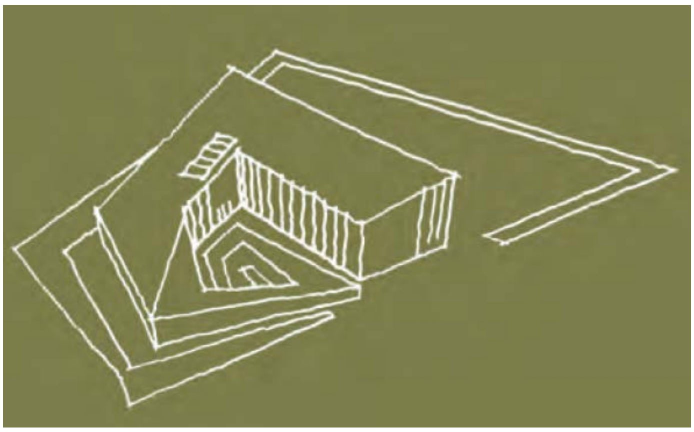
Figure 2-3 North facade of the Woodland Trust HQ. The roof slopes down to the south to accommodate future photovoltaic panels

A unique feature of the three-storey building is its construction from timber, with its inherent negative embodied carbon, but also using an innovative *concrete radiator* system, with concrete panels bolted to the soffits of the structural timber floors and roof. These panels enhance the rigidity of the floors and provide the thermal mass required for natural ventilation and night-time cooling. The structure is entirely cross-laminated timber (CLT), with no structural frame apart from a row of columns and beams up the centre of the three storey office section, shown in the photograph above and in Figures 2-6 and 2-7.

The building is located about 1 km to the west of the centre of Grantham and the railway station, in an undistinguished area containing a mix of industrial, commercial, retail and sports buildings. Externally, the tall north facade makes a strong statement at the brow of the access road, both on arrival and from a distance. Internally, the building's helical shape (see **Error! Reference source not found.**) completely encloses a courtyard garden and lets un in over the low roofs to the south and east. The courtyard offers a variety of sun and shade and is used for breakout sessions and meetings in good weather.

Figure 2-4 The design concept, with the building spiralling down from the three-storey offices facing north (towards the top right) via single storey meeting rooms to the south (left) and round to covered outdoor meeting spaces and a bicycle shed (bottom), all enclosing a garden courtyard.

See Figure 2-7 and Figure 2-8 for plan and section.



A key finding from the Heelis survey was to avoid unnecessary and, particularly, unmanageable complication. Specific measures adopted at the Woodland Trust included:

- Procurement by a traditional contract (Heelis was design-and-build).
- Elements of Soft Landings incorporated.
- Simple detailing of external walls, with the thermal continuity of a CLT panel structure.
- Natural ventilation only for most of the spaces (Heelis was mixed-mode, with background mechanical ventilation available).
- Task-ambient lighting. Heelis had suspended and recessed ceiling-mounted fittings.
- Wall-washing lights, to improve the interior appearance in the dark and in dull weather. Even when natural light on desktops was sufficient, the area lighting in parts of Heelis had to be switched to brighten up dark parts of wall and ceiling, whilst lighting these directly would have been more economical.
- Simple manual and timed lighting controls. The electronic system at Heelis included daylight dimming and occupancy detection, but programme adjustments had caused some difficulties in practice.
- No catering kitchen, partly because the one at Heelis had used considerably more energy than anticipated. Heelis was also a much larger building including public access, for which a catering kitchen was more appropriate. Instead, in addition to tea points on each floor, the Woodland Trust had a kitchen on the ground floor that staff could use.
- An energy-efficient ICT system, using "thin clients" in place of PCs. These also had the advantage of reducing heat gains in the office space, helping to avoid overheating.
- Simpler control systems. Both buildings have relatively standard heating systems, with three gas boilers (one a condensing unit at the Heelis, all three at the Woodland Trust), perimeter trench heating with a compensated flow temperature and local zoning and a domestic hot water cylinder (the Heelis survey did advocate independent hot water, but this was partly related to the cast iron boilers and large loads from the catering kitchen).

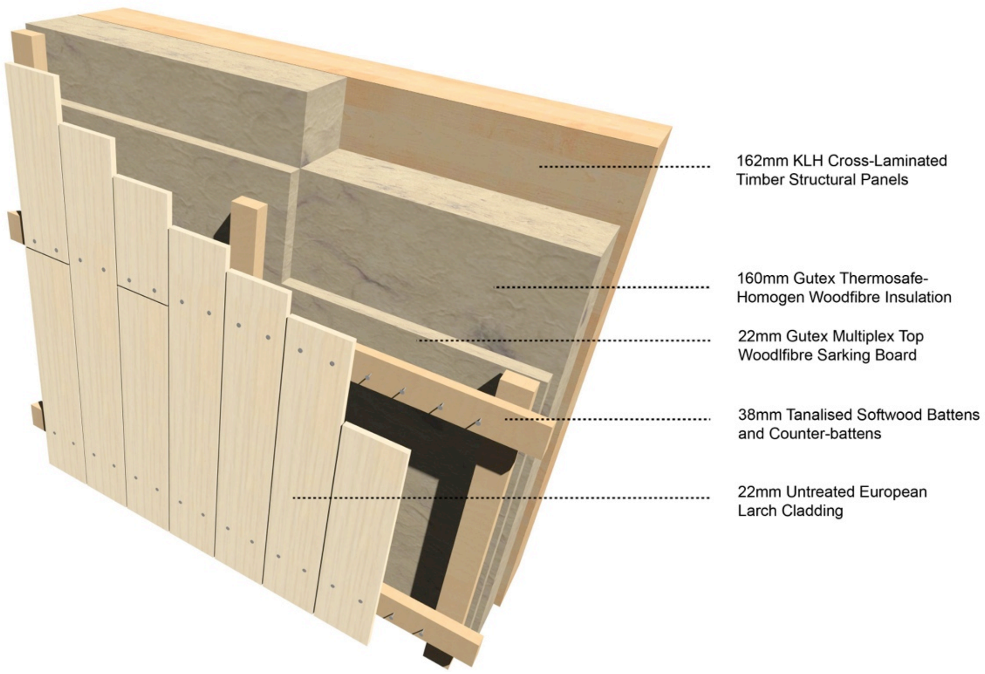


Figure 2-5 Build-up of the wall construction, which is transfusive, allowing water vapour to be released
The roof construction is similar, but with larger section outer battens (50 x 75 mm) and a covering of profiled fibre cement sheets.

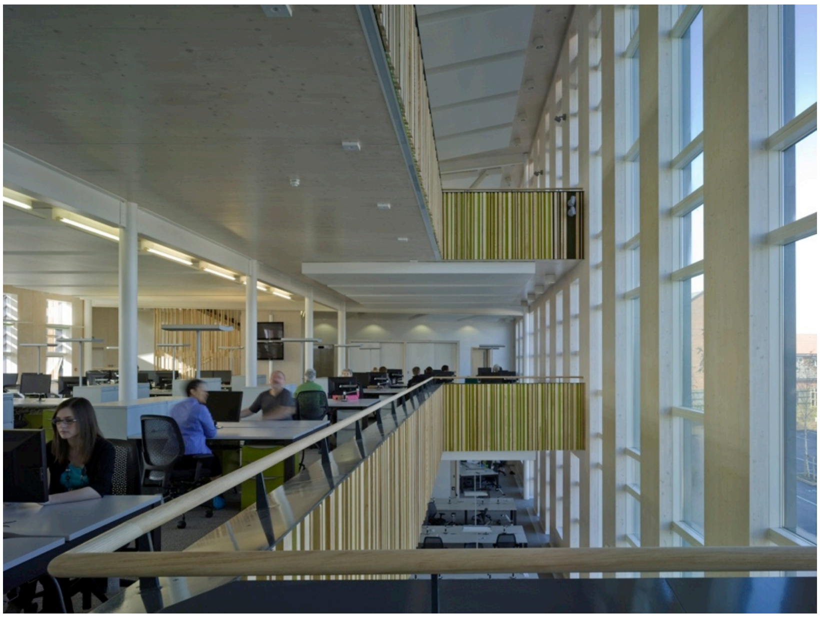


Figure 2-6 The atrium which unites the three office floors on the north side.

Note the central steel columns and beams and the concrete radiators to the left and in the background at the centre and at the top. All the rest of the wall, roof and floor structure is cross-laminated timber panels with fairfaced interior surfaces painted with a translucent white fire-protective finish.

The wall-washing lights can be seen on the west walls, and the ambient lighting up the centre of the office.

The limited use of the free-standing task lights above the desks is also revealed by the splashes of light on the ceilings above those in operation.

See also the cross-sectional drawing below, Figure 2-7.

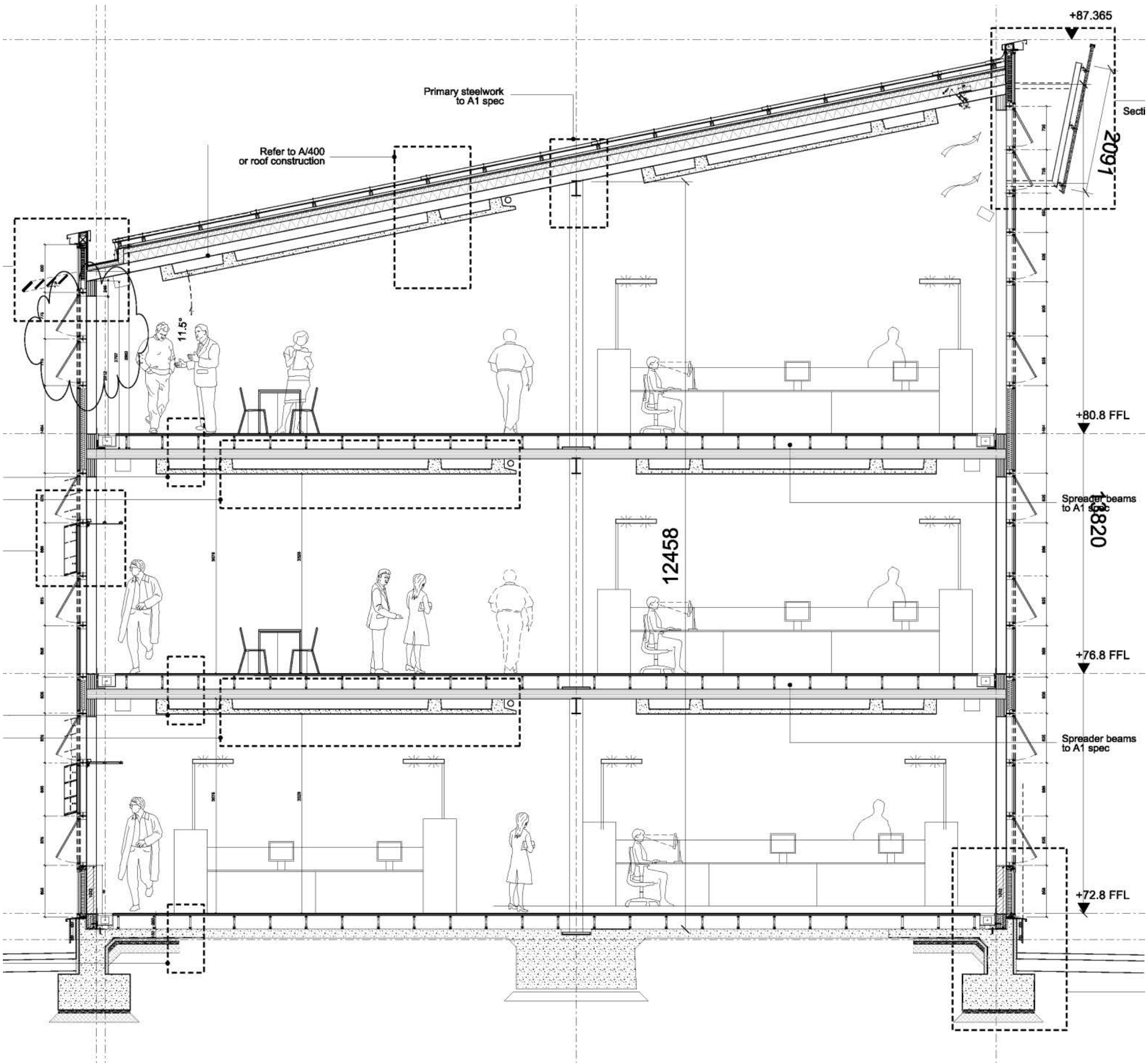


Figure 2-7 Cross-section through the three-storey offices. The projection to the top right (north) helps to create a negative pressure at the top of the building whatever the wind direction, and to reduce sky glare. Note also the solar control louvres, light shelves and overhangs on the south side (left). After in-use experience, to avoid sun glare, roller blinds were fitted to all the south-facing windows. Blinds were also fitted to the lower windows on the north side to counter upward reflections from windscreens and adjacent buildings.

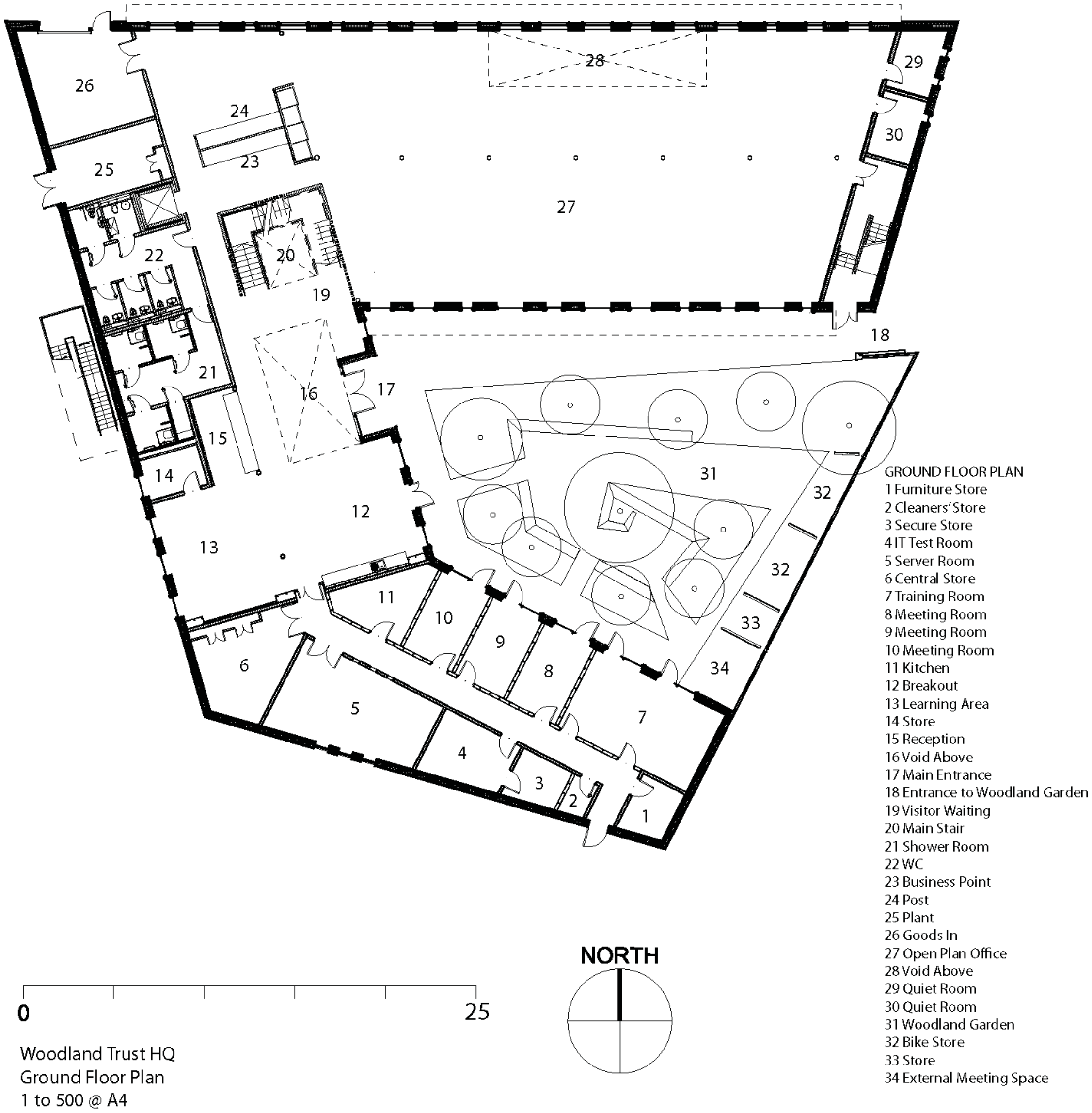


Figure 2-8 Ground floor plan, showing how the building encircles the courtyard garden

To the north are the three main floors of open-plan offices, 15 m across, with small meeting rooms and an escape stair to their east. On the upper floors, there are meeting rooms and printer/copier rooms above the ground floor loading bay and plant room at the west end.

To the south, a single storey wing with meeting rooms on the north side and windowless service rooms to the south, including stores, the server room, and an IT workshop/ test room. This is the only part of the building with comfort cooling available, using ceiling-mounted fan-coil units which borrow chilled water from the server room cooling system when buttons in the rooms are pressed.

In between, on the west side, a two-storey link with reception, waiting, breakout and learning areas on the ground floor and an open-plan "project space" above, used for special projects and large meetings.

Light and air can move between the office floors in three places: the cutaway atrium to the north, the stairwell in the middle, and an opening between the entrance and the reception desk. Rooflights above the second and third openings allow sunlight to enter the core of the building and be reflected from surfaces in common areas, enlivening the interior without causing glare at workstations.

Table 2-1 Key facts

Name of project	Woodland Trust Headquarters
Address	Kempton Way, Grantham, Lincolnshire
Post code	NG31 6LL
Procurement method	Traditional contract
Occupation date	21 October 2010
Project team	Woodland Trust, client, owner and occupier Feilden Clegg Bradley Studios, architects & BPE team leaders Max Fordham, environmental engineers & BPE monitoring William Bordass Associates, BPE advisers
Contact details	P Burgon, Max Fordham, 42-43 Gloucester Crescent, London, NW1 7PE
TSB evaluator name and details	Jason Palmer, Cambridge Architectural Research, Jason@carltd.com
Floor areas	2728 m^2 gross, 2650 m^2 treated, 2386 m^2 nett
Fabric performance	Nominal U-values (W/(m^2.K)): walls and floor 0.2, roof 0.18, windows 1.4, rooflights 1.2. Measured air permeability at 50 Pa 2.44 m^3/(m^2.h).
Occupancy pattern	200 workstations, average 150 occupants. Building open 7.30 AM - 6.30 PM Monday to Friday only.
Environmental and energy performance	BREEAM Excellent, EPC rating B
Occupancy survey	BUS methodology survey February 2012. 90% response rate.
Carbon Buzz reference	168536
URL of project team	www.woodlandtrust.org.uk www.fcbstudios.com www.maxfordham.com
Key features	Keep it simple strategy. Timber construction with added concrete thermal mass. Natural ventilation (manual and motorised). Server room supports the whole organisation, using a system of “thin clients” for the 180 staff based in the building and another 110 off site.
TSB unique reference number	450028

2.2 Building performance review

The first site visit was made in August 2011, ten months after the building was handed over. The visit included a walk-through survey, spot measurements, discussion with the facilities department and individual staff members, and initial arrangements for the services engineers to obtain remote access to the data from the BMS. Sadly it also coincided with a chiller breakdown, requiring hire of emergency cooling equipment.

October 2011 saw the anniversary of handover passing with several outstanding items not attended to, particularly those relating to the BMS, the metering systems, and the water chiller's control and free cooling systems. The BPE team therefore convened a meeting in January 2012 to review findings and actions with the occupier and all members of the design and building team. This helped to clear the air, but some items remained outstanding until summer 2012, some within the maintenance contract.

The occupant survey using BUS methodology took place in March 2012 and a first year report was completed in July 2012. Since then monitoring has continued, with approximately quarterly visits to review progress, make spot checks, and discuss possible changes and their consequences. These have been timed to coincide with routine BMS maintenance visits.

A contingency sum for additional investigations was used for:

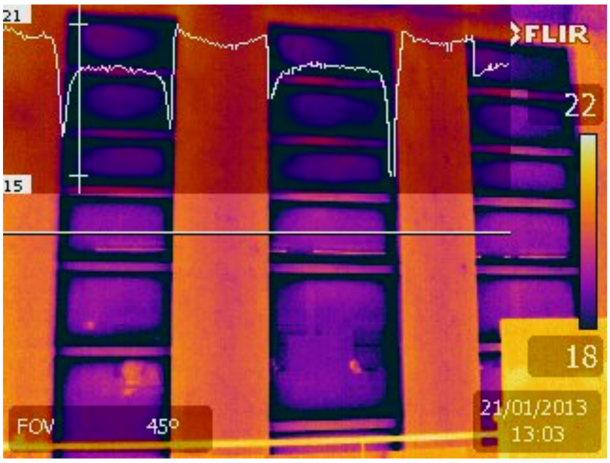
- Advice from an ICT efficiency consultant on reducing energy use of the server room, computer and telephone systems.
- Instrumented tests of the night cooling system over a weekend, using heat flux sensing of the concrete radiators, infra-red temperature checks and time lapse infra-red photography.

More detailed measurement and optimisation of night cooling took place in Summer 2013, using "follow-on" supplementary funding from TSB.

The ambition to use the building's inbuilt BMS and metering facilities for data logging proved somewhat unsatisfactory. In particular:

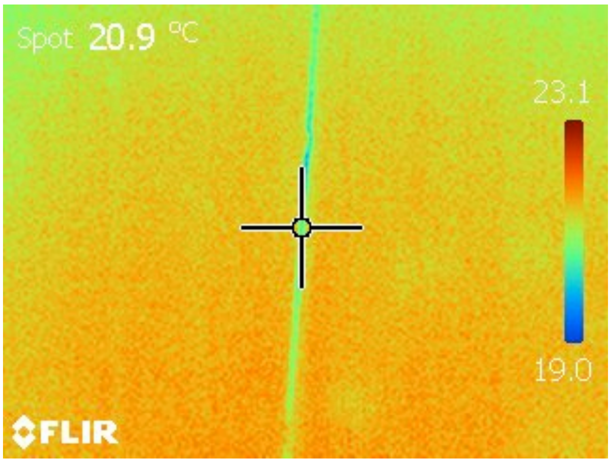
- It took a long time to get all the BMS sensors calibrated. The outdoor temperature sensor also had to be moved to the dustbin compound, as it was affected by warm air rising from the lightweight cladding in sunshine.
- The metering system turned out not to be fully compatible with a thin client system, leading to a loss of readings, sometimes occasional, sometimes in blocks. It took a long time for the manufacturer to come up with an explanation, eventually suggesting a hardware upgrade – but no budget was forthcoming to do it.
- There were shortcomings in data transfer to the engineer's offices, requiring archives to be collected from site and causing delays in identifying and resolving problems.

2.3 Low embodied energy construction material



The construction using cross-laminated timber (CLT) structural panels for walls, floors and roof, performed well thermally. Infra-red photos taken internally showed minimal cold bridges, as there were no structural members or panel frames to create weak spots, Figure 2-9. External IR photos were not informative owing to the highly-insulated rainscreen construction.

Figure 2-9 Infra-red photograph inside the north facade on a frosty January day. Note the uniform temperatures across the CLT panels, as there is no thermal bridging by structural elements. The windows have timber frames which largely cover up the aluminium opening elements, which form localised cold bridges.



The CLT panels shrank during the first year, exposing some cracks some 5 mm wide, some of which have opened further over time. The mastic will be replaced when re-decorating. However, infra-red photographs and smoke pencil tests indicated that these were not causing significant leakage of heat and air, see Figure 2-10. A selection of IR photos is included in Appendix 10.3.

Figure 2-10 Infra-red photograph of the junction between two CLT panels. The joint between the panels is a little colder, but that can largely be attributed to the absence of the insulating properties of the timber in the gap. Joints between all CLT panels were sealed externally with laps and tape.

2.4 Conclusions and key findings on design and delivery

The design and delivery process benefited from the feedback from the team's earlier Heelis project. However, the BPE investigation also made it clear that in each project there are new things to learn; and that a problem addressed is not necessarily solved as unintended consequences may well emerge. Lessons for future projects by team members include:

- Advocate Soft Landings to clients at the outset,
- Identify champions to carry Soft Landings forward throughout a project.
- Progress the keep-it-simple approach.
- Seek to do more follow-through after practical completion, with budgets both for time and money to carry out any minor alterations quickly and effectively. However hard you try, fine tuning will always be necessary and should be properly planned for.
- Encourage clients to take independent advice about the energy efficiency of ICT systems.

3.0 REVIEW OF BUILDING SERVICES AND ENERGY SYSTEMS

The building services in this largely naturally-ventilated building are relatively simple, as summarised in the tables below.

Table 3-1 Heating and Hot Water Equipment Summary

Boilers	Pumps	Emitters	Calorifier	Ancillaries
Buderus GB162 Cascade. 3no. 80kW. 80/60 Weather compensated.	Boiler primary Integral Heat secondary Twin Head Grundfos TPED 40-230. 2.94 l/s @ 130kPa DHW circulation Grundfos UPS15-50 0.18l/s@21kPa. 35W @ Speed 1	Trench heaters BG Perimeter 254 m total length at 733 W/m average	Heatrae Sadia Megaflow Indirect 300 litres Capacity. 30min reheat time - 24.5kW coil	Expansion Vessel and Pressurisation Unit. Flamco Basepak 200-125D Electromagnetic Water Treatment PowerMag 200 Flamco 60l Dosing Pot Air and Dirt Separator Flamco Flamcovent Clean 65 S

Table 3-2 Cooling and Ventilation Equipement Summary

Chiller	InRow coolers	Air handling units and fans	Fan coil units	Ancillaries
Stulz CLO631A Free Cooling Chiller. 51.7kW @ 10/15 CHW flow/return. Integral Variable Speed Pumps. Grundfos TPE 2.5 l/s @ 250 kPa	APC InRowRC 4no. (3 run, 1 standby) @10 kW cooling each with variable speed fans currently running at 50%	2 no. MVHR AHUs VES Ecovent NRG Mtg rooms: 0.58m³/s @ 200Pa. 0.99 W/l/s WCs: 0.4m³/s @ 250Pa. 1.17 W/l/s Kitchen Extract Fan Vent Axia ACM 60 l/s	7no. Ability FCU Fans: 0.24m³/s @30Pa Htg: 2.9kW, Clg: 2.4kWt	600 litre Chilled Water Buffer Vessel Expansion Vessel and Pressurisation Unit. Flamco Basepak 50-125D. Air and Dirt Separator. Flamco Flamcovent Clean 65 S Dosing Pot. Flamco 60l

Table 3-3 Electrical power equipment summary

Fuel tank	Generator	UPS	Switchgear	Distribution boards	Underfloor busbar	Metering
2130L double skinned fuel storage tank	Power technique sound proofed diesel generator 136 kVA continuous Remote start	APC w/ SineWave 20-480A Active harmonics conditioner	2 Form 4, Type 2 Panels: Essential – Server, Chiller, MCP, Fire & Security Alarms Non-essential – the rest Merlin Gerin	6no. Schneider TPN type B Isobar w/lighting extension board. All but external lighting board Split Metered.	CMD Betatrak Dual circuit	Schneider PM700/ MP750 electrical submeters EX100 Gateway PowerView software

Table 3-4 Lighting Equipment Summary

Task lights	Battens	Downlighters	Wall lights	Pendants	External Columns	External Bollards
Iguzzini Y-light 4 x 55W 3000lm	Central circulation: Thorn PopPack 70W 6550lm Teapoints: Uplights HTL Linear HTBT 248HF 56W Under cupboard Thorn Arrowslim 35W	Open office: HTL Gravity G05 26W WC recessed: HTL Gravity DL05 18W, 26W Kitchen recessed: HTL Academy DFR 3x18W Business point recessed: HTL Finesse AK414 4x14W	Main Stairs: HTL DisQ 2x26W Escape stairs: HTL Galaxy Pearl 38W	Reception: Artemide Castore calice sospensione 42 23W Meeting rooms: Zumtobel Aero II 2x80W 12300lm	Kingfisher Omega 5m height 150W 17000lm	Pavement inlaid: HTL T9 Bol 42W Landscape: Deltalight Sonar 105/102 18W, 12W

Table 3-5 Communications/ICT Systems Equipment Summary

Server room	Printers	Terminals	Phones	Others
Equipment includes servers, telephone switch, UPS and power conditioner. Peak running load approx 17 kW plus 1 kW for InRow fan coil air conditioning unit and fans at half speed.	3 No. Xerox ColorQube 9203 solid ink print/copier, average day 750 W, sleep 113 W. 1 No Xerox 4112 electrostatic copier with collator for bulk mailings. Average running 1900 W, off otherwise.	Oracle Sunray 2 “thin clients”, each with a 230 volt power adaptor. Average 24-hour load 4 W. Dell LED screens of various specifications. Typical load when in use 30 W. Off at night.	Mostly Mitel 5340 VoIP phones, 4.8 W each, powered over LAN from the server room.	Fire Detection System – 2 loop analogue addressable panel with LED zone card Disabled Refuge System – 2 outstations on external fire escape Disabled Toilet Call System Intruder Alarm System and external CCTV Access Control – card reader and video intercom to goods in.

3.1 Heating and hot water

The fairly conventional low temperature hot water central heating system has three modular wall-hung balanced flue condensing gas boilers with integral pumps supplying a low-resistance header, from which duty and standby variable speed glandless pumps feeds the heating circuit. Each boiler has a modulation capacity from 20 to 80 kW. The system is filled through a packaged pressurisation unit with break tank.

Heat emitters are mostly trench heaters set into the raised floors around the perimeter of the building, controlled by location, floor and orientation with 2-port valves under BMS control from zone temperature sensors. The main circulation pump is set to operate at constant pressure, so the amount of water circulated reduces as the valves close.

The four meeting rooms in the south wing have both trench heating and 4-pipe fan coil units (FCUs) in their ceilings. The FCUs only operate for a period after a button is pressed in the relevant room. This also brings on the air handling unit for the south wing, AHU 1.

Boiler No 1 also serves the primary coil of a 300 litre domestic hot water calorifier via a 3-port diverter valve. The calorifier also includes a standby immersion heater, under manual control. Hot water leaves the calorifiers via an electromagnetic water conditioner on the outlet pipe, with secondary return via a glandless bronze secondary circulation pump.

Control of the heating is split between the BMS (which runs the secondary pumps and provides an enabling signal for the heating) and the integral control unit by the boiler manufacturer, which controls the hot water cylinder and provides sequence, and compensated flow temperature control for the three boilers.

3.2 Ventilation and cooling

Open plan offices, reception and project space
The natural ventilation and cooling strategy for the main office space uses a combination of motorised windows with chain drives under BMS control (and local override by floor) and manually-operated windows that occupants can open. The concrete radiators help to improve thermal stability, absorbing heat during the day and either carrying it forward to the next day or allowing it to be removed by cross-ventilation overnight. Air circulation is enhanced by openings between the floors at the main stairs, in the reception area, and via the atrium behind the north facade.

Figure 2-6 shows the window arrangement in the main offices. In general, upper windows are motorised and the lower ones manual. The design intent can be summarised as follows:

- Occupants open windows as necessary during the day.
- If the average CO_2 levels in the offices exceed a threshold level (initially set at 1200 ppm), the windows are opened automatically by the BMS.
- During the day, if the heating is not enabled and the office temperature rises above a set value (initially 24°C), the BMS opens the windows automatically if the external temperature is lower than that indoors and the wind speed is not too high.
- At the end of the day, if the office temperature is above a set value (initially 24°C), and heating has not been on in the previous 36 hours, automatic night ventilation is activated until the beginning of the next working day, unless the outdoor temperature or wind speed is too high, or the internal temperature falls below a certain value (initially 18°C).

Meeting rooms and quiet rooms
The meeting rooms and quiet rooms in the main building have openable windows only. The meeting rooms in the south wing are mixed-mode, with mechanical ventilation and cooling available from ceiling-mounted FCUs described in Section 3.1, controlled by the BMS to

operate the FCU in the relevant room for a timed period after the button is pressed. A demand in any of the meeting rooms also brings on AHU1, see below.

Air handling Units (AHUs) and extract fans

The building contains two constant-volume AHUs. AHU 1 ventilates the south wing in response to demand. AHU2 serves the three floors of toilets off the main offices, and is time scheduled to match the opening hours of the building. Extract fan in the server room and kitchen operate on-demand, with push button and runback timer.

3.3 Lighting

Open plan offices

The open-plan offices and Project Space are designed for good daylight, supplemented by:

- Time-controlled ambient lighting in the middle of the space, using 35 Watt fluorescent batten fittings recessed into the edges of the concrete radiators.
- Time-controlled wall-washing lighting around the edges of the open-plan offices and the Project Space, using 18 Watt surface-mounted circular compact fluorescent downlighters generally, but 28-Watt wall-mounted linear fluorescent pelmet fittings on the east walls of the offices and the north and south walls of the Project space.
- Task lighting at workstations, using floor-standing up- and down-lighters with four 55 Watt compact fluorescent U-tubes each, manually switched locally, with high (4 tube) / low (2 tube) and Off settings. Typically two task lights are shared between three workstations, except beside the atrium where it is one between two; and in breakout areas and the Project Space, where they are used for supplementary light as necessary.

The ambient lighting and wall-washing is typically time-controlled to be on from 07:00 to 09:00 to brighten the space and limit the number of task lights being switched on at the beginning of the working day. Similarly, at the end of the day, the ambient lighting is normally switched on at 16:00 until just after the offices close at 18:30. They can also be over-ridden on or off from reception.

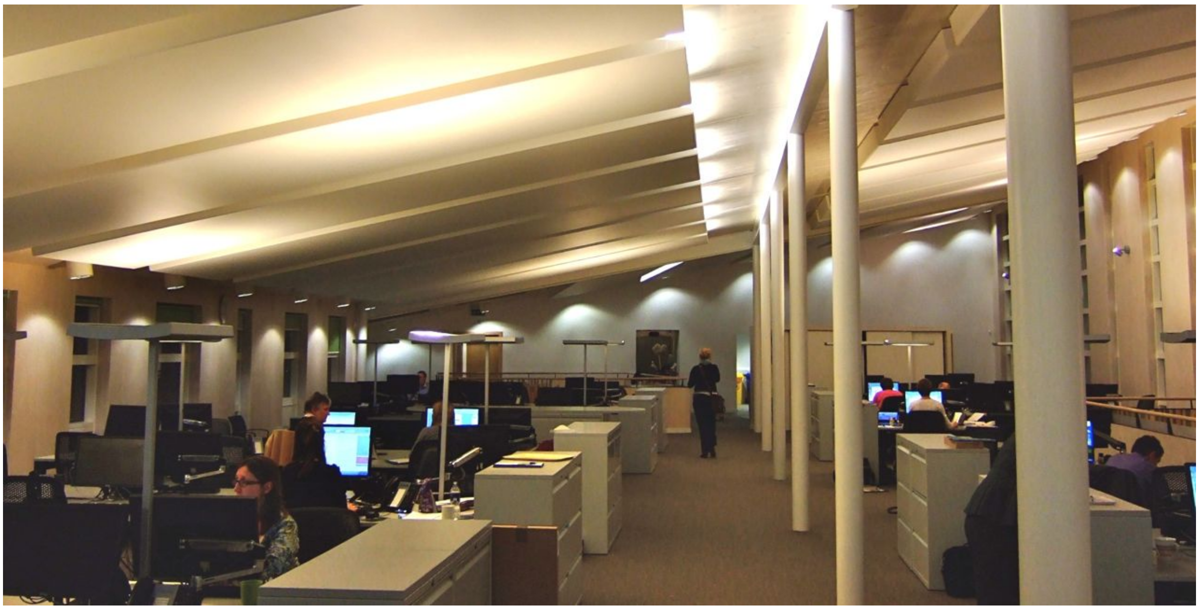


Figure 3-1 Second floor offices on a dark January evening, showing wall-washing, ambient lighting and the limited use of task lighting. with only five of the fourteen units visible in operation, as revealed by the bright patches on the ceilings.

Other areas

- Corridors, WCs, quiet rooms and the server room are lit by 26 Watt recessed compact fluorescent fittings, controlled by presence detectors. The same fittings are used above and in front of the reception desk, with manual switching.
- Lighting in print rooms and the kitchen uses 600 mm square recessed fittings with four fluorescent tubes each, controlled by presence detectors. The same fittings are used in the security room, IT test room, loading bay, with manual switching.
- The larger meeting rooms combine 28 Watt recessed compact fluorescent fittings around the perimeter, plus 80 Watt twin-tube dimmable suspended fluorescent up-and-downlighters above the table, with independent local controls for each.
- The waiting, learning and breakout areas by reception have suspended decorative light fittings with 26 Watt compact fluorescent lamps.
- The main stairs have a combination of 40 W circular fluorescent fittings and 3 W LED tread fittings. The rear stairs have 28 W circular fittings, controlled by presence sensors.
- Linear fluorescent fittings of 28 and 35 Watt ratings are also used in a number of other places, including decorative strips around the edges of the atria, linear strips behind the main stairs, above and below kitchen cabinets at the three tea points, and in a basic form in the plant room and store rooms.
- Outdoor lighting is a mixture of post-top and bollard lamps on a solar switch, which operates automatically from sunset to 19:00 on weekdays. In the morning, it is switched on manually as necessary and timed off at sunrise.

The lights in the reception, main stairs and waiting area are switched on manually for the working day to brighten up the entrance to the building, particularly the waiting area, which is otherwise relatively dark.

3.4 ICT Systems

The Woodland Trust's strategy to use a "thin client" system was driven by a number of concerns, including data security, standardisation of software, consistent archiving, and reduced heat gains in the offices. Organisationally, it also support staff wherever they happen to be: provided they can obtain a data connection, users can insert their ID card into any workstation to get direct access to their desktop and files.

The server room operates 24/7. It contains server equipment, the VoIP telephone switch and the UPS. Power is supplied through a Schneider Sinewave harmonic filter and power factor correction unit in the adjacent store. It supports both the 180 Woodland Trust staff based in the building and the 110 in other locations. The Trust's public access website is based offsite.

The average electrical loading of the server room equipment was 14 kW initially, but has climbed gradually to about 16 kW in 2013 as new equipment has been added. The load is virtually flat around the clock: apparently archiving takes the whole weekend.

Desktop equipment
A typical workstation includes an Oracle SunRay 2 thin client with mains power supply adaptor drawing about 4 Watts, a Dell LED screen with typical power consumption of 30 Watts when in use, and a Mitel VoIP telephone drawing 5 Watts over the Ethernet link to the switch in the server room. A small number of workstations have two screens, PCs or Macs.

Printers
The Woodland Trust policy was similar to that at Heelis, to reduce the demand for printing and the associated energy use by having centralised facilities. The Woodland Trust has a paperless policy, and only one shared printer/copier per floor, plus a fourth printer/copier for bulk mailings. To reduce the costs of consumables and the wastage of their cartridges, solid ink printers were chosen for the shared units. However, this proved to be at the cost of additional electricity consumption in relation to electrostatic printers. In addition, toner wastage when starting from cold made it more economical to leave the units on standby overnight, which accounted for approximately another 750 kWh per year per printer.

3.5 Server room cooling

The original design concept for server room cooling was a development of the system at Heelis, which combined a chilled water system and direct "free" cooling by outside air. Changes at the Woodland Trust included four InRow fan coil units that ventilate and cool the equipment cabinets directly and an independent ventilation unit for free cooling.

Value engineering during the design stage queried the need for two separate cooling systems. Instead the Stultz Cybercool packaged twin-circuit scroll compressor water chiller was upgraded to a unit that included a waterside "free" cooling coil on the chilled water return pipework, which was filled with glycol antifreeze. Given the relatively large (70 kW) nominal capacity of the chiller in relation to the cooling load (a growth margin required by the Trust), it was hoped that free cooling could be used for much of the year.

Unfortunately the combined system was vulnerable to common-mode failure, and after a series of failures in 2001-12 a backup system was also installed, with three standard wall-mounted Mitsubishi split system comfort cooling units, of nominal capacity 9.4 kW each.

The server room system also supplies chilled water to above-celling FCUs in the meeting rooms and IT Test Room in the south wing, which only operate on-demand.

3.6 Other energy-using items

The main additional items of equipment are:

- A hydraulic passenger/goods lift, which is not heavily used.
- Three tea points, each including a ZipTap boiling and chilled water dispenser; and a domestic refrigerator and dishwasher. The ZipTaps were originally on 24/7 but were re-programmed by the BPE team to operate during office opening hours only.
- A hot drinks machine on the ground floor. This stays on 24/7 as timed operation proved to be unsatisfactory.
- A domestic kitchen in the south wing, containing two refrigerators, three microwaves, two four-slice toasters and a vending machine for cold food and drinks.
- Security and alarm systems including CCTV, fire alarms, refuge alarms, emergency lighting and magnetic locks on the main entrance, loading bay and fire escape doors.

3.7 BMS, controls and metering

A Siemens BMS provides overall supervisory control of the heating and ventilation and cooling systems. However, both the boiler plant and chiller plant have their own integral controllers, which the BMS merely enables.

An independent Schneider PowerLog system oversees the electricity sub-meters. The supervisory software is implemented using the Trust's thin client system, which has led to some problems in use, as discussed later.

Pulses from the gas utility meter are monitored by the BMS. Since the maximum demand of the building is less than 100 kW, the electricity contract and utility meter are on a day/night tariff only and half-hourly data is not available. However, a check meter is also fitted to the incomer to the main electrical panel.

4.0 KEY FINDINGS FROM THE OCCUPANT SURVEY

4.1 User Experience

The survey
The Building Use Studies (BUS Methodology) occupant questionnaire survey was undertaken in March 2012. The Woodland Trust has a paperless policy, so insisted on using the internet version. Normally, BUS achieves the best response rates (typically in the region of 80-100%) with a paper questionnaire, while internet responses tend to be well under 30%. The team therefore made clear to the Trust the importance of getting a good response. As a result, the facilities manager prepared the ground carefully, alerting the occupants and obtaining endorsement and encouragement from the directors. In the event, the outcome was impressive, with the response rate of over 90% setting a new benchmark for future internet surveys, with 171 successfully completed questionnaires from the estimated 180 people who work for the majority of their time in Grantham. The other 110 staff members who are based away from Grantham but use its thin client system were not surveyed.

The summary report produced after the BUS survey is in Appendix 10.2 and the detailed results in Appendix 10.7.

Overview
For the BUS summary indicators, shown in Figure 4-1, the results were relatively good. Overall satisfaction levels were generally in the top quintile of the BUS reference dataset, though scores for summertime temperature and health were only average. The other summary indicators (Air quality, Winter temperature, Lighting, Design, Meeting needs and Perceived productivity) were all above average, at the 95% confidence level. The only summary indicator that was below average was for noise and unwanted interruptions.

Ventilation
Relatively good overall scores did however conceal significant problems with ventilation and stuffiness that affected some occupants in both summer and winter. Consequently, attention was given to improving the performance of the natural ventilation and optimising night cooling, both to improve conditions in the building and to capture the learning to benefit the design and building team and the wider community. This work was supported by the TSB-funded follow-on project in Summer 2013, which looked explicitly at heat transfer into the concrete radiators. This is the subject of a separate report, see Appendix 10.5.

Noise
There were widespread comments about how noise travels both within and between the various spaces. Some of these may be attributable to the move from the more cellular environment in the Trust's previous building into a completely open plan working environment here. One particular issue was noise from meetings and training activities in the Project Space on the first floor, which had not been intended for such events. However, the popularity of the building and the availability of this large, flexible space meant that events that would previously have been held externally (or even not at all) were drawn to it. The Trust is now considering providing a semi-enclosed meeting space in the project area.

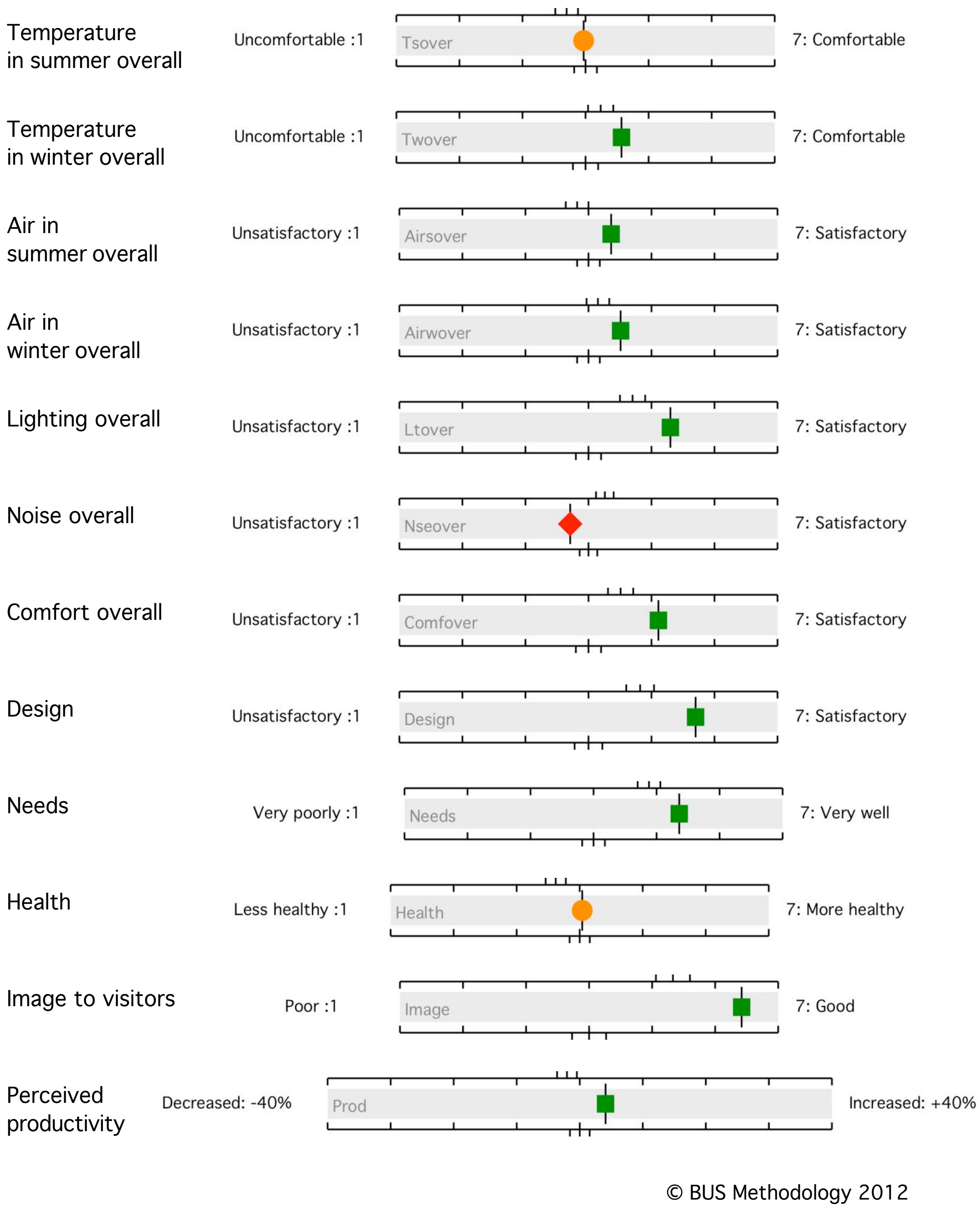


Figure 4-1 BUS Occupant Survey summary indicators at the Woodland Trust in February 2012

This shows the average scores from the occupant survey responses in relation to twelve key variables related to the environment in the building.

The satisfaction scales run from 1 (poor, on the left) to 7 (good), apart from the final question (the effect of the environment in the building on perceived productivity) which goes from -40% to + 40%. The flashes above each of the scales represents the benchmark from the BUS reference dataset for that particular variable, together with the 95% confidence limits:

- If a score falls below the lower confidence limit, it is marked by a red diamond as being lower than average.
- If it falls between the two confidence limits, it is indistinguishable from the average and is marked by an orange circle.
- If it is above the upper confidence limit, it is significantly better than average and is marked with a green square.

Overheating
When commenting on summertime temperatures, occupants reported problems with automatic control of the windows. These referred to the first summer (2011), when the main causes were failing link pins that connected the actuator chains to the top-hung windows; and a line in the control logic that held off night cooling. Both problems were dealt quite rapidly during the defects liability period. Summer 2012 was unusually cold and did not test the building, so normally any overheating was dealt with by daytime ventilation. In spite of this, overheating continued to be reported. TSB provided "follow on" funding to investigate this further in summer 2013, when the performance of Concrete Radiators was monitored and the control of night cooling modified, see Appendix 10.5.

Health
Comments from the BUS questionnaire included complaints of smells from building products, dry eyes, infections and headaches. These had been expected to subside as initial offgassing from building materials and finishes died down. When complaints persisted in Winter 2012-13, steps were taken to increase ventilation, firstly manually by the FM and more recently by improved control logic which permits finer control of the automated windows, both by the FM and automatically in relation to monitored indoor CO_2 levels.

4.2 Comparison with the BUS surveys at Heelis

The shape of the overall occupant satisfaction profile is similar to that for Heelis, the National Trust's head office in Swindon, when it was also surveyed some 16 months after occupation, see Figure 4-2 below.

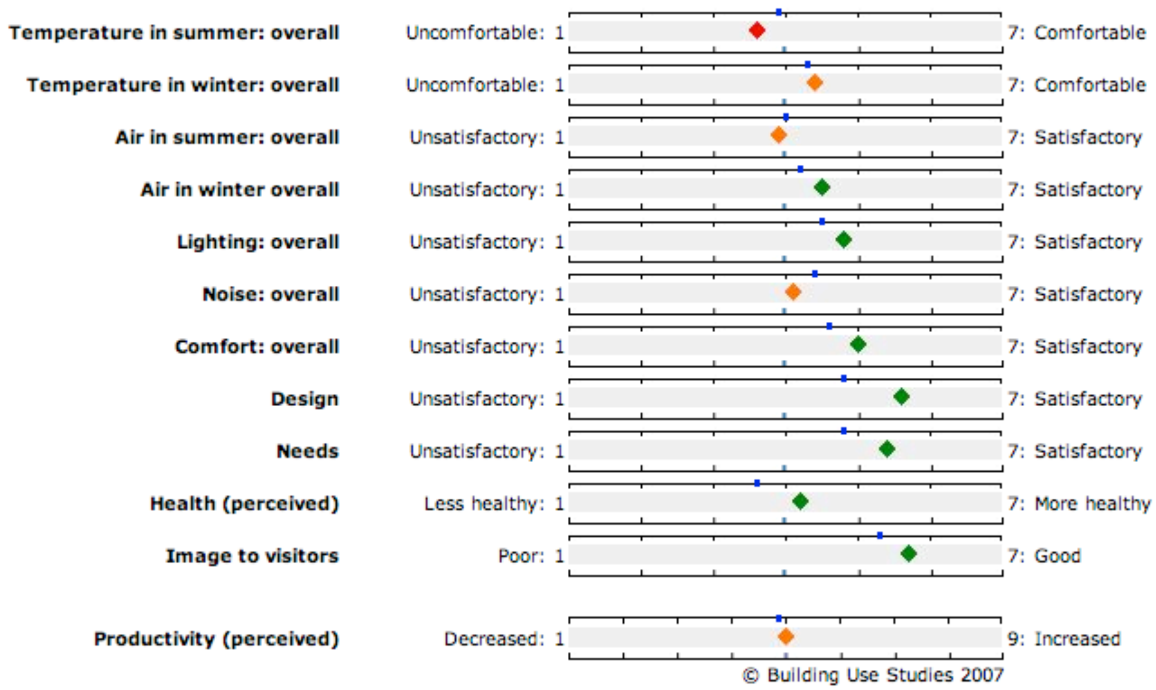


Figure 4-2 BUS Occupant Survey summary indicators at Heelis, November 2006.

The blue flashes above each of the scales represents the benchmark from the BUS reference dataset for that particular variable. There are some small differences between these and Figure 2, as the benchmarks have since been updated. However, this makes no difference to the conclusions, apart from summertime temperature where the 2006 Heelis score would now be regarded as average.

In spite of the very similar overall shape of the distribution of responses, the following points are of interest. Working from top to bottom in Figures 4-1 and 4-2, and mentioning only the variables for which there are significant differences:

- **Summer temperature** was the only variable where Heelis scored worse than average. By 2007, control and management had been improved; and a student survey using the BUS method indicated that the score had risen 0.4 points to average, very similar to the Woodland Trust survey result.
- **Winter temperature.** The response at the Heelis was average. That at the Woodland Trust was marginally better, putting it above average at the 95% confidence level.
- **Summer air quality.** Again, Heelis was average and the Woodland Trust slightly but significantly above. In the 2007 survey, Heelis also rose to significantly above average.
- **Lighting.** While occupants regarded the lighting in both buildings as significantly above average, Woodland Trust scored 0.4 points better, supporting the task-ambient strategy.
- **Noise** was the only variable where the Woodland Trust scored worse than average. Heelis had an average rating, which improved 0.3 points in the 2007 survey, in spite of an increase in occupation density, suggesting that staff were becoming more accustomed to an open plan environment. The same may well be happening at the Woodland Trust.
- **Overall comfort** was similar in the two buildings, and better than average.
- **Health.** While the scores for the two buildings were very similar, the a marginally higher score at Heelis tipped it above average.
- **Perceived productivity.** The score at the Woodland Trust was significantly above average, while Heelis was only average. However, this may have been influenced by the fact that many of staff at Heelis had been relocated to Swindon from other parts of the country. In the 2007 survey, the Heelis score was 0.2 points better, but still average.

4.3 Conclusions from the occupant survey and related discussions

At the organisational level, the Woodland Trust HQ has helped to bring together staff who work there, both with each other and with those in the field, as non-resident staff are keen to come to the building for meetings etc., while previously they had preferred other venues. The image to visitors was perceived to be good, though some donors reportedly regarded the building as too luxurious for a charity, even though the budget had been modest.

The BUS survey shows that while occupant satisfaction was relatively good, there were problems with winter air quality and summer overheating, mostly related to the control of the windows. These were tackled in 2013, with reasonable success, and the prospect of further fine tuning as more operational experience is gained. The comparison with Heelis is encouraging, including the improvements revealed by the second BUS survey there.

Not everybody was happy with the open plan, or with the clean desk policy, particularly some of those who needed to work with objects, for which they also felt there was not enough local storage. Breakout areas were liked, but not always the noise from them.

Probably the main drawback for staff has been this spread of noise through the open-plan space. A particular problem is noise from meetings, presentations and training sessions in the Project Space, which was not initially designed for this purpose, but is now widely used for them, owing to the popularity of the building and a shortage of large meeting rooms.

5.0 DETAILS OF AFTERCARE, OPERATION, MAINTENANCE AND MANAGEMENT

5.1 Operation of the building

The Woodland Trust owns and operates the building, with its own Facilities Management (FM) and Information Services staff and supporting maintenance contracts including mechanical, electrical, BMS controls, and the lift. The chilled water system for the server room requires specialist support on a separate contract.

The building is open from 07:00 to 18:30 on weekdays only, when heating, ventilation and hot water services operate as necessary. Outside these periods, it is not accessible to anyone, except by special arrangement. When the building is unoccupied, most systems are off, apart from control, security and alarm systems, the server room, its cooling plant, and the associated information systems. Out of hours alarms are relayed automatically to the mobile phones of FM staff.

Night surveys revealed that occupants were diligent at turning off equipment under their direct control, particularly screens and including PCs where used, which contributed to the building's relatively low energy use for ICT in the office space. However, the IP phones, WiFi base stations and thin client power supplies remained on 24/7.

Operating and maintaining the BMS
The occupier had no prior experience of day to day operation of BMS. Two FM staff members were trained after handover. However, the one routinely responsible left unexpectedly at the end of 2011, leaving limited cover until two more staff were trained. A particular difficulty was that the written guidance in the O&M Manual was not easy to interpret and to apply. The FM staff therefore wrote guides in their own words for reference and training, and to help non-technical staff to operate the BMS if necessary.

The Trust is fortunate to have a BMS contractor who was involved in the installation, understands it well, and has proved to be effective in both maintaining it and in making effective improvements in response to feedback. The BPE team also worked with him to alter some functions to extend and simplify intervention by FMs, see Appendix 10.4. However, with the Trust's thin client arrangements, altering the BMS software is relatively slow and laborious, which somewhat inhibits making changes

5.2 Aftercare

Soft landings process
The Soft Landings approach was adopted informally by the designers, but not formally incorporated into the procurement process. Soft Landings seeks to increase the focus of briefing, design and construction on outcomes; and to devote more effort to preparing for handover and to collaboration, troubleshooting and fine tuning afterwards.

The approach was largely successful in embedding findings from the POE of Heelis into the design and procurement of the building, in managing expectations during design development and construction, in preparing for handover and occupation including the early appointment of a facilities manager. The Soft Landings approach was also instrumental in the team seeking and in obtaining support from the TSB for this Building Performance Evaluation (BPE) project.

However, some items that had proved valuable at Heelis were not fully used at the Woodland Trust, including the CIBSE Log Book, which describes the operational principles, and anticipated energy use relatively clearly and concisely. In Soft Landings projects, this has proved useful not just as a record, but throughout the delivery of a project, allowing the design intent to be summarised at an early stage and reviewed as the design is developed and equipment selected and configured. It also provides a good bridge to facilities management. While a draft began to be prepared for the Woodland Trust, it was not used in discussions and never completed.

BPE Team involvement
The BPE contract started in August 2013, with a visit to the site. Since the BPE team included the building's architects and environmental engineers, it gave added impetus to the aftercare. A number of items were identified, which are summarised in Table 3.1 and described in more detail in Section 7, Technical Issues.

October 2011 saw the anniversary of handover passing with several outstanding items, particularly relating to the BMS, metering systems, and server room cooling systems, so the Defects Liability Period was extended. The BPE team also convened a meeting in January 2012 to review findings and actions with the occupier and all members of the design and building team.

The meeting helped to clear the air and a number of items were resolved. However, although the extended Defects Liability Period continued to April 2012, some items remained outstanding. This applied particularly to controls and metering, which were important in terms of optimising the performance of the building, but not seen as major issues from a construction standpoint. However, it also took over a year to resolve all the problems with the chiller, in spite of its high specification and its criticality to maintaining the Trust's operations. Ironically, it became easier to get results when the participants were on direct maintenance contracts and no longer bound together by the building contract.

5.3 Conclusions on operation, management and aftercare

It is perhaps surprising how many aftercare issues arose in what is essentially a relatively small, simple and well-executed building, and one which (apart from the problems with the server room cooling) performed much closer to its design intent than most. This reveals the need for buildings to receive much more fine-tuning and for there to be suitable resources and budgets to do so. As the facilities manager said:

"The Woodland Trust is lucky to have got less complication than most.
It is difficult enough to cope with the complication we have got".

Table 5-1 Summary of emerging issues addressed

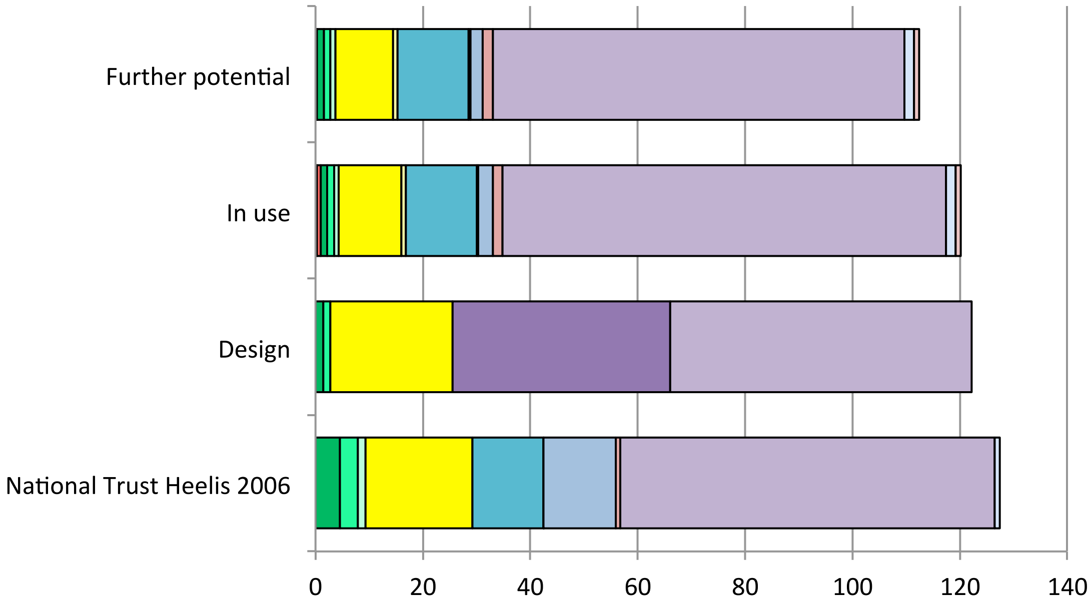
Item	Effect	Action taken	Comment
BUILDING FABRIC			
Nuisance triggering of motorised front doors by passers-by, particularly inside.	Unnecessary opening and draughts.	Changed from presence detector to push button on the inside. *The outdoor problem is less severe.*	Designers to note.
Confusion by visitor of door button with adjacent fire alarm button.	Unwanted fire brigade callout.	Lift-up cover placed over fire alarm button.	To avoid such mistakes, do not put fire alarm buttons adjacent to door buttons.
Double doors open for one person.	Excessive draughts, in cold and windy weather.	Switch installed to hold one door off.	Designers to note. Results appear satisfactory.
Greater deflections of floors with CLT structure.	Vibrations of computer screens with footfall and closing filing cabinet doors.	An adviser to the Trust recommended dampered articulated joints for screens, but these were expensive.	Designers to note. The Trust advised staff to tread gently and installed soft closers on the filing cabinets
HEATING AND HOT WATER			
Hot water primary circuit not piped direct to Boiler No 1 as designed.	Slow recovery of hot water. Heat leakage into offices as common flow temperature exceeds compensation value.	With manufacturer agreement, contractor connected flow pipe from Boiler No 1 to primary coil via a 3-port diverter valve.	Return pipe not altered, so excess heat still supplied into building in winter. Boiler manifold also heated unnecessarily in summer.
BMS enabling of boilers and heating pump not operating correctly.	Some loss of heating. Circulation of hot water into offices in mild weather, mostly blocked by 2-port zone valves.	Controls corrected under maintenance contract. *A new problem emerged in Summer 2013.*	Still potential for heat leakage because the manifold is shared with the HWS. *2013 problem now corrected.*
Immersion heater found permanently on in 2011.	Unnecessary. Gas should have been more economical.	Immersion heater switched off. Switches better labelled.	Emphasise needs for labels, indicator lights and possibly time controls in design documents.
Some heating pipework in the centre of the Project Space by-passes the zone valve.	An area of uncontrolled heat output.	None. Output normally tolerable because the heat spreads into a large volume, including the main offices.	Wasted heat and potential discomfort when heating pump was wrongly operating in summer.
Air infiltration from floor void through open ends of trench heaters.	Could chill small rooms under certain wind conditions.	Ends closed in problem rooms, typically in corners with short lengths of heater.	Even with low air infiltration rates, leakage can be concentrated.
Downdraughts from atrium windows in cold weather.	Downdraught scissors between updraughts from trench heaters.	Temperature settings in north zone raised, south zone lowered, to stop atrium zone valves closing prematurely.	Designers to consider complex downdraught patterns from tall windows.
NATURAL VENTILATION			
Window chain drives started to disconnect in Summer 2011.	Automated ventilation was not usable for a period.	Modified link pins were fitted rapidly under the contract.	No failures reported subsequently.
Health, safety and vandalism concerns about the extent of window opening.	Window opening restricted from that agreed with insurers and the Trust during design.	Opening areas reduced using stays to manual windows and settings of motorised ones.	Seek robust design solutions: circumstances may change. Effects not severe to date, but there has not yet been a

Item	Effect	Action taken	Comment
			prolonged hot period.
Insufficient background ventilation in winter.	Complaints of poor air quality or draughts.	FM cracked open some windows manually to increase ventilation.	Designers to consider more robust background ventilation systems.
Motorised windows open too far when CO2 levels exceed threshold.	Complaints of chills and draughts.	Initially, CO2 setting raised to 2000 ppm. In 2013, BMS altered to allow more control over settings by FM.	Designers to note that only small amounts of well-distributed opening are necessary in winter.
Night cooling and concrete radiators disappointing in the summer 2011 & 2012.	Automatic windows did not operate as much as anticipated, with many contributing factors.	Follow-on funding was successfully obtained from TSB for an in-depth investigation.	See Appendix 10.5.
MECHANICAL VENTILATION			
AHU 1 (S wing) operating overnight owing to BMS over-ride for IT test room.	Meeting rooms in the South wing chilled as heat is off overnight.	On-demand BMS runback timer button installed in IT test room.	In practice, mechanical ventilation was only occasionally requested in these rooms.
LIGHTING			
Low-angle sun glare from south-facing windows.	Complaints from office workstations.	Roller blinds fitted by FM.	Solar protection needs to address glare as well as unwanted heat gains.
Reflected solar glare from windscreens and adjacent buildings through low-level north-facing windows.	Complaints of upward reflections at some office workstations.	Roller blinds fitted by FM.	Reflected glare can come from unexpected place, and particularly through low-level windows.
ICT SYSTEMS			
Thin clients connected to mains power 24/7.	Electricity wasted outside occupancy hours	Successfully experimented with using auxiliary audio supply from display instead.	Display settings needed changing. Not all displays had auxiliary outputs. Sunray thin clients are no longer supported by the manufacturer and may soon be replaced.
IP phones powered from the server room 24/7.	Electricity wasted outside occupancy hours at both phone and in server room.	IT efficiency consultant engaged. Recommended programming auto power-up and power-down.	Not yet implemented.
Flat electricity use in the server room.	Possible waste of electricity.	IT efficiency consultant recommended software update and traffic survey.	Software update only done to date, with small benefits. Traffic survey might reveal scope for considerably more.
SERVER ROOM COOLING SYSTEM			
Chiller breakdowns.	Rapid increase in server room temperature. Complete loss of ICT.	Emergency cooling had to be rented by the Trust. Replaced in 2012 by a permanent backup installation.	Make sure value engineering doesn't undermine the resilience of critical systems.
Chiller control failures after power interruptions (quite	Complete loss of ICT and need for controls to be	Manufacturer eventually upgraded controls including a	Commissioning procedures to evaluate the effect of a

Item	Effect	Action taken	Comment
common in Grantham).	re-programmed.	backup battery.	power interruption.
Chiller performance not optimised for chilled water flow and temperature.	More electricity used than theoretically necessary.	None, owing to the Trust's prime concern about reliability.	Scope for future improvement. Need for design caution about sophisticated systems.
Fans of DX standby cooling units run constantly.	More electricity used than if interlocked to an alarm system. The compressors also come on occasionally too.	None, owing to the Trust's initial tests, and its prime concern about reliability. Electricity use has also not increased significantly since the backup was installed.	Scope for future improvement. The monitoring systems of the InRow chilled water fan coil units should be able to provide robust alarms.
BMS AND METERING			
Unsatisfactory data logging.	Missing data, causing difficulties in analysis.	Investigated and largely related to incompatibilities with a thin client system.	Designers need to be aware when thin clients are used.
Faulty electricity submeters	Further complicated the monitoring	Replaced as maintenance, after the end of the defects liability period.	Specifications need to emphasise effective commissioning of meters.
Faulty check meter	Further complicated the monitoring	Failed shortly after the other meters were repaired and not yet reinstated.	A contingency fund would have been desirable to tackle these issues quickly.
Poor resolution of some meters and lack of data buffering.	Impossible to determine demand profiles for some meters.	Manufacturer recommended a new interface unit, but no funds could be found to install it.	A contingency fund would have been desirable to tackle these issues quickly.
Calibration drift of CO2 sensors.	Inconsistent readings between different sensors.	Advised the FM to rely on the more representative sensors in the office areas.	Self-calibrating units can be confused in airtight buildings.
Outdoor air temperature sensor often read high.	Inhibited day and night cooling unnecessarily.	Convection currents found from solar-heated timber cladding. Sensor moved to a less vulnerable position.	Good locations for outdoor sensors can be very difficult to find.
BMS temperature average inappropriate for night cooling.	The point used for frost protection was initially employed: it included sensors in rooms with no night ventilation.	BMS average changed to offices only.	Take care deciding what sensors to use for what purposes.
BMS software inhibiting night cooling.	The algorithms that calculated the need for night cooling and the interlock with heating were too complicated.	Algorithms were simplified and user interfaces improved, to give more control to the FM to change programmes and settings.	Sometimes people are the best judges of whether to choose the particular mode in which the BMS should operate.

6.0 ENERGY USE BY SOURCE

Electricity Demand



	National Trust Heelis 2006	Design	In use	Further potential
Space Heating	0	0.0	0.2	0.0
Hot water	0	0.0	0.7	0.3
Fans	4.6	1.4	1.3	1.3
Pumps	3.3	1.4	1.2	1.2
Controls	1.4	0.0	0.9	0.9
Lighting (Internal)	19.9	22.7	11.6	10.8
Lighting (External)	0	0.0	0.8	0.8
Small Power	0	40.6	0.0	0.0
ICT Equipment	13.2	0.0	13.2	13.2
Vertical Transport	0.1	0.0	0.3	0.3
Catering - Central	13.4	0.0	2.6	2.3
Catering - Distributed	0.9	0.0	1.8	1.8
Regional server room 1	69.7	56.2	82.6	76.7
Security Systems	1	0.0	1.8	1.8
Emergency Lighting	0	0.0	1.0	1.0

kWh/m²/year

Figure 6-1 Comparison of annual electricity consumption (kWh/m² GIA)

6.1 Introduction

The Woodland Trust HQ aimed to be a low-energy building, learning from the previous experience of the architects and environmental engineers, and from the POE of Heelis, the National Trust's head office, in 2006-07[1].

Energy use details are recorded in the CIBSE TM22 (2013) workbook, see Appendix 10.6. Figures 6-1, 6-2 and 6-3 summarise the annual electricity consumption, gas consumption and CO_2 emissions per unit of gross internal area for:

- Heelis, using the estimated breakdown of consumption figures in 2006 from the POE. These included a number of approximations owing to difficulties with the sub-metering.
- The design estimate for the Woodland Trust calculated by IES for building regulations approval and Max Fordham's design estimate for the server room and its cooling system.
- Actual annual energy use in the year from September 2012 to August 2013.
- Scope for future improvement by relatively minor alterations.

6.2 Annual electricity use

At 120 kWh/m^2 in-use annual electricity consumption is very similar to the design figure, see Figure 6-1. The design estimates are collated from the dynamic thermal simulation results for building regulations and estimates of unregulated loads, based on what was known at the time. For the regulated loads this is reassuring. For the unregulated loads, particularly the server room, the correspondence is somewhat fortuitous. The overall similarities conceal a wealth of detail underneath, as discussed below.

Fans
The lower fan energy use at the Woodland Trust arose from the choice of natural ventilation for the main office areas. The mixed-mode system at Heelis had background mechanical ventilation and heat recovery available in winter.

Pumps
The lower pumping energy at the Woodland Trust relates to a simpler, lower-powered system with shorter hours of operation and better variable volume pumping. In both the Woodland Trust and Heelis, chilled water pumping is assigned to the server room.

Lighting
While the design estimate was similar to that at Heelis, in practice lighting energy use at the Woodland Trust was nearly halved owing to the success of the ambient lighting strategy and the low usage of the task lighting. Gratifyingly this was also coupled to high levels of occupant satisfaction with lighting in the BUS survey. Emergency lighting for the Woodland Trust is shown separately, at the bottom of the table.

Small power and ICT
The IES allowance for small power (which includes a few things additional to ICT, e.g. distributed catering) was about three times as high as ICT energy use in the office space at

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[1] When revisited in 2013, electricity consumption at Heelis was similar, but gas consumption was 30% higher, reportedly as a consequence of savings in facilities management and maintenance in 2008-11. This was being taken in hand with repairs and alterations to the plant and upgrades to the controls, including individual controls for the automated windows.

Heelis and at the Woodland Trust. In both buildings, energy use by printers was relatively low owing to a strategy of centralisation. PC consumption was also low owing to widespread use of laptops at the National Trust and to the thin clients at the Woodland Trust.

Vertical transport
Both buildings had good central stairs, which minimised the use of the lift. The lower figure at Heelis relates primarily to the building being nearly three times as large, and only having two floors and the one lift.

Central catering
The conscious decision not to include a catering kitchen at the Woodland Trust removed a significant segment of the demand. The Central category is used here to designate equipment in the staff kitchen in the south wing, together with the hot drinks machine in reception - the only one in the office. Note that the kitchen at Heelis also uses gas for cooking and hot water, as discussed in Section 6.3.

Distributed catering
The higher figure for the Woodland Trust relates partly to the absence of services from a central facility and more tea points in relation to its floor area.

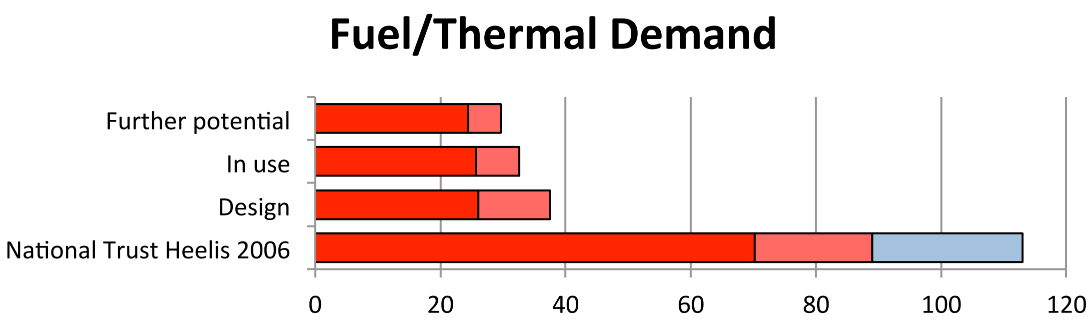
Regional server room, including its air conditioning.
At Heelis, the high electricity consumption of the server room came as a surprise, being about 2.5 times the design estimate in its Log Book.

At the Woodland Trust, a serious effort was therefore made to reduce this; and the Trust estimates that it uses two-thirds as much electricity as their previous installation. Nevertheless, the final out-turn was nearly 50% above the design estimate and significantly more than at Heelis in 2006. Reasons included more processing in the server room with the thin clients, and a reluctance to fine-tune the chilled water system owing to its initial unreliability. Annual electricity use for cooling the server room at the Woodland Trust was 45% of that used by the equipment in the room. The figure was virtually unchanged before and after installing the backup equipment.

6.3 Annual gas use

At 32.6 kWh/m^2, annual gas consumption was significantly below the design estimate, and that in a very cold year (Midlands 15.5°C degree-days to August 2013 were 2751, as against a 20-year regional average of 2162). Even after deducting the catering kitchen (which the Woodland Trust decided not to have), consumption is 37% that at Heelis. Reasons included:

- Better thermal insulation with minimal thermal bridging. Infra-red photos at Heelis in 2013 revealed many thermal bridges with its embedded steel structure.
- A compact plant room with more efficient, lightweight, condensing boiler plant.
- Control problems at Heelis, leading to overheating and unnecessary operation of the automated natural ventilation system.
- Some under-ventilation at the Woodland Trust.
- Shorter and more regular operating hours at the Woodland Trust.



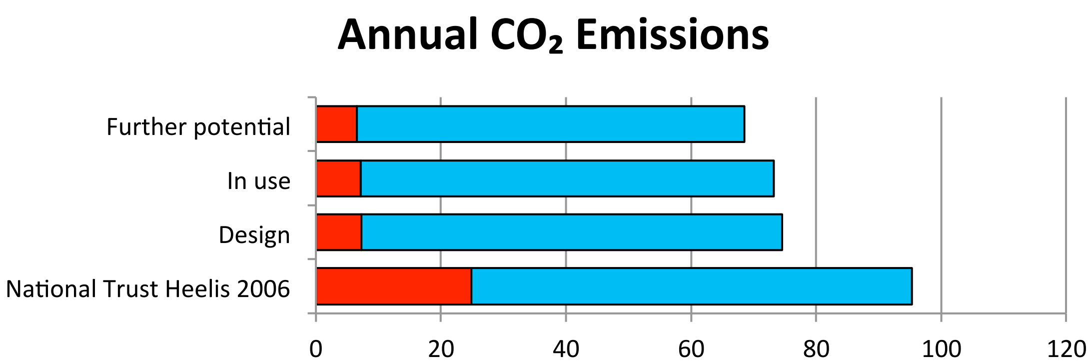
	National Trust Heelis 2006	Design	In use	Further potential
Space Heating	70.2	26.1	25.7	24.4
Hot water	18.8	11.4	6.9	5.2
Catering - Central	24	0	0	0

kWh/m²/year

Figure 6-2 Comparison of annual fuel/thermal demand (kWh/m^2 GIA)

6.4 CO_2 emissions

Figure 6-3 shows the important effect the reduced gas consumption had on the overall carbon footprint of the Woodland Trust in relation to Heelis. What it does not show is the renewable energy supplies. The Woodland Trust had none, while Heelis had a large PV array which provided some 65,000 kWh per year, reducing the its overall footprint by 5 kg/m^2.



	National Trust Heelis 2006	Design	In use	Further potential
F/T	24.9	7.3	7.2	6.5
E	70.4	67.3	66.1	62.0

$kgCO_2/m^2/year$

Figure 6-3 Comparison of annual CO_2 emissions (kg CO_2/m^2 GIA))

6.5 Potential for future savings

The estimate of potential made in TM22 estimates that a further 6.4% saving of emissions may be possible using relatively simple measures, as outlined below.

Table 6-1 Priority areas for future potential energy saving

Area	kWh(E)/m²/yr saving	kWh(F/T)/m²/yr	% emissions saving
Server room	5.9	0	4.4%
Hot Water	0.4	1.7	0.8%
Internal lighting	0.8	0	0.7%
Space heating	0.2	1.3	0.5%

Server room
This offers the biggest potential. The measures chosen include:

- Switching off the power supplies to the VoIP phones when the offices are closed. This is feasible, but requires programming to power the system up progressively in the morning.
- Interlocking the backup cooling to the alarm system for the InRow chilled water units, so they only operate in an emergency, and do not stay on hot standby as at present.
- Associated savings in cooling energy.

Further savings would be possible if the performance of the chiller could be optimised to maximise the use of free cooling an minimise use of the compressors. However, we suspect this will be difficult given the understandable sensitivity of the Trust to its reliability.

We have not allowed for savings in other ICT systems, as the Woodland Trust is currently reviewing its plans in relation to the withdrawal of manufacturer support for the Sunray thin clients. The review will take careful account of the implications for energy use.

Heating and hot water
The electricity saving shown for hot water relates to the magnetic water treatment unit. When specified, the manufacturer's data sheet said it used 3 Watts, while the true figure is 230 Watts. Since it is placed on the outflow from the hot water cylinder, there seems little point in operating it when hot water is not circulating. We suggest switching it from the same timed power supply as the hot water secondary pump.

The estimated gas saving would come from completely separating the hot water from the boilers. This has two parts: one increasing the efficiency of hot water generation and the other stopping heat leaking unnecessarily into the heating system. This would probably not be feasible until the time of plant replacement. An intermediate step would be to re-pipe the return from the calorifier direct to Boiler No 1, following the original design intent.

Internal lighting
The savings here would come from circuit improvements to unlink the lights that need to be on during the day (particularly in the visitor area), from those that do not - particularly those in the Project Space, the entrance canopy, and around the opening just inside the entrance. Further savings would be made by improving the control of the ambient lighting, which currently operates to rigid time controls unless over-ridden from Reception.

Renewable energy
The Trust is about to review energy strategy across for its whole estate. One option is PV panels on the roof of the HQ. The architects made provision for this by orienting the entire roof area to the south. A feasibility study by Solar Century in 2012 estimated the potential to accommodate a 110 kWp installation, producing about 90,000 kWh per year, or 33 kWh/m^2. This is very similar to the electricity consumption of the whole building, apart from the server room and its cooling system.

6.6 Use of TM22 Methodology

The use of the TM22 spreadsheet to carry out this assessment has been challenging. Its presumption of complete, error free data reduces its power for gaining a rapid overview of a building's energy use and gradually adding detail to the picture. This restricts its benefit for investigative purposes. Earlier versions of TM22 made it easier to proceed iteratively towards a final assessment, with tweaks and refinements along the way. TM22 now has an audit-like rather than a probing feel. The new use of Excel software features in this conversion may also have moved it beyond the robust capabilities of the format.

6.7 Summary of findings on energy

The most noticeable difference between in-use energy performance of Heelis and the Woodland Trust is in gas use for heating and hot water. Even though the Woodland Trust does not use mixed-mode mechanical ventilation and heat recovery, consumption has been kept low by decent fabric and build quality; the avoidance of a catering kitchen in the brief; and some potential compromise on air quality lowering ventilation heat loss.

On the electrical demand side, internal lighting shows a significant improvement, while the energy use and heat gains from ICT in the office space have also been kept low. The good performance is helped by a favourable culture and climate, where occupants do switch off their lighting and equipment when not in use.

Unfortunately, the hope to reduce the overall ICT energy use in relation to Heelis was not fulfilled, with the server room and its associated cooling system dominating electricity consumption at the Woodland Trust HQ and eroding many of the gains made elsewhere.

The big lesson is that, to create truly low-energy office buildings, there needs to be a dedicated effort to reduce the energy use of their ICT services. The ICT energy consultant who reviewed the installation for the BPE team considered that it might be possible to cut annual energy consumption by a factor of three when specifying new systems, and not without outsourcing this energy use to the Cloud either.

7.0 TECHNICAL ISSUES

7.1 Introduction

This section draws attention to technical issues that arose, capturing lessons to assist the design of better, comfortable, economic low-energy buildings it the future. Many of these are inevitably about things that did not work out quite as anticipated, and the scope for improvement in the future. Before starting, it is therefore important to state that the building was very successful in meeting its objectives as an asset, and to support the Woodland Trust as an organisation. Its energy performance was also similar to predictions, in a world where differences of factors of two or even three are not unusual. Part of this is related to the relative simplicity of the building, and the level of attention to detail. Energy economy was also reinforced by the operating practices of the Trust, with the office open between 07:00 and 18:30 on weekdays and not normally accessible to anyone at other times; and everybody switching off their computer screens, task lights and other equipment when leaving their workstations.

The BUS occupant survey indicated responses were in the top 20% for occupant satisfaction and perceived productivity, albeit with some drawbacks, particularly in respect of noise: the only principal indicator that was significantly worse than average. This may be partly because many staff were unused to working in open plan offices. Noise travels also quite freely within and between all three floors of the office space, with meetings and events in the Project Space being particularly intrusive.

Reported problems regarding temperature, air quality, health and draughts have all been investigated and improvements made. Further improvement is likely over time, as alterations are made and operational experience is gained. A repeat BUS survey would be of interest if the general experience in 2014 is thought to have been better: a second survey at Heelis indicated that fine tuning had improved the user experience.

Write-in comments by respondents included much more praise than in most BUS surveys. This included its appearance, light, sense of space; the ease of finding other people; the furniture, facilities, breakout areas, IT system; and the helpful staff. Some individuals who were critical of specific aspects also praised the building generally. This quote sums it up:

"The building is beautiful and light, inspirational. The new social hub area is a real bonus and is changing the way we work. However, there are a few niggles."

7.2 Space use and activities

Uniformly sized workstations
Many felt the standard workstation was generous. Some would have preferred smaller ones, with more nearby space for layout, visitors and part-timers, e.g. perhaps with the standard 3-person width unit having slightly narrower workstations and some spare at the end. Though breakout space was provided for visitors and ad hoc meetings, the pressure on meeting rooms has been greater than anticipated.

Paperless policy
The office has a paperless policy, including clean desks overnight and limited local storage. However, several people whose jobs involved papers (e.g. technical drawings) or objects (e.g. marketing materials and training equipment) commented that they would have welcomed workstations with more layout space and local storage.

Meeting rooms
The overall attractiveness of the building has increased the demand for larger meeting and training areas. The Project Space is now used for some of these activities, but because it is open to the main offices, noise breakout is a problem. The Trust is therefore considering an acoustically baffled enclosure, open enough not to impede natural ventilation. The Project Space also provides space for ad hoc teams, in accordance with the original design intent.

Open planning and noise
The Project Space is not the only source of noise nuisance. There is little masking noise (e.g. from traffic or mechanical systems) and few absorptive surfaces apart from the carpet, so noise also spreads from office activities and breakout areas. Some people and groups have therefore been relocated in order to separate the noisier activities from particularly noise-sensitive areas. Quiet areas have also been introduced in parts of the open-plan office, and designated by symbols.

WCs
In the occupant survey, some people objected to the unisex WCs. There have also been some problems with the wall hung WC pans, which are supported by a timber structure that has weakened in places. Where this has happened, the Trust has found it simpler and cheaper to replace the pans with floor-standing ones, than to reinforce the structure.

7.3 Building fabric

The fabric achieved its objectives of good airtightness and insulation with minimal thermal bridging. Minor issues that arose included:

Shrinkage of the CLT panels
This is natural for a timber structure, and was not found to cause significant additional heat loss, as the joints between panels were sealed externally with laps and air tight tape. The cracked mastic pointing on the inside will be replaced when the interior is redecorated to maintain the fire-retardant coating.

CLT floors with concrete radiator reinforcement
Floors vibrated more than normal concrete or composite floors, causing computer display screens on articulated joints to shake in response to heavy footfall. Articulated joints with dampers were recommended, but expensive, so people have been asked to tread gently. Slammed filing cabinet drawers also caused vibration, so soft closers have been fitted.

Draughts from automatic sliding front doors
Several problems arose in use:

- The indoor presence detector opened the doors unnecessarily every time someone walked past the reception desk, so was replaced by a large push switch.

- The outdoor sensor is also triggered by people walking past to the garden or cycle shed, but this occurs much less, so no changes were made.
- The new push switch was located under the fire alarm button, which a visitor once pushed in error, calling out the fire brigade. The fire alarm is now protected by a flap.
- Both doors opened together initially, causing uncomfortable draughts in cold and windy weather. The traffic is not high enough to need both doors open in normal circumstances, so a keyswitch was added to lock one door off, which it normally is.

7.4 Heating and hot water

Heating
The three modular condensing boilers on a common primary header are directly sequenced and compensated via a proprietary unit. They have generally worked well, with gas consumption below the predicted level. A few problems emerged in operation:

- The interlock between BMS and controller did not function properly, allowing hot water to circulate into the building when not required. This proved difficult to correct during the defects liability period, but the BMS maintenance contractor dealt with it rapidly.
- One heating loop (in the centre of the Project Space) was permanently connected, as a length of pipework bridged between flow and return, by-passing the zone control valve. This caused heat wastage at times when hot water was circulating unnecessarily, but is not significant now the controls have been improved, given the large volume of the Project Space, and the air circulation between this space and the main offices.

A single occupancy time schedule was originally used to control both heating and night ventilation, with various interlocks to decide which was required and to avoid conflicts. In practice, night cooling was often inhibited and sometimes the heating ran unnecessarily. During the follow-on project in 2013, the two programmes were separated, leaving the FM to decide on heating and night cooling seasons and enabling schedules and settings. Initially, a vestigial interlock remained, inhibiting operation of the motorised windows during the day (manually or automatically) unless heating was enabled. This was subsequently corrected.

Hot water
On the first visit in August 2011, the BPE team found that the emergency immersion heater for hot water had been left on inadvertently, probably for many months, as was confirmed by subsequent submeter readings. It was turned off and a warning notice provided.

The hot water calorifier coil was initially fed from the heating header, not directly from Boiler No 1 as designed. This slowed down the rate of recovery of hot water temperature, raised the temperature of water circulating to the perimeter heating when hot water was being heated, and increased standing losses. The contractor subsequently connected Boiler 1’s flow to the coil via a 3-port diverter valve, but the return pipe remained connected to the header, rather than having a direct route back to the boiler. This improved performance (as the large modulation range of the boiler allowed the flow temperature to be higher) but diluted the return temperature and did not eliminate the header and circulation losses.

The BPE team would have preferred the return pipework to have been installed as designed, but the contractor said that the manufacturer, had endorsed their modification as appropriate for the boiler configuration they had supplied.

Cold rooms
Meeting and quiet rooms sometimes struggled to warm up. Smoke tests and infra-red photographs showed that cold air could enter the floor void through the open ends of the perimeter trench heater casing. Although the airtightness of the building was good, under some wind conditions, any infiltration into the floor void could be concentrated in a small room, where the short length of trench heater also had a proportionally much larger area of open end in relation to its output. The ends of the trench heaters in troublesome rooms were closed. The problem was exacerbated in the south wing for a period, when the server room floor void barrier was also cut away to accommodate emergency cooling pipes.

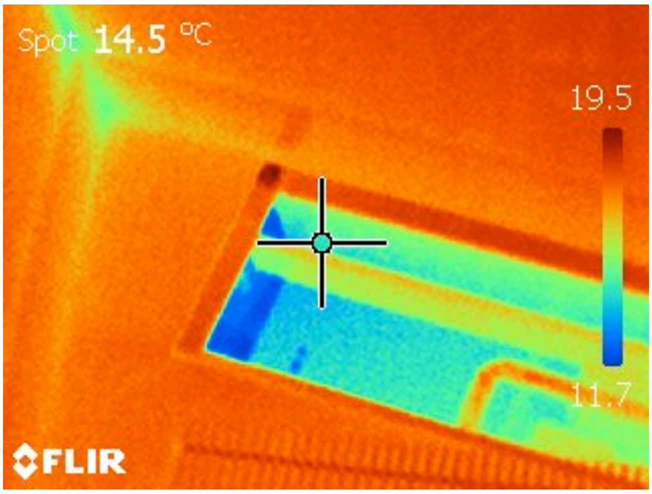


Figure 7-1 .Corner room, ground floor offices NE

Note the cold housing of the trench heater unit (covering grille removed), and the yet colder concrete sub-floor beneath the open end of the trench heater. With south and west winds, air from the cold floor void could blow in through here.

A localised thermal bridge is also visible at the acute-angled junction between the north and east walls (top left).

Atrium downdraughts
Complaints of occasional draughts at workstations near the base of the north atrium were related to complex air flow patterns. Trench heating on all three floors offsets heat loss and draughts, but at the atrium this is on the ground floor only, so with stronger downdraughts to counteract. Smoke pencil tests revealed that sometimes the downdraught bifurcated the hot air plumes from the trench heaters, with the warm rising up the inner surface of the CLT panels, while the downdraught air was driven out into the space at about shoulder height. The effect was strongest at mid season when weather compensation or zone temperature control reduced heat output; or when windows were open a little for ventilation and the incoming cold air could attach itself to the downdraught. To counteract the effect, the temperature settings were also altered to give priority to the north zone, raising its set point by 0.5°C whilst lowering that for the south zone by a similar amount.

7.5 Ventilation and cooling

Window opening restrictions
At the design stage, the amount of window opening for night cooling was agreed with the Trust and its insurers. However, shortly after the building was opened, the site (which had been an informal route between a housing estate and the town centre) suffered vandalism. This included kicking over nearly all the external lighting bollards, which had to be rebuilt and refixed more strongly. The Trust and its insurers then became concerned about window opening for night ventilation, and a restriction of 20% was introduced. It may be possible to relax this for windows facing onto the enclosed indoor courtyard, but this has not yet proved necessary.

Although not a building regulations requirement for offices, restrictors were also placed on accessible openable windows for health and safety reasons. Three motorised windows within arm's reach were also disconnected. This reduced available ventilation in relation to design intent, but so far with few ill effects.

Winter fresh air
The design concept was for individual occupants to open windows as necessary. In winter, this happened less than anticipated, partly because the openings of the top-hung windows are at desk level and could give rise to local draughts, particularly when windy and when windows on opposite sides of the building were open. A more diffused and less direct input would have been preferable.

Although the motorised windows are higher up, automated opening also caused draughts as they were initially programmed to open in coarse notches, with a minimum 10% setting. The FM therefore increased the trigger CO_2 level from 1200 to 2000 ppm. This higher level was seldom reached (the BPE team's spot measurements indicated typical peak values in the region of 1600 ppm), but there were some complaints about air quality and headaches. During winter 2012-13, the FM therefore opened windows manually in places remote from workstations, with some success. In September 2013, the BMS was altered to allow motorised windows to be opened very slightly, either under automated CO_2 control or manually by the FM. Since then, the numbers of complaints are reported to have fallen.

Ground floor meeting rooms
The ground floor meeting rooms in the south wing could get very cold overnight. In addition to the trench heater problem outlined in Section 7.4, AHU1 was found to be operating 24/7 even though not activated by the BMS time schedules and meeting room runback timers.

AHU1's constant operation wasted energy and also drained the meeting rooms of heat overnight when the boiler plant was off. In addition AHU1, which is located in the deep ceiling void above the server room, was operating with heat recovery only, as the Trust had disconnected its heater battery and the associated pipework to avoid leakage risks.

Eventually the BMS maintenance engineer found a hidden override deep in the software. It must have been installed in response to a request for ventilation in the windowless IT Test Room, which had previously only been ventilated incidentally, at times when AHU1 ran on request from a meeting room. An additional push button was therefore installed to ventilate the Test Room on demand.

In practice, AHU1 was seldom required to operate: the meeting rooms normally used their openable windows, while most of the time the Test Room was only occupied by equipment on test, and could be cooled as necessary by its FCUs. The BMS was also programmed to hold off AHU1 at external air temperatures below 7°C if necessary.

Summer time night cooling with automated window opening
Though the summers of 2011 and 2012 were not particularly hot, there were complaints of overheating. While the concrete radiators contributed usefully to increasing the building's thermal inertia and reducing peak temperatures, it took considerable effort to get the control functions to operate effectively, particularly for night cooling, as outlined below. Full details are given in the report of the follow-on study, Appendix 10.5.

Night cooling did not work reliably at first, owing to problems with the logic, and the outdoor temperature sensor reading high. The original control strategy proved to have been too complicated in the logic of calculating when and how much night cooling was required; and too simple in having a shared occupancy time schedule, with time-delayed interlocks between heating and night cooling.

Although the outdoor sensor was in a well-ventilated and shaded position under the roof of the external escape stair on the west facade, the building's timber rainscreen cladding heated rapidly in the sunshine. Ad hoc checks revealed that convection currents could then raise the sensor temperature by as much as 8°C, inhibiting window opening because the BMS thought it was too warm outside, not just at the time but also the following night as the software used a moving average to calculate the need for night ventilation.

In May 2013, the external temperature sensor was moved to a better location in the dustbin compound (there was one spare BMS point in the chiller outstation nearby), the control strategy was simplified, and the operating schedule for night cooling was separated from that for the heating. The BMS was also re-programmed to give more authority to the operator to change time schedules and settings, with more user-friendly user interface screens for both heating and night ventilation, see Appendix 10.4.

The result was a very simple control strategy for night cooling based on three things:

- A decision by the facilities manager whether to operate night cooling and its timing, typically 8 PM- 6 AM, and what to do at weekends (see below).
- A threshold average temperature to activate night cooling, typically 23°C.
- A threshold average temperature to terminate night cooling, initially 18°C.

This proved satisfactory in Summer 2013. In May and June, night cooling was enabled from Sunday night to Thursday night only, but not on the Friday or Saturday nights because the heat might have been welcomed were it to turn cold over the weekend. When the weather became hotter at the beginning of July 2013, weekend cooling ceased to be adequate and the enabling schedule was increased to seven days a week.

Concrete radiator heat storage

The most important finding from the monitoring was obvious in hindsight. Owing to their high thermal capacity, the concrete radiators are the slowest things to cool overnight. As a result, the air, furniture and timber in the building could be cold in the early morning, even though the concrete radiators were still relatively warm, see Figure 7-2. If night ventilation was terminated two hours in advance of occupancy, surface and air temperatures could come closer to equilibrium, as residual heat in the concrete radiators warmed up the air and the colder surfaces, see Figure 7-3.

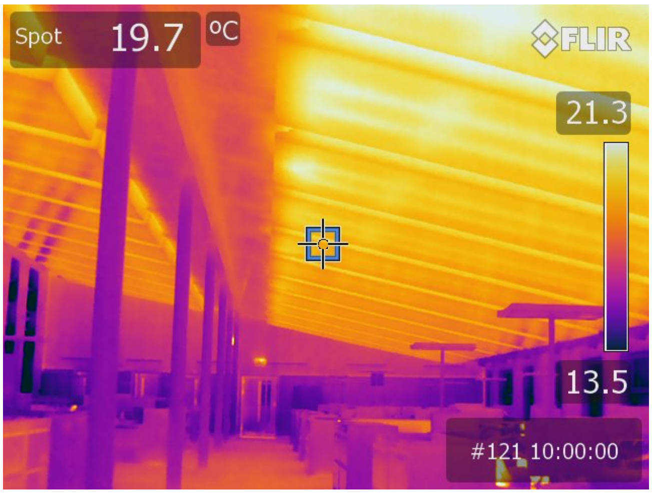


Figure 7-2 Infra-red photograph of the interior of the second floor office, looking east, after ten hours of night cooling

Note the cold furniture, columns, and wall at the far end. The patterns on the concrete radiators indicate where the central ribs are. The ribs at the edges cool more than those in the centre, owing to the additional surface area.

Figure 7-3 Two hours later

The windows were closed immediately after the photo in Figure 7-2 was taken. Two hours later, when the office is ready for occupation, the interior temperatures have become more uniform.

NOTE: These photos were taken during tests in relatively cool September weather. The temperature differences are not as great on normal summer nights.

The restrictions on the amount of window opening at night allowed the control of night ventilation to be relatively simple, namely from a decision whether to cool that night or not. Infra-red camera checks of all concrete radiators on several visits confirmed that they cooled similarly in all parts of the building, and on all floors. If the windows had been opened further, the cooling effect on individual concrete radiators would have been more affected by wind speed, direction and proximity to windows. These variations might have created local comfort problems under some conditions.

Stratification

Only a small amount temperature stratification was observed in the three-storey office during occupied hours or with night cooling, both during the Summer 2013 follow-on monitoring and with spot measurements throughout the project. The reasons are though to include limited solar gains, the large motorised window area at high level on the north facade and the design to maintain negative pressure at the eaves, see Figure 2-6. Significant stratification did occur on sunny weekends when windows were shut, see Figure 7-4.

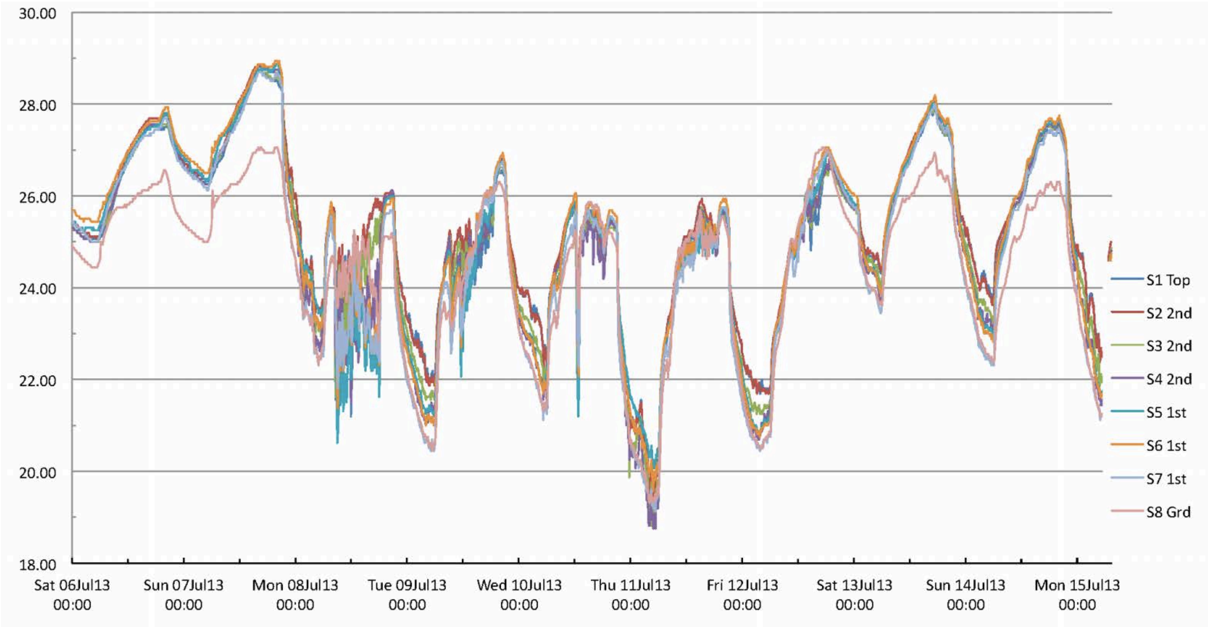


Figure 7-4 Stratification in warm weather

This shows the temperature recorded by a vertical array of temperature sensors, suspended on a cable from the roof in the SW corner of the 3-storey atrium on the North side of the building. This was at a time when full night ventilation had not been activated, and the motorised windows opened on Sunday to Thursday nights only. To the left and right are sunny weekends with the windows shut, the temperature of air on the ground floor is up to 2°C cooler than on the floors. Stratification is less on weekdays, when the offices are occupied and windows may be opened both manually and automatically. At the time, automated window control during the day was coarse, so its operation can be identified by ragged traces when it happened, here particularly on 8 and 9 July.

7.6 Lighting

The lighting strategy proved successful, with good use of natural light, supplemented by centrally-controlled ambient lighting and occupant-controlled task lighting. The main change since occupation has been to fit roller blinds to all the south-facing windows to avoid sun glare at workstations. Blinds also had to be added to the lower windows on the north facade to counter upward reflections from windscreens and adjacent buildings, particularly through the low-level windows.

Most staff worked happily at desktop illuminances well below published standards, particularly on screen-based tasks. On winter evenings, illuminance levels could fall to 50-70 lux at some workstations without any complaint owing to the largely screen-based work and because the ambient and wall-washing lights made the surroundings look bright.

Task lighting
Occupants used the task lighting economically, with only 20% of the fittings operating on average, rising to 30-35% on dark winter evenings, so there was no need to change the system or its use. A few people were in the habit of switching their lights on when they arrived, but others hardly ever used them. Not surprisingly, the task lights were found to be used most on the ground floor where there was less daylight, owing to internal and external obstructions. Although the task lights had user-selectable high (4 tube) and low (2 tube) settings, the high setting was predominant.

Ambient lighting
The ambient lighting was generally successful, washing the walls and illuminating the centre lines of the office, project area and reception spaces in an effective and economical manner. Its timed operation, typically from 7-9 AM and 4:30-6:30 PM stopped most people feeling a need to switch on their task lights when they arrived or when daylight faded at the end of the day.

The system might have been even more effective and efficient had the fittings had optics better suited to wall-washing, but these were value engineered out. It was also on more than necessary, owing to switch groupings and to inaccessible timer controls in local electrical distribution boards. A central timing facility would have been better, with a good user interface, readily adjustable at Reception.

In the reception area and project space, a single circuit served both well-daylit areas (including the entrance canopy) and poorly-daylit ones (including the visitor waiting area). In order to make arrival cheerful for visitors, this circuit therefore tended to be kept on all day. Ideally it would be split into four.

Lighting controls
The BPE team advocated regular changes to the time control settings for the ambient lighting. However, the timers were mounted in line with the circuit breakers in the local electrical distribution cupboards, and their small displays and buttons made them fiddly to use. Changes were also difficult to make operationally, as access to the electrical cupboards was regarded as a job for an electrician. As a result, time schedules needed to be liberal. The ambient lighting could also be switched on and off from Reception.

7.7 ICT Systems

Thin client ICT as an energy-saving measure
Thin clients offered advantages to the Trust in terms of software, archiving and security. However, they increased the dependency of the organisation on the reliability of the server room. In the event of a failure, all office ICT and telephones were lost.

The BPE study team engaged an independent ICT energy consultant to review the energy use of the server, client and telecoms equipment. Several energy-saving modifications were identified, including upgrading server power management software, undertaking a traffic survey, programming Ethernet power supplies to the IP telephones off when the building was unoccupied, and powering thin clients from the display screen's auxiliary power output, which goes off with the screen, avoiding the overheads of each thin client being connected 24/7. So far only the server power management software has been upgraded.

Unfortunately the manufacturer of the thin clients used was taken over by a larger company, who has now ceased to supply and support them; and will withdraw support for the associated server software entirely in 2017. The Trust is currently considering whether to use different thin client hardware or move to PCs. Depending what is finally selected, this may lead to some increase in energy use at the desktop, but it is hoped that savings can be made with the server and the telephone system.

7.8 Server room cooling

Chiller performance and reliability

During the first two years of operation, the chilled water system suffered from multiple problems – particularly related to controls, power interruptions, and a leaking outdoor free cooling coil which took a long time to repair, owing to argument between the supplier and contractor whether the fault was related to manufacturing, installation or maintenance.

The resultant lack of confidence in the system became a barrier to attempts to improve its efficiency, even though the server room and its cooling were the dominant electricity users on site. The complete dependency of the office on the server exacerbated these concerns.

Brief mains power interruptions can occur every few months in Grantham. Although backup power was available from a generator and server room UPS, these caused the chiller's inbuilt controller to forget its settings and also revert to German language.

After a year or so of argument and rented emergency backup arrangements, the chiller’s free cooling coil was finally repaired, its controls upgraded, and a permanent backup system with three direct expansion (DX) split units was installed.

Following tests, the Trust decided to leave the fans of all three backup running permanently: as otherwise they could not guarantee a safe transition following a failure to the chilled water system, because the temperatures in the equipment racks increased so fast there was barely time to power down. The differential between the temperature settings of the main and backup systems was supposed to keep the DX compressors off unless there was a chilled water failure, but site observations revealed that they did run occasionally.

Support for the relatively sophisticated chiller also proved difficult to obtain. The Trust eventually had to organise two contracts: one for local rapid response and a second for support and servicing by the manufacturer's agents.

The backup system has restored confidence in the continuity of the server room environment and the computing installation, but understandably a reluctance remains to undertake any fine-tuning to reduce energy use further, in particular:

- Decreasing the volume of chilled water and raising its temperature, in accordance with the original design intent; and
- investigations control strategies that would allow the DX units fans and compressors to stay off unless there was a chilled water failure, for example by using the alarm settings of the InRow units to initiate the backup, but with manual reset.

The situation is complicated because the facilities department is responsible for providing the operating environment for the information services department, and both departments are concerned that a lower-energy operating regime might carry risks to reliable control in an environment where the temperature can run away within 10-15 minutes of failure.

For a period after the waterside free cooling system was brought back into service in March 2012, the chiller worked less efficiently than using the compressor alone, see Figure 7-4 below. After another breakdown, the controls were adjusted for more efficient free cooling operation, as visible to the right of Figure 7-4. However, the chiller controls continued to fail when there was a power interruptions, until battery backup was eventually installed.

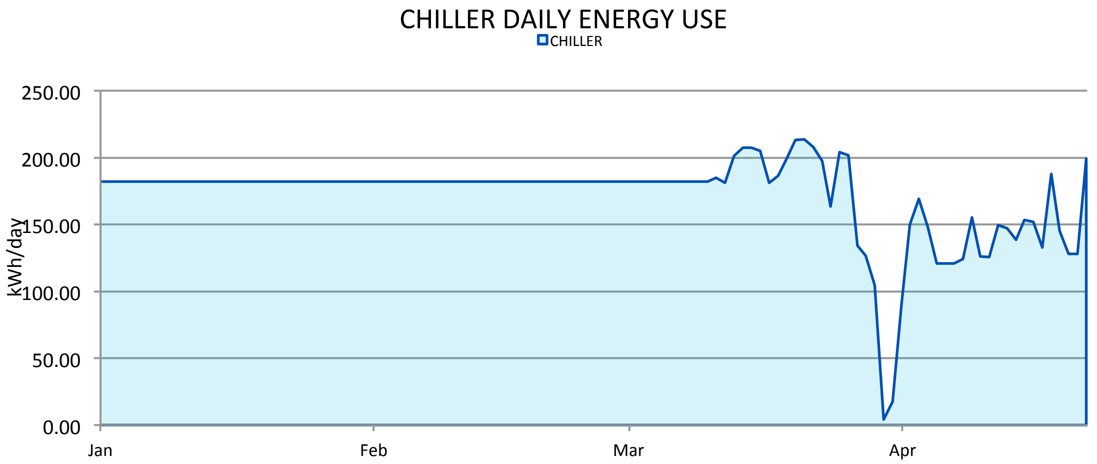


Figure 7-4 Daily chiller electricity use for the first four months in 2012
Until the middle of March, the free cooling circuit was not in use and daily electricity consumption was flat, suggesting the compressor was its minimum setting and capacity controlled by condenser fans at very low speed. In mid-March, free cooling was activated, but on average increasing electricity use, with the extra cooling fan energy exceeding the compressor savings. The chiller then failed and the manufacturer reset the controls. After this, operation became more efficient on most days.

As this report was being written in 2014, two new problems emerged with the chilled water system: a second failure of the free cooling coil; and corrosion pinholing of the small bore horizontal copper piping in the ceiling that connects chilled water to the fan coils in the south wing. Although some chemical and metallurgical analysis has been done, the causes of failure are not yet clear. Replacement of the small bore piping in the south wing is planned.

7.9 Controls and metering

Gaps in BMS and meter data logging and inappropriate sub-meter calibration.
The building's BMS and metering systems proved less effective at collecting useful data than had been anticipated. Problems included missing data owing to incompatibilities with the building's thin client system, a main check meter that did not record accurately, meters with insufficient resolution to allow daily profiles to be determined, and difficulties interrogating data remotely by the design engineers and BPE team, as had been planned.

Operating the BMS
Some BMS control functions proved to have been too highly automated, with not enough information or discretion readily available to the operator. This particularly affected operation of the motorised windows (both for air quality control and for night cooling) and the interlock between heating and night cooling.

CO_2 sensor calibration
CO_2 levels as recorded from zone sensors differed from each other and those measured by a handheld meter. The effect got worse over winter. The CO_2 sensors are self-calibrating and use standard automatic baseline calibration (ABC). This assumes that at some time during a week the building will be unoccupied and that the lowest reading it records will be close to

that of outside air (400 ppm) and resets accordingly. In practice the building is airtight enough to hold some of its stale air when unoccupied with the windows closed. A half-life of 26 hours for the decay of CO_2 concentration was measured over one weekend.

Lighting controls
Time programmers for circulation and ambient lighting were small DIN-rail units within the relevant local distribution boards, These were not readily accessible, small and fiddly to operate, and so the Trust only allows them to be adjusted by an electrician. A large bank of switches provides facilities for manual over-ride of ambient lighting from Reception, but these are not very clearly organised or labelled. It would have been better to have put all the time controls here.

Sub-metering
A number of problems afflicted the sub-metering system, not all of which could be resolved in the course of the project:

- Faulty sub-meters for the chiller and second floor lighting and a faulty connection of the pulsing unit on the gas utility meter. These were not corrected until after the defects liability period was over (they just did not seem to be a priority within the contract), but were dealt with as an maintenance item shortly afterwards, in May 2012. Subsequently the main electricity check meter lost calibration.
- Gaps in data logging for meters and BMS, sometimes for individual records or values and occasionally for hours or days. These proved time-consuming to detect and correct, as the metering system did not interpolate between missing readings. The main cause was the thin client system and the absence of buffering within the interface units between the meters and the server, so any data not recorded at the time of transmittal was lost.
- Poor resolution of some of the meters, which were supposed to be auto-ranging. This made it impossible to determine useful demand profiles for the smaller loads, i.e. everything apart from the server room and chiller.
- Problematic data links between the Woodland Trust and Max Fordham's offices.

Improvements to the metering were investigated by the BPE team. After considerable discussion including many referrals, the manufacturer concluded that the problem lay with the Trust's thin client architecture and that a new IP interface unit with minimum 24-hour buffer would solve all three problems: data loss, auto-ranging and resolution. The client's electrician came to a similar recommendation independently. Unfortunately no budget was available to install the new unit, for which the list price was £ 2500, but with uncertain commissioning and programming costs. In hindsight, it would have been best to have had a contingency budget to deal with problems or this kind quickly, as the effects on the quality of the data collected and the time spent to make use of it were enormous.

8.0 KEY MESSAGES FOR THE CLIENT, OWNER AND OCCUPIER

8.1 Introduction

The building has achieved many of its objectives, and the problems revealed in the occupant survey have been addressed, at least to some extent. Scope nevertheless remains for further improvement as changes take place and as further operating experience is gained. The points summarised below include those identified by the Woodland Trust as well as the BPE team.

8.2 The indoor environment

Noise control
Probably the largest outstanding issues is noise in the offices, which is partly related to the demand for meeting and training areas and the use of the Project Space, part of which could be enclosed to reduce noise breakout, as the Trust is already considering. There may also be a case for introducing more acoustic absorption in the offices. However, our impression is that some adaptation has occurred in space use and, as staff have become used to working in the open plan, their tolerance to noise and in taking care not to make too much.

Draughts
Ideally all open ends of the trench heaters would be sealed. Priority should be given to the shorter lengths of heater in enclosed rooms, where the relative effect will be worse.

The route to the garden and bicycle shed could be slightly altered to put pedestrians passing by out of range of the presence detector for the main entrance doors.

Unisex WCs
If objections persist, some cubicles could be designated women-only.

Another BUS survey
A second BUS occupant questionnaire survey would be helpful, to identify changes in perceptions since 2012, particularly in relation to noise, summertime temperatures, winter air quality and the associated comments on health. A good time might be in early 2015, after the changes made to heating and ventilation control and management during and after the follow-on project will have been operating for a year. However, if the acoustic treatment of the Project Space proceeds, it may be worth waiting to be able to include its effects.

8.3 Heating and hot water

While the system operates relatively economically, there is some scope for further savings:

- Connecting the return pipe from the hot water calorifier directly back to boiler No 1, and not into the manifold. This would reduce response time, cut standing losses from the header, and avoid the risk of any excess heat leakage into the building.
- Subject to the manufacturer’s comment’s linking the a time control for the electromagnetic water conditioner to that of the hot water secondary pump, to avoid electricity wastage outside normal occupancy hours.

- Considering the possibility of changes to heating time programmes and settings.
- Flow restrictors on taps could be considered.
- To improve comfort in the vicinity of the atrium, the trench heating could be made into a separate zone and given priority. There may also be a case for isolating some or all of the motorised windows here in cooler weather. The wiring does not allow this to happen floor by floor, it would have to be in vertical banks.

Now BMS control has been improved, there is only a weak case for re-piping the uncontrolled circuit in the Project Space.

8.4 Ventilation and cooling

Following the changes made in 2013, we think suitable BMS controls and operational practices are in place to make effective use of the automated ventilation. However, further fine tuning may be necessary, including revising the time and temperature settings; and possibly opening the courtyard windows further, in order to enhance night cooling in hot weather. Operational experience over summer 2014 would be worth reviewing.

On the final review of BMS data, we noted that the calibration of some CO_2 sensors had drifted badly. Since spot checks with a hand-held meter during our site visits indicated that CO_2 levels on all three office floors were normally within the range ± 50 ppm, we suggest that one, more accurate sensor is purchased and the others are retired. Alternatively, the Trust could purchase a hand-held CO_2 meter to make occasional checks and to decide which of the existing sensors could be trusted.

Mechanical ventilation to the ground floor meeting rooms in the south wing may not be necessary, but the windowless IT Test Room will need to retain some on-demand provision.

8.5 Lighting

Control of ambient lighting
The lighting works well generally, but minor alterations to circuits and controls would reduce its energy use as outlined in Section 6, in particular:

- Reducing the use of ambient lighting when daylight is sufficient. This could be done manually, by periodic reprogramming of the time switches, or by providing new time controls in reception or via the BMS, or possibly by solar switches and daylight-linking.
- Dividing up the circuit for the entrance, reception and visitor areas to avoid unnecessary use when daylight is sufficient.

8.6 ICT systems

Thin clients
Opportunities were identified for reducing out-of-hours electricity use by the thin clients by implementing automatic power-down. Better still, they could obtain DC power from the auxiliary outlet from the display screen instead of individual dedicated mains power bricks.

Power over the Ethernet is also possible, though this would only be sensible if the LAN could be switched off at night. It might not be economical even then, as all terminals would be powered during the working day, while screen power would only be available when occupants switched on their screens.

Whether it is worth investing in making changes of this kind will depend on the choices made to replace the Sunray 2 thin clients. Whatever happens, electricity use in and out of hours should be a key criterion in making a selection.

Server room equipment

- A traffic survey should be undertaken to review scope for more economical operation.
- The power-down of the IP phones at the end of the day should be investigated and implemented if practicable.

8.7 Server room cooling

Scope remains for optimising the overall performance of the packaged chiller system, including pumping, free cooling and the use of its compressors. Since the both the chiller and the room units were considerably oversized to allow for future growth in demand, there is the opportunity to run the pump at variable speed, and raise the chilled water temperature to maximise the proportion of "free" cooling. However, this might require thorough investigation of operating performance under a range of control settings and outdoor conditions.

An easier win would probably be to minimise unnecessary use of the three backup DX units. At present their fans run all the time and their compressors occasionally, imposing an average load in the region of 1 kW, though perhaps half of this displaces cooling energy that would otherwise be used by the chiller. The DX units could be activated when the InRow units go into an alarm condition, and keep running until manually reset after confirmation that the chiller is again operating normally. Sub-metering of the DX system is also desirable.

8.8 Controls and metering

BMS

Settings may need to be altered as operating experience is gained. The BMS maintenance contractor is also capable of making changes to the logic if they become necessary. If the Trust moves away from a thin client system, there may be benefits in using a PC as the supervisor.

Metering

Meter upgrading is desirable, in particular an IP/buffer unit, some programming work, the recalibration of the main check meter and a new meter for the backup cooling in the server room. These would improve the Trust's understanding of when and where energy was used and to identify the most efficient operating modes. It might also help the Trust's tariff consultant to negotiate a more favourable electricity supply contract.

9.0 WIDER LESSONS

9.1 Introduction

This final section summarises the broader lessons from the BPE at the Woodland Trust that may be of general interest to many future projects. The findings are grouped under the following headings:

1. Procurement
2. Occupier requirements
3. Design strategy and building fabric
4. Occupier equipment
5. Technical details.

9.2 Procurement

Learning from previous projects
Briefing, design and implementation at the Woodland Trust demonstrated the value of feeding forward findings from previous projects, specifically the post-occupancy evaluation (POE) at Heelis, the National Trust's head office in Swindon. Designed by the same architects and environmental engineers, Heelis was occupied in late 2005. To fine tune the systems, the National Trust also appointed Max Fordham to provide some support to their facilities manager in the first two years after handover.

Heelis received many awards, one of which included prize money, which the architects used to commission a POE in 2007. The POE was timely, feeding straight into the design of the Woodland Trust HQ, which started in February 2008. Table 9.1, at the end of this section, summarises key findings and suggestions arising from the Heelis POE that were incorporated into briefing and design at the Woodland Trust.

Right first time is not enough
Despite the best efforts of the architects and environmental engineers, several issues exposed in the Heelis POE were not resolved as comprehensively as the design team had hoped, particularly user interfaces to HVAC and lighting control systems, energy use by ICT systems, and the sub-metering installation. Considerable work was also required to fine-tune performance, particularly the BMS-controlled natural ventilation and night cooling system.

While as much as possible can and should be got right first time, It is unrealistic to expect a design to fulfil its potential in practice without some review, fine-tuning and feedback. A client brief to innovate by simplifying the design was helpful but not sufficient in itself. Even with the best intentions, missed opportunities, divergences from specification and unanticipated problems can lead to surprises.

With any complex system there will always be both intended and unintended consequences, particularly with any innovative aspects. Engineering systems will also need adjustment as operational experience is gained and the full range of occupancy and seasonal conditions are encountered. Post-handover aftercare is essential, feeding forward knowledge of the design intent to the occupiers and operators and feeding back the experience to benefit future projects and practice generally.

Soft Landings process
The architects and environmental engineers therefore applied the Soft Landings approach to the project, with some success. However, this was early days for Soft Landings - the Framework document was not published until 2009, though the architects and engineers had been involved in research with its originators in 2002-03.

In future projects, more could be done to improve the focus on outcomes during briefing, design and construction and the effectiveness of the aftercare, in particular:

- Explicit agreement to adopt Soft Landings at an early stage, with an outline of what this will entail, so all parties involved are aware of it at the time of their appointment.
- A designated champion or champions who are committed to taking it forward.
- Considering how emerging problems will be dealt with during the defects liability period. At the Woodland Trust it proved difficult to tackle some of the issues identified (particularly in relation to controls, metering and some details of the building services) until the defects liability period was over and direct relationships were established with BMS and electrical contractors.

The industry needs to give more attention to fault-finding, fine tuning and any remedial work after handover. This may require new skills and attitudes and a contingency budget. A number of items identified at the Woodland Trust were in the grey area between defects and improvements; and it would often be better just to sort them out than to argue about whether it was a defect and who should pay for it.

It will normally be necessary to hone natural ventilation controls post contract, as operational experience is gained. This not need take long If everyone is there at the right time: designer, facilities manager and crucially a willing BMS maintenance contractor. Unfortunately, while the requirement for such fine tuning is common, advance plans are seldom made to deal with them. Against all the evidence, the unrealistic expectation continues to be made that everything will be right first time and need no further attention.

9.3 Occupier requirements

The brief required the building to be an inspirational and efficient place to work; demonstrate an innovative response to its current and future operational needs; strengthen core cultural values. These objectives were largely fulfilled, though not without some difficulties, as revealed in this report and the occupant survey.

The Trust also sought high quality whilst demonstrating frugal use of funds. The keep-it-simple-and-do-it-well approach helped to achieve this, using architecture and imagination rather than technology to solve many of the problems and to create an attractive and distinctive building. Future projects may however wish to review some of the strategic requirements in relation to their circumstances, including those outlined below.

Adaptability
A new building may itself generate activities unforeseen at the time of briefing. The popularity of the building led to an unexpected demand for meeting and training spaces,

which has been difficult to accommodate without creating noise nuisance in the open plan office areas. Greater convertibility of space might have been preferable.

Standard workstations
The Woodland Trust adopted a principle of open-planning, with standard sized workstations, and no individual offices, even for directors, and a largely paperless policy. In practice, this did not suit everybody, particularly those whose work involved handling of large drawings or physical objects, and some visitors and part-time staff who would have been better accommodated alongside workstations than in breakout space. This also increased the requirement for meeting rooms over that anticipated in the brief.

Clean, uniform workstations appeal to the democratically-minded and the preference of clients and architects for tidy, open spaces. But will they suit all the activities that need to be carried out? More diversity or flexibility in workstation sizes might have been preferable. Certain types of job or activity are also best undertaken in quiet, enclosed spaces with the minimum of interruption.

Acoustics
Occupant surveys reveal growing problems with noise and unwanted interruptions as office spaces become more open, occupancy densities increase, and hard surfaces are used to expose thermal mass. With natural ventilation, the lack of masking mechanical background noise makes disturbances more noticeable. As a response, some people put on earphones, which rather undermines one of the management reasons for open plan: good informal communication.

Unisex WCs
Unisex design allows flexibility to suit changing workforces, but some people object to them. Operationally some may need to be designated.

9.4 Design strategy and building fabric

Building structure and envelope
The cross-laminated timber structure provided a good thermal envelope with minimal thermal bringing. At 2.44 m/h at 50 Pascals, air permeability also met design targets and was more than enough for a naturally-ventilated building: the measured half-life of CO_2 decay over a weekend was 23 hours.

Even with good airtightness overall, if air infiltration becomes concentrated in particular places, it can lead to problems. The weak spot at the Woodland Trust was the open ends of the trench heaters, which allowed cooler air from the floor void to pass out into the space. The effect was negligible in the main offices, with their large volumes and long lengths of heater, but did affect small rooms with short lengths of heater, under certain wind conditions. Ensure that such potential air transfer paths are closed.

Cross-laminated timber floors
While the concrete radiators were effective at stiffening the long-span CLT floors, architects and engineers should think about the effects of vibration, and warn clients about possible effects, as with the articulated joints for display screens. If the screens at the Woodland

Trust had been on pedestals, the vibration would probably not have been noticeable; or articulated joints could have included dampers.

Automatic front doors
Where people may pass by doors without wishing to use them, consider modifying routes or providing barriers to avoid unnecessary opening and the associated draughts. Where this is impossible, consider control by push-button rather than presence detector. When pairs of automatic doors are used, and traffic is normally relatively light, specify the ability to lock off one of them.

Ventilation strategy
While natural ventilation was largely successful, a number of issues emerged, including:

- Difficulties obtaining sufficient draught-free natural ventilation in winter. This can particularly affect well-insulated buildings because perimeter heating may be absent, or off when it is quite cold outdoors. The situation was exacerbated because the manually-openable top-hung windows created air movement at desk-top level and the automated system opened the upper level windows in coarse notches. More widely diffused natural ventilation would have been preferable, or perhaps a mixed-mode system, as at Heelis, with a simple mechanical ventilation and heat recovery system to provide economic background ventilation to the open plan areas in cold weather.
- Restrictions placed on the amount of window opening permissible, owing to changing health & safety, security, and insurance requirements, and in spite of agreements reached with the occupiers and their insurers at the design stage. Ideally night ventilation facilities would be completely secure against intruders and day ventilation against falling. When planning natural night ventilation, take care to discuss security risks and occupier and insurance concerns. Ask clients to seek direct advice from insurers and to confirm agreement to the final strategy in writing. Take account of previous use of the site and any impact of events on occupier confidence during initial occupation.
- Where a strategy of thermal mass and night cooling is adopted, considerable care and fine tuning may well be necessary to get it to work to best effect. Some considerations are discussed in Section 9.6.

Atrium downdraughts
Even in well insulated buildings, where precautions have been taken against downdraughts, there can be comfort-disrupting effects, especially at times when the building is largely self-heating. Care needs taking particularly for large vertical surfaces of glass. Where possible space plan to keep permanent seating, such as desk space, away from large atria to avoid nuisance air movement effects which are localised, seasonal and unpredictable.

The observed effects might also be overcome by increasing output of atrium trench heating and/or placing it further away from the glass, so the down draught air could fall unimpeded into the trench before being heated and recirculating upwards. Other solutions, such as adding heating across the facade at upper floor levels are thought to be disproportionate.

Lighting strategy
Office lighting design is often dominated by providing a uniform desktop illuminance, while sometimes ignoring the quality of light in the space as a whole, both under daylight and artificial lighting. In today's screen-based environments (the Trust has a paperless policy), it

becomes more important to provide a good luminous environment than the specific levels on the desktop, provided these can be increased by occupants that want more light.

The lighting strategy worked well, with good natural lighting, supplemented as necessary by ambient lighting of circulation routes and perimeter walls, plus task lighting under occupant control. Sunlight was also admitted onto the main stair and landings via rooflights, enlivening the space without causing excessive glare or solar gains at workstations.

Emerging issues included the need for window shading to control glare and not just solar gain on the south facade. Unexpected reflections of sunshine and from car windows also caused glare on the north side, especially coming upwards through low-level windows. So be careful when installing floor-to-ceiling windows in workspaces.

9.5 Occupier equipment

A sense of proportion

As buildings and their services become more efficient, the equipment introduced by the occupier can begin to use increasingly large proportions of the energy, so overall energy figures can tell one less and less about the performance of the building itself.

At the Woodland Trust, with its low energy use for heating and lighting, the ICT systems - predominantly the server room and its air conditioning - were responsible for 80% of annual electricity use and 72% of annual CO_2 emissions.

Thin client ICT as an energy-saving measure

Just because loads are small, e.g. thin clients, IP phones and WiFi base stations, doesn't mean they are unimportant. At the Trust they account for an unnecessary electricity load of at least 2 kW during unoccupied hours, totalling at least 12,000 kWh or 4 kWh/m² - over 10% of the building's annual electricity consumption outside the server room.

For server rooms themselves, there appears to be scope for substantial reductions in size, capital cost and running costs if a specialist ICT energy efficiency consultant is appointed to assist with briefing and specification, and is retained for review during selection, installation, commissioning and operation. There would also be knock-on benefits for the capacity and cost of the associated electrical, UPS and cooling systems.

Server room cooling

The reliability problems with server room cooling illustrated several important issues:

- The dangers of having relatively complicated, sophisticated and rare equipment, particularly for relatively small installations in locations at some distance from service centres. Standard and readily-available and understood equipment is often desirable.
- The risk that value engineering removes essential redundancy from a business-critical system. However, the right kind of value engineering might have been able to make an appropriate and resilient system smaller and cheaper, had independent IT energy efficiency consultant been engaged at design stage.
- Where there are sophisticated items with a variety of operating modes, energy use needs to be monitored to help ensure the system is optimised. For example, the initial energy waste after the "free" cooling system was brought back into use might not have been noticed had it not been for monitoring under the BPE scheme.

- Commissioning of critical equipment should simulate the consequences of power interruptions: at the Woodland Trust the chiller lost its control settings and was unable to re-start, requiring the server room to be shut down.

9.6 Technical details

Heating and hot water
Even the relatively simple and straightforward heating system at the Woodland Trust needed review and fine-tuning. This was complicated by the division of control between the BMS (which enabled the system and ran the pumps and zone controls) and the boiler plant's proprietary sequencing, compensation and hot water controls. Proprietary controllers have the strength of standardisation and self-containment, but direct control by the BMS might have given more flexibility, and avoided problems of interlocks and of operating and maintenance staff having to deal with yet another system.

Gas use for hot water was below the design estimate, but there was still some wastage into the heating system owing to the interaction between the two systems. Independent hot water production, (e.g. a self-contained condensing gas storage water heater) would have eliminated any possibility of such interactions.

Natural ventilation and cooling
Cooling by night ventilation is a simple concept that proved tricky to implement without fine tuning, which then allowed the control strategy to be simplified. One important aspect was that a building can feel too cool on occupancy, even when more heat could have been usefully extracted, because the heavyweight elements take the longest time to cool, while everything else can get too cold for comfort. The effect was particularly marked at the Woodland Trust, with its wooden structure and concrete radiators. The solution was to ventilate to the maximum extent overnight and to close the windows at 6 AM, one hour before the office opened and two hours before most people began to arrive.

The windows at the Woodland Trust were not designed to drive air over the concrete radiators. While this reduced the heat transfer rate, it had the advantage that the concrete radiators cooled fairly uniformly throughout the building, minimising local variations between floors.

Multi-storey buildings in which air can flow between floors can often suffer thermal stratification. The effect was noticeable at the Woodland Trust on sunny summer weekends when the windows were closed, but small during the day and with night ventilation. Reasons included the relatively low solar and internal heat gains, the dominance of north-facing glazing, bulk circulation of air via the two atria and the stairs, a tendency for warm air to rise towards the north under the sloping roof, and a high proportion of the motorised windows being on the top floor.

If automated windows are to be used for natural ventilation in winter, it is important that they can be opened only by very small amounts to provide a sufficient amount of low-velocity well-diffused air. The performance of normal windows at small openings is also likely to be variable, owing to backlash in the linkages, so (as for night ventilation) it is helpful to allow for some ready adjustment of control settings by the facilities manager.

Airtight buildings hold their stale air. In winter, consider a purge cycle at the end of the week regardless of sensor readings, or select CO_2 sensors that can be calibrated manually as required, or on annual routine maintenance cycle in the autumn.

Mechanical ventilation and cooling

At the Woodland Trust, only the four meeting rooms and the ICT room had mechanical ventilation and fan coil cooling, using chilled water from the server room system. The system nevertheless provided a number of lessons for detailed design:

- On-demand control can be very effective, here the push-button interval timers that activated the fan coil units in the individual rooms and the common ventilation plant.
- Avoid combining mechanical ventilation systems for rooms with and without windows. The windowless IT test room brought on the whole ventilation system (initially 24/7 until a push-button was fitted here too), while the meeting rooms (with openable windows) usually did not need it, and the unwanted ventilation chilled them on winter nights.
- Do not put water piping or plant requiring maintenance above server rooms. The equipment could have been in the adjacent store room.

Lighting controls

Take care to ensure that lighting circuits are well arranged in relation to use and daylight, and that the time controls and not just the over-rides are accessible, well-labelled, easy to understand and adjust. This needs care; and may not necessarily happen where there is an element of contractor design. Make sure that what could be day-to-day operational adjustments are not confused with time-to-time maintenance adjustments.

BMS

Pay careful attention to usability of BMS and metering, their compatibility with the occupier's ICT systems, and the practicality of remote monitoring. This may need practical demonstrations: manufacturers may not be aware of the limitations of their equipment.

Use a soft landings approach to allow the occupier to gain confidence and familiarity with operating the building without losing sight of the design intent. Allow for fine tuning after occupancy, and have a contingency fund for minor upgrades. The value of BPE time wasted trying to sort out the problems and clean the data (ultimately with limited success) was far more than that of upgraded interface arrangements.

O&M manuals play an important role in documenting the building, but it is difficult for technical experts to write manuals from the point of view of users. The CIBSE Log Book potentially provides a useful bridge and should be developed in closer dialogue with the client as the design and specification evolve and as equipment is selected.

Simple guides should also be drafted before handover and revised in consultation with users and operators, after in-use experience has been gained. Controls algorithms themselves seem too bespoke. Consider incorporating pre-programmed mass produced "Internet of things" products. Ways of modelling the implications of control strategies for buildings need developing. For example using energy modelling techniques beyond regulatory and BREEAM requirements, such as IES Apache HVAC module or Matlab Simulink.

Good features for a BMS maintenance contractor: familiar with the system, as free as possible of the contractual millstone of defects liability, one who won't get carried away introducing new complications.

9.7 Summary

Appendix 10.1 contains a table summarising the key findings from the BPE at the Woodland Trust. It is divided into three sections, each of two pages:

- Relationship to design intent.
- Emerging issues of broad interest.
- Emerging issues of specific interest.

Table 9-1
Feedback from Heelis fed forward into the design approach for the Woodland Trust HQ

FEEDBACK FROM HEELIS	APPROACH AT WOODLAND TRUST	COMMENTS
PRINCIPLES AND PROCUREMENT		
Keep things simple where possible. *Avoid unmanageable complication.*	The keep it simple principle was adopted.	See also a number of the technical points below.
Maintain continuity of design intent throughout the process. *Once the scheme design for Heelis was complete, the National Trust sought a developer to build it. This caused a loss in design continuity and attention to detail.*	A traditional contract was used. Contractor selection criteria included sympathy with the design intent and considerable experience of building in timber.	After the developer took over Heelis, the design team was no longer directly responsible to the occupier. For legal, financial and management reasons some continuity of design development was lost.
Improve handover processes and follow-through afterwards. *Soft Landings was suggested.*	Soft Landings was followed in principle, but the framework was not yet published. It could have been applied more rigorously.	Support at the Woodland Trust also led to the successful application for TSB BPE funding.
Improve prediction of energy performance, e.g. using CIBSE TM22.	Not adopted formally, though the predictions proved quite good.	The CIBSE Log Book also provided a useful summary at Heelis, but was not completed at the Woodland Trust.
Make sure operators are well trained in the use of BMS and controls.	Partially successful, but more could have been done in hindsight.	The Woodland Trust now has 3 trained people.
BUILDING FABRIC		
Simplify building envelope detailing for good insulation and airtightness.	A cross-laminated timber structure was of interest to the Trust and made it much easier to create a continuous thermal envelope.	The steel frame construction of Heelis led to a number of problems with air leakage and thermal bridging.
HEATING, VENTILATION AND HOT WATER		
Keep it simple approach.	Natural ventilation adopted, instead of mixed-mode at Heelis.	Mixed mode makes winter air quality control easier.
Consider a separate gas-fired hot water system.	Not adopted. A hot water calorifier was fed by the boiler plant.	Partly because the Woodland Trust had no catering kitchen and more efficient boilers.
Control perimeter heating more carefully.	Direct temperature compensated flow, plus on/off zone valve control by floor, activity and orientation and variable speed pumping.	Closer control at the Woodland Trust reduces waste and tendencies to overheat.
LIGHTING		
if natural and electric lighting are to be successfully and economically combined, consider illumination of walls and ceilings, not just desktops.	This principle strongly influenced the task-ambient lighting strategy adopted.	Woodland Trust included uplighting and wall washing to brighten the interior economically.

FEEDBACK FROM HEELIS	APPROACH AT WOODLAND TRUST	COMMENTS
Simple, user-friendly and demand-responsive lighting controls. *Heelis had automatic occupancy sensing and daylight dimming.*	Task lighting locally controlled. Ambient lighting controlled by time switch and manual over-ride. Presence sensors in corridors, stairs, WCs and occasionally used rooms.	Woodland Trust largely successful apart from design and location of the time switches for ambient lighting.
ICT SYSTEMS		
Pay careful attention to energy use of ICT systems in the office space.	Adopted centralised printing together with a thin client system, which further reduced heat gains into the office space.	With centralised printing and many staff using laptops not PCs, Heelis used less energy for desktop and printing equipment than originally predicted.
Pay great attention to energy use by server room ICT equipment.	Carefully taken into account, but energy use was similar to Heelis.	Consider using an ICT energy efficiency consultant.
Provide energy-efficient server room cooling. *Heelis adapted the chilled water server room units to include outside air free cooling.*	A more robust system with independent chilled water and free cooling systems was designed, but value-engineered out.	The resultant chiller with waterside free cooling at the Woodland Trust proved unreliable.
CONTROLS AND METERING GENERALLY		
Improve controls, user interfaces, demand-responsiveness and staff training in their use and management.	Fewer things to control, but problems persisted, in particular with user interfaces and for equipment with dedicated controls not accessible through the BMS.	Contractor-design of controls can be problematic. Needs careful attention by designers in both specification and review of details.
Make sure sub-metering is properly commissioned, and the data is logged automatically and reviewed regularly.	Dedicated meter logging software.	Commissioning and logging were still problematic at the Woodland Trust.
OTHER ITEMS		
Specify energy efficient equipment and services in catering kitchens.	Decided against having a catering kitchen.	Partly because it was a smaller building. *The Heelis kitchen also served both staff dining and a separate cafe for the public.*

10.0 APPENDICES

10.1 Table of main findings

WT-BPE Table of Main Findings.pdf

10.2 BUS Occupant survey – topline summary results

WT BUS Occupant Survey Summary Final May12.pdf

10.3 Selection of infra-red photos

Twelve characteristic thermographic images, including short notes on each.

Selection of infra-red photos.pdf

10.4 Notes on BMS for Facilities Managers

Notes prepared by Max Fordham to explain the new BMS user interfaces for heating and for night cooling to the facilities managers.

Setting Zip Hydrotap Timers.pdf

Guidance note on Night Cooling Operation.pdf

Note on main incomer electrical check meter communications loss.pdf

Note on meeting room mechanical ventilation.pdf

Note on temperature sensor calibration.pdf

Note on DB7 lighting meter calibation.pdf

10.5 Final report of the follow-on project into concrete radiator performance

Refer to Annexed Appendices Dataset.

10.6 TM22 Design and In-Use Assessment output summaries

Refer to Annexed Appendices Dataset.

10.7 BUS Appendix A

Statistical details of the BUS Method occupant questionnaire survey results.

Refer to Annexed Appendices Dataset.

10.8 BCO Conference 2012 Slide set

Presentation of the interim findings included a session at British Council for Offices Conference 2012 in Manchester, co-presented by the BPE team and the Woodland Trust's facilities manager.

Refer to Annexed Appendices Dataset.

10.9 Slide set 14 February 2013

Presentations of the findings included three CPD seminars: at the Bath and London offices of the architects Feilden Clegg Bradley Studios and at the London offices of Max Fordham, for which the slides are included.

Refer to Annexed Appendices Dataset.

10.10 Case Study

Refer to Annexed Appendices Dataset.

10.11 Key drawings and schematics

Refer to Annexed Appendices Dataset.

10.12 BCO Awards 2011 Report

Refer to Annexed Appendices Dataset.