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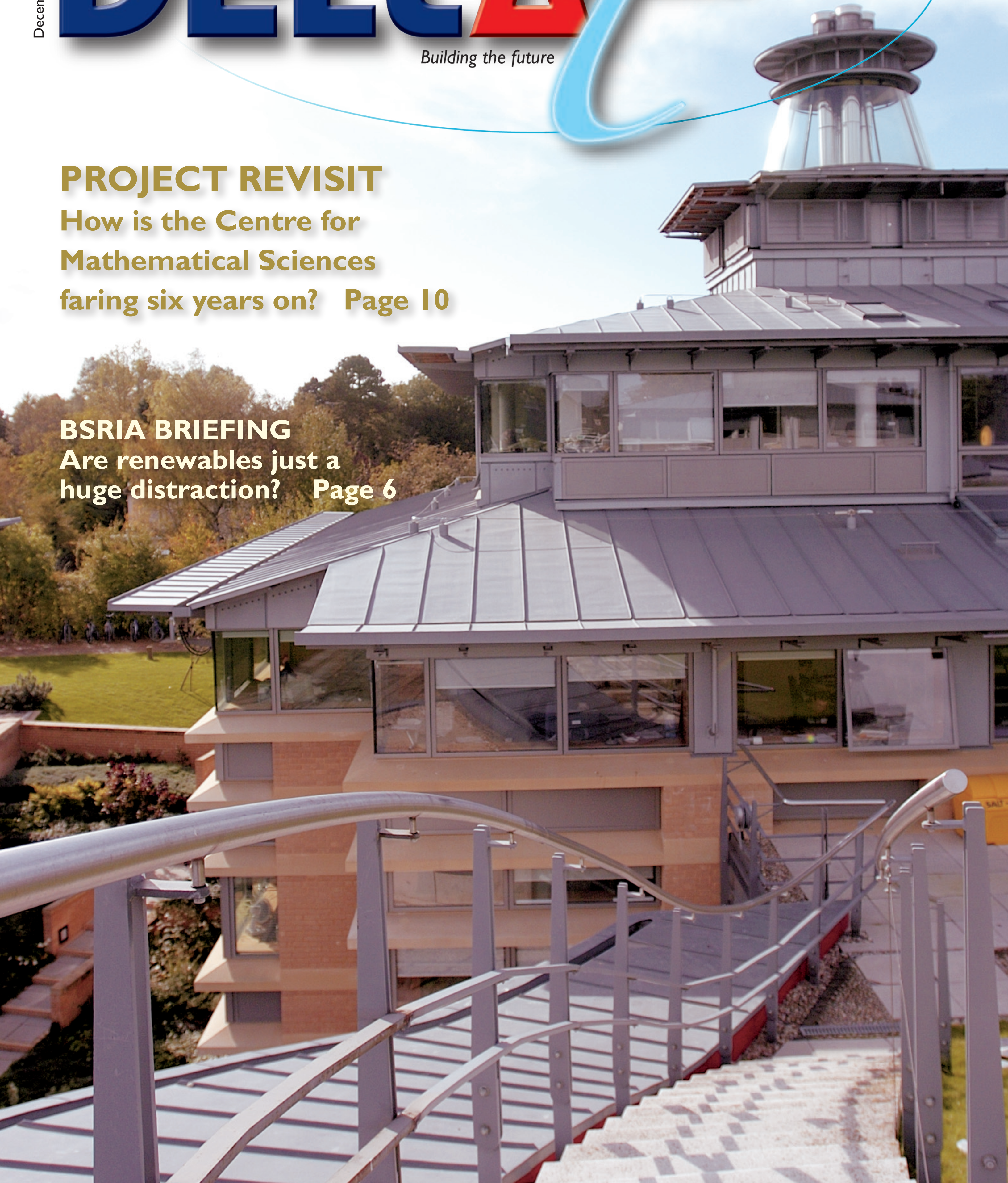


PROJECT REVISIT

How is the Centre for Mathematical Sciences faring six years on? Page 10

BSRIA BRIEFING

Are renewables just a huge distraction? Page 6

Centre for

THE **PROBE PROJECT**

Post-occupancy Review Of Buildings and their Engineering (PROBE) was a research project managed by *Building Services Journal* (*BSJ*).

Design and construction details of the Centre for Mathematical Sciences were featured in the October 2000 issue of *BSJ*, while the PROBE report was covered in the July 2002 edition. These surveys covered Phase 1 and included an occupant satisfaction survey on Pavilion B, the first pavilion to be completed.

Chris Parkin, a building services engineer at Roger Preston & Partners, carried out the latest investigation as part of his MSc dissertation. The PROBE methodology was followed, applying stage 2 of CIBSE's *TM22 Energy Analysis Reporting Methodology* and the Building Use Studies occupant satisfaction survey.

BSRIA Members can access all *BSJ* building analyses and PROBE articles via BSRIA's on-line abstracting service, IBSEDEX. PDF versions of PROBE investigations can also be downloaded from www.usablebuildings.co.uk.

The multi-building Centre for Mathematical Sciences (CMS) was completed in two phases between 2000 and 2003. Designed by architect Edward Cullinen Architects with Roger Preston & Partners as services consultant, the site comprises six pavilions, a double pavilion, a gatehouse and a library. Figure 1 shows the layout and the phased construction.

A post-occupancy analysis of the CMS development was carried out in 2002 under the PROBE project (see box). This latest project revisit covers all pavilions and includes a new occupant satisfaction survey of the Phase 2 pavilions.

Design description and history

The CMS development pulled together several mathematics, physics and statistics departments on a greenfield site west of Cambridge City centre. The site has a total area of around 20 000 m^2.

Six of the pavilions are very similar in design. Each pavilion has a lift shaft in the centre, surrounded by a spiral stair encased in a concrete and glass block tower, topped with a glazed lantern. Circular corridors give access to largely cellular offices around the perimeter. Lecture theatres, common rooms and meeting rooms are largely located in the basements.

Pavilion A at the centre of the CMS development houses the large, barrel-vaulted and grass-roofed cafeteria, along with some administration offices and the main reception. Pavilion B is double-sized.

All the buildings are predominantly naturally ventilated, although mechanical ventilation with comfort cooling is provided for lecture theatres, some inboard rooms, and areas with high heat gains.

The phased development of the site led to two separate building management systems: a Siemens system for Phase 1 and a Honeywell system for Phase 2.

The CMS development is a very interesting example of advanced natural ventilation, with automatic controls and manual override for the opening windows and vents, and internal blinds. The latter meets planning requirements for controlling light pollution to the neighbourhood, as well as for controlling glare.

Results of the original PROBE survey

The PROBE researchers found that the design strategy of exposed thermal mass, solar shading, buoyancy driven single-sided natural ventilation and night cooling was essentially sound. However, it was not possible to undertake a detailed energy analysis, as departmental billing had not been implemented at the time of the PROBE survey.

Although an airtightness test of Pavilion D returned a value of $19{\cdot}03\ m^3/(h.m^2)$, the buildings were designed before airtightness values were stipulated in the *Building*

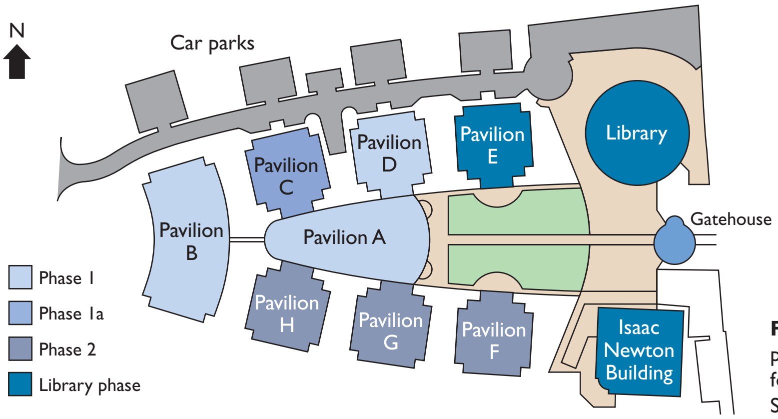


Figure 1: The site plan for the Centre for Mathematical Sciences.

Mathematical Sciences

Chris Parkin and **Roderic Bunn** revisit the Centre for Mathematical Sciences at Cambridge University to find out how the campus buildings have performed over the long term

Regulations. The planar glazing on the first floor above the entrance from the concourse was particularly leaky, along with air leakage through the high-level ventilation outlets, and at the sills and reveals of the fixed corner windows. Very significant air leakage occurred through perforated steel panels enclosing services risers. Airtightness was apparently improved for the Phase 2 pavilions, although no pressure tests were carried out.

The combination of automatic and manual control of ventilation gave mixed results. The overall approach proved sound, but occupants reported irritating delays in windows driving to new positions. In the Phase 1 pavilions the occupant controls for blinds and windows provided proved unintuitive to use, and confusing for new occupants.

Performance four years on

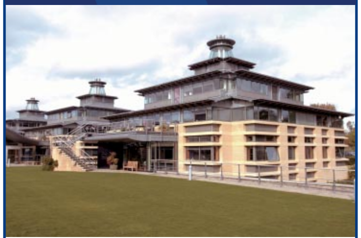
The assessment of the Phase 2 pavilions began in 2005, culminating in a new energy and occupant survey in summer 2006. While Chris Parkin concentrated his study on the Phase 2 pavilions (F, G and H), feedback was also obtained on the Phase 1 and Phase 1a buildings (see Figure 1).

The facilities team reported that some of the pumps in Phase 1 had been retrofitted with inverters to achieve the correct operating point. In some cases, smaller pumps were installed.

The airhandling units are equipped with run-around coils that pre-heat or pre-cool the incoming air. A cooling coil provides dehumidification and cooling, while a re-heat coil deals with any supplementary heating needs. Re-heat coils in multi-zone supply ductwork systems allow for local control of heating and cooling.

Unfortunately, it is not clear how the system should be controlled. On the day of the revisit, it was evident that incoming fresh air at 17°C was being heated by a

BSRIA PROJECT REVISIT



Project revisit articles look at notable buildings designed by BSRIA Members and investigate their performance over time. The engineering services at the Centre for Mathematical Sciences were designed by building services consulting engineer Roger Preston & Partners. The architecture was designed by Edward Cullinan Architects.

A building worthy of a revisit is either a construction project notable for its contribution to design innovation and sustainability, or a project that demonstrates a step-change in delivering improvement through the supply chain.

All photographs: ©Roderic Bunn/BSRIA

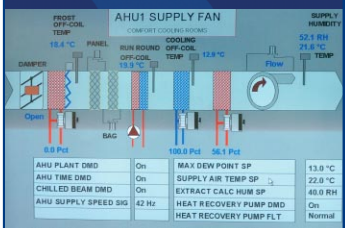
Above: The popular cafeteria behind the entrance of the grass-covered Pavilion A. Six years after occupation the Pavilions appear to have worn extremely well.

THINGS THAT WORK

The lanterns for Phase 1 were built *in situ* by a contractor inexperienced with bespoke design. Phase 2 pavilions benefitted from more airtight detailing, particularly around risers and the lanterns. The latter were built on the ground and then craned into position.

User controls for window and blinds were vastly improved for the Phase 2 pavilions. Despite being a little fiddly, they are ergonomic, clear in intent, well labelled and give instant feedback to the occupant.

AREAS OF CONCERN



Some run-around coils are running inefficiently, wasting refrigeration and pump energy. The fault lies in a lack of control over when and how to operate the heat recovery, and a lack of facilities management time.

The symmetry of the site and the centre-lined path lead visitors directly to the fully-glazed main entrance. However, the main door is to the left, at ninety degrees to the facade to prevent draughts when people enter and leave. What appear to be motorised doors are actually sealed glass-panels. A makeshift sign is needed to redirect the spatially confused. Better path design would alleviate the problem.

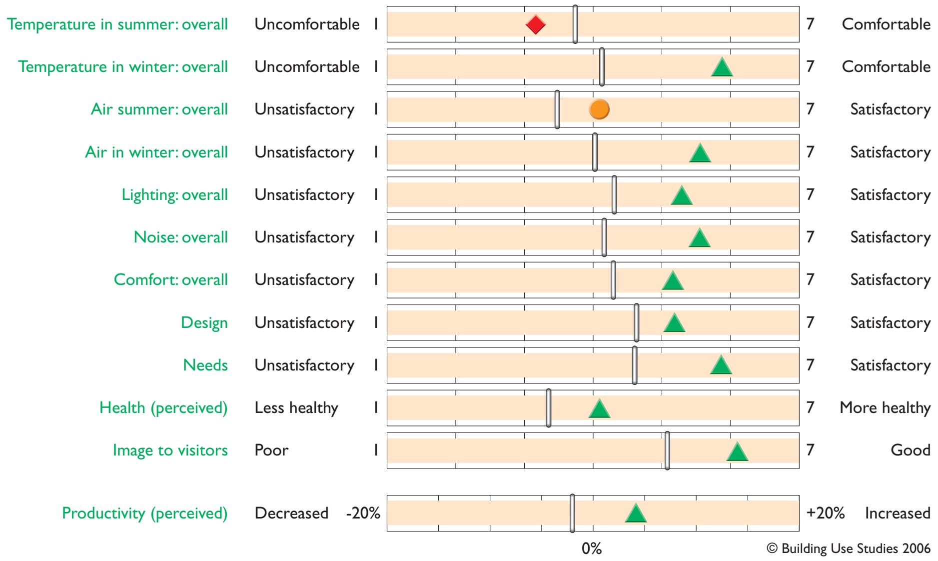


Figure 2: Building Use Studies carried out an occupant satisfaction survey in Pavilions F, G, and H at the Centre for Mathematical Sciences. Green triangles represent mean values significantly better or higher than both the benchmark and scale midpoint. Amber circles are mean values no different from benchmark. Red diamonds are mean values worse or lower than benchmark and scale midpoint. Be careful to read the directions of the scales and the scale labels. Benchmarks are represented by the white line through each variable.

run-around coil to 19·7°C, then cooled to 15·9°C and finally reheated by a duct reheat coil to 21·4°C. The fault probably lies in the setup of the cooling coil and its interaction with the run-around coil, something that requires closer investigation.

The quality of the operating and maintenance manuals is regarded by the facilities team as inadequate and incomplete. As a consequence the facilities team do not have strong grasp of how the systems are supposed to work. Furthermore, the site's two bms systems are largely used for faultfinding rather than energy management.

In the cellular offices, the manual override controls for blinds and windows demonstrate the importance of good ergonomics. In Phase 1, the user controls are not intuitive. The buttons were not labelled by the controls supplier or installer, and the occupants were forced to add their own labelling with indelible markers.

In Phase 2, far more attention was paid to usability. The controls are clear in purpose, well labelled, and have red lights that give immediate feedback.

However, conflict between the demands of the central bms and the needs of the occupants occurs in all pavilions. Weather override is under the control of the bms, which closes windows when it rains (and opens and closes them for cooling).

Not only is there a delay in window actuation, during which time rain can get in, but also the bms can't remember users' preferences. For example, if an occupant has opted to have the windows closed on a hot day, and it rains, when it has finished raining the bms will open the windows to cool the room. Occupants have to reset their window and blind positions – one occupant reported that they have to do this twice before the system settles down.

For a site with hundreds of window-opening motors and actuators, the system has proved robust. However, in Pavilion A, virtually every window motor has been replaced since 2001. The new motors have software that only drives the motors for a certain period. This prevents the motors trying to push the actuators beyond the point of maximum window opening. For the earlier motors, a pressure sensor would sense that the window was fully open. When those sensors failed, the motors would continue to drive the actuators, forcing gears to slip over the chains.

The lighting throughout the site is under the control of a Philips ECS system. Absence detection was employed in Phase 1 to cover for occupants failing to turn off lights when they left work. As most occupants of the (largely cellular) offices do turn off their lights, it was decided not to extend the absence detection system into the Phase 2 pavilions. In any case, absence detection proved to be a mild irritation to seated occupants working for longer than 20 minutes, as the system turns off the lights.

Lighting has significant out-of-hours use, due to long working hours. When a person enters a pavilion at night, all access routes stay lit for security reasons. In Phase 2 pavilions (which have no passive infrared detection) the lighting can stay on all night.

Energy performance

Pavilions F, G and H were subjected to an energy assessment to stage 2 of the CIBSE *TM22 Energy Analysis Reporting Method*.

Pavilion F is home to a COSMOS supercomputer that runs 24 h/day. The maximum load of the computer and its accessories is around 36 kW, but there is no sub-metering to verify its consumption. Pavilion G houses boilers and pump sets.

Occupants' computers are left running overnight in all pavilions as a matter of IT policy, primarily to perform campus-wide mathematical calculations (that would otherwise mean a much larger server) but also to enable out-of-hours software upgrades and maintenance.

Treated floor areas were estimated using guidance from *Energy Consumption Guide 19*.

The averaged electricity consumption for each of the three pavilions is estimated at 106 kWh/m^2/y. As there are no established energy benchmarks for the CMS type of building, Chris Parkin created a set of bespoke benchmarks based on the proportions of the pavilions that were either naturally ventilated or air-conditioned (the latter estimated at 20 percent). Adjustments were also made for longer operating hours, but at a reduced 2300 degree-days per year.

As a consequence, electricity use comes in between the bespoke good practice benchmark of 74 kWh/m^2/y, and a typical benchmark of 126 kWh/m^2/y.

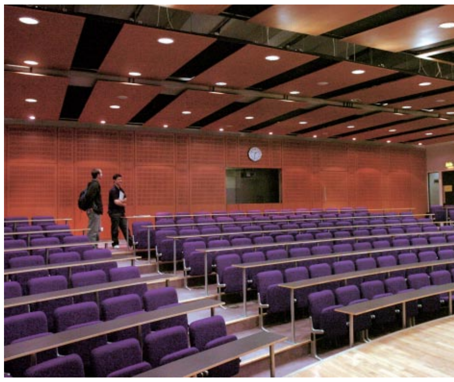
It was not possible to dis-aggregate the gas consumption of the three pavilions from that of an adjacent Ambient Flow Facility building (AFF), as there is no sub-metering on the gas supplies or heat meters. The gas consumption figure is therefore based on the sum of the treated floor areas of the pavilions and the AFF (5007 m^2).

Correcting for degree days, the (estimated average) gas consumption for each pavilion is 155 kWh/m^2/y – considerably higher than the bespoke good practice benchmark of 86 kWh/m^2/y but below the typical benchmark of 163 kWh/m^2/y.

Occupant survey results

In 2001, an occupant satisfaction survey was carried out in Pavilion B – plus smaller studies of Pavilions C and D. This revealed that the occupants regarded the buildings as comfortable. The responses were in the top decile for overall comfort and air quality in winter, lighting overall, comfort overall and needs. Relatively low scores were for temperature in summer, space at desks and health perception.

In July 2006, an identical survey was carried out in the three Phase 2 pavilions. As in 2002, the Pavilions returned very good scores for all criteria except air temperature and air quality in summer (Figure 2). The aggregated scores may be adversely affected by the large proportion of Pavilion B that has a high south-facing component, and the well-known problems with user controls and window opening. July was also the warmest month since records began in 1659. The maximum temperature measured in Cambridge University Botanical Gardens was 35·6°C on the 19 July. This compares with the dry bulb design condition of 28°C.



Right: A main lecture theatre. In some of the seminar rooms, the use of occupancy detection to link electric lighting and mechanical ventilation has been abandoned, as switching off the lights for a projector presentation also switched off the fans, accidentally robbing the occupants of ventilation.

Conclusions

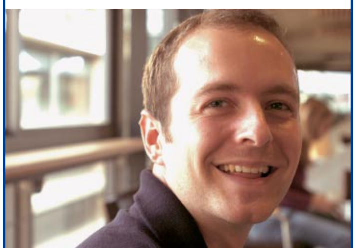
The CMS site is an extremely agreeable place to work, and the site plan fosters a strong sense of community. The buildings have aged well, a consequence of a good choice of building materials and high levels of building services maintenance.

The building highlights the virtues of good user controls and the importance of proper operating and maintenance manuals in order for the buildings to be operated in line with the design intention. The lack of heating and chilled water sub-metering, absence of energy monitoring software, and inability by the facilities staff to spend any time on energy saving activities militates against improvements in the site's energy efficiency. Despite these shortcomings, the estimated energy consumption has bettered what might be considered typical for buildings of this kind. It would be interesting to see how the site would improve given sufficient time, effort and metering technology.

PROJECT WHO'S WHO

Centre for Mathematical Sciences assistant facilities manager **Mick Young** experienced problems with over-driven window actuators.

"We would hear windows clicking as chains were slipping over the cogs," said Mick Young. "We've resolved it, but we think it's up to the industry to solve those kind of problems."



Chris Parkin, Roger Preston & Partners (designers of the environmental services at CMS).

"In hindsight, it may have been possible in the early stages of the project, and with the co-operation of CMS, to set up monitoring of electricity consumption for different electrical end uses. This would have avoided the need for estimates and would have produced more accurate results."