Photograph ©BBLB Architects

Stoke Local Service Centre

Roderic Bunn reports on the post-occupancy performance of Stoke Local Service Centre, a blend of the new and the old that attempted to reduce energy use and carbon dioxide emissions to below good practice levels

CARBON TRUST RESEARCH

The research for Stoke Local Service Centre was carried out by the Carbon Trust as part of its four-year Low Carbon Buildings Performance programme (LCBP).

The purpose of the LCBP was to test combinations of low and zero carbon energy technologies for their potential to reduce carbon dioxide emissions.

Building designs that had already adopted low energy solutions were eligible for grants from the Department of Energy & Climate Change (DECC). Grants of between 40-45 per cent of eligible costs were available. In return, the DECC, the Carbon Trust and the Energy Saving Trust required access to the design team and installation contractors, and a watching brief over the technological, financial, political, and behavioural issues and challenges.

The Carbon Trust research team also required access to the post-completion performance data, with the aim of making the results publicly available.

How's this for cruel irony? While Spurs and QPR were busy contesting the 1982 FA Cup Final, the people of Stoke were watching their much-loved Victorian market burn down. 27 years on, a new building has risen from the rubble. And, for the first time in its history, Stoke City got through to the 2011 FA Cup final.

Poetic justice found form in a 1389 m² library-cum-conference centre, built and run by Stoke-on-Trent City Council. Opened in January 2009, the Stoke Local Service Centre (SLSC) is a meld of the old and new – around half of the new building uses the original 1883 clock tower, entrance arch, and shop frontage.

The entire project – and its performance post-completion – has been studied by the Carbon Trust as part of its Low Carbon Buildings Programme (see box item). Every step of the SLSC project was scrutinised, the design choices pored over, and the building's subsequent performance measured in detail.

Building layout

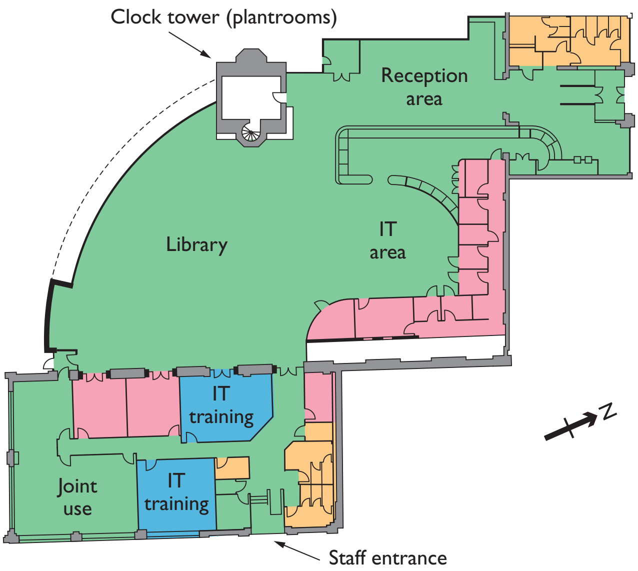
Stoke-on-Trent City Council wanted a building that could perform a number of civic functions: a public library, a place for corporate training and conferencing, and a point of contact for the public with the Council. This design brief led to a gaggle of very different functions and spaces all under one roof.

Figure 1 shows the building's layout. The building is orientated with the new glazed façade and existing clock tower to the south. The south elevation also has a 2.5 m overhang, with louvres angled to provide shading against direct solar radiation while allowing useful diffused daylight into the library.

The fabric performance of both the new and existing structures exceeded the minimum standards specified in the 2006 *Building Regulations*. A commendable air permeability of 6.52 m³/h.m² at 50 Pa was achieved, slightly better than the design target.

Environmental systems

The services strategy is divided into five separate zones: the library and information area, the conference and meeting rooms, joint training rooms, IT rooms, the interview and staff rooms, and



Right, Figure 1: The layout of Stoke Local Service Centre, with coloured areas showing the ventilation strategy. Green shows areas naturally ventilated, pink areas are mechanically ventilated (not heated or cooled), and blue the IT training suites which are air-conditioned. The toilet areas in orange are extract only.

the toilet areas.

As part of the application for Government grants for low carbon measures, the Council pledged to reduce the building's carbon footprint by 58 per cent over the 2006 *Building Regulations*, of which around 30 per cent was to be achieved by renewable energy systems. The grant funding enabled the project team to heat the building using three 30 kW brine-to-water ground-source heat pumps (GSHP). These units provide low-temperature hot water to an underfloor heating system. This is installed throughout with the exception of the IT training rooms.

The GSHP extract heat from 16, 100 m deep boreholes underneath the piazza. The system is closed-loop, and estimated to deliver a seasonal performance co-efficient (CoP) of 4. The system was sized to deliver 100 kW of heating (75 600 kWh per annum) and 30 kW of cooling (subsequently not used).

The 5 m high, 20 m-deep library, reading and information areas are naturally ventilated. Perimeter zones are ventilated by top-hung windows opened by manual winders. Deeper into the library space, seven wind-assisted ventilators operate under the control of a BMS, with the degree of opening dictated by room temperature settings. Supplementary cross-ventilation is provided via louvres at high level in the north-facing external wall.

The two IT training rooms each have an air-handling unit supplying fresh air and incorporating a plate heat-exchanger for heat recovery. Comfort cooling and heating is also provided using two 7.1 kW air-source heat pumps. Toilet areas have conventional dedicated mechanical extract.

A set of meeting rooms at the back of the building are ventilated by double-glazed openable fanlights, manually operated by winders.

Lighting in the main library and information area is by T5 lamps in suspended luminaires. In corridor and ancillary areas, lighting is a combination of compact fluorescent downlighters and surface circular luminaires.

Some sunpipes have been installed, positioned in between the wind-assisted ventilators, to provide a little daylight.

All luminaires are fitted with high frequency low-loss control gear. Presence detection lighting control is used in meeting rooms, while daylight sensors have been used in perimeter zones. The electric lighting in the library is not dimmed or otherwise controlled against the output from the sun-pipes.

Around 55 m^2 of polycrystalline photovoltaic panels have been installed, courtesy of the Carbon Trust grant. These were designed to generate 7946 kWh of electricity – offsetting around 22 per cent of the Centre's carbon dioxide emissions.

A 2.5 m^2 flat-plate solar collector pre-heats the domestic water. In addition to the solar thermal pre-heating coil, the storage cylinder contains an electric immersion heater for times when the solar thermal can't handle the load.

All the mechanical systems are under the control of the BMS. The system communicates with the Council's existing central supervisor to allow off-site

Photograph ©BBLB Architects

Above: The library areas with reception just out of sight in the background. The lighting is controlled by switches in a lobby to the right. The lighting adjacent to the windows is able to dim automatically. Just visible are the diffusers for two of the roof-mounted wind-assisted ventilators.

PERFORMANCE MATTERS

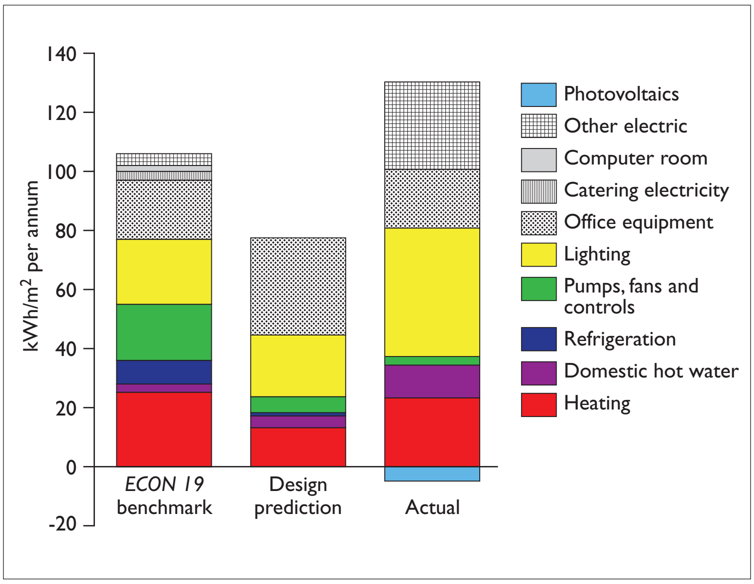
The solar thermal panels are generating useful amounts of heat for the domestic hot water system, but the system is not separately metered

Extensive sub-metering was installed to the guidelines of CIBSE *TM39*. The BMS was not reading all the pulses from the meters. Such systems need careful setting up for meters to be truly useful

On the sunny day of the author's visit, it was noticed that electric lights in the library area were staying on despite good daylight penetration from the sun pipes. As the contribution from the sun pipes does not lead the library lighting to dim down or even turn off, the sun pipes do not save lighting energy. One reason is...

...that the main staff entrance contains the library light switches for staff to use when they arrive. This means the library light switches are outside the library area, by the card-swipe doors behind the photgrapher

Right, Figure 2: Energy consumption of Stoke Local Service Centre from October 2009 to September 2010.



changes of setpoints and operating schedules.

Energy targets

There are no published energy benchmarks that fit the SLSC building, with its mixture of spaces and end uses. As there are no significant catering facilities and the occupation characteristics are similar to a naturally ventilated open-plan office, with approximately 25 per cent of the area given over to meeting rooms, the SLSC can justifiably be compared to a Type 2 naturally ventilated office in *Energy Consumption Guide 19* (*ECON 19*).

An initial good practice (all-electric) hybrid benchmark for the SLSC was set at 84 kWh/m^2 per annum, based on 90 per cent of a naturally-ventilated open-plan office and 10 per cent air-conditioned standard office.

This was later revised upwards to 106 kWh/m^2 per annum by including 50 per cent of the Type 3 energy consumption for office meeting rooms and IT rooms, and 50 per cent of the Type 3 office to account for more extensive heating and ventilation systems, and fan and pump power.

The final modelled prediction set by the designers was 77.4 kWh/m^2 per annum, a smidgen under the most relevant *CIBSE TM46* benchmark of 78 kWh/m^2 per annum.

The main energy targets set by end-use, with *ECON 19* good practice figures in brackets, were:

- Ground source heat pumps: 13.2 kWh/m^2 per annum (18 kWh/m^2 per annum)
- Lighting: 21 kWh/m^2 per annum (22 kWh/m^2 per annum)
- Pumps, fans and controls: 5.4 kWh/m^2 per annum (19 kWh/m^2 per annum)
- Hot water: 4 kWh/m^2 per annum
- Refrigeration: 1.1 kWh/m^2 per annum (8 kWh/m^2 per annum)
- Small power: 33 kWh/m^2 per annum (27 kWh/m^2 per annum)

The expected yield from the solar thermal and photovoltaics were:

- Solar thermal yield: 6.3 kWh/m^2 per annum (7 kWh/m^2 per annum)
- Photovoltaics: 5.8 kWh/m^2 per annum.

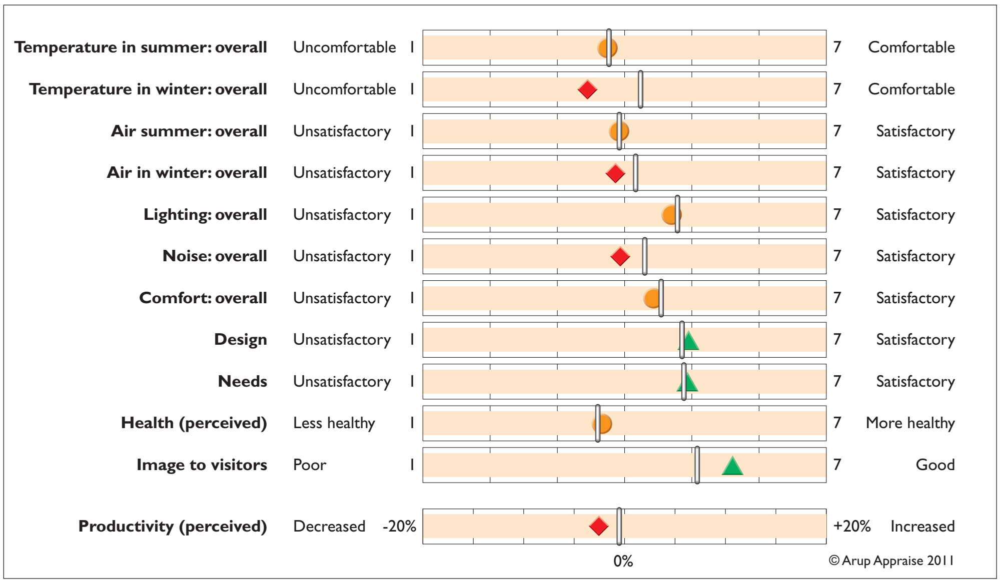
Note that the projected yield from the 2.5 m^2 Solkit solar thermal panel was estimated to be five times the hot water use, at 1.1 kWh/m^2 per annum (26 m^3 per annum). The storage tank is fitted with a 6 kW immersion heater, which was expected to handle about 50 per cent of the annual demand.

The manufacturer of the 55 m^2 photovoltaic array quoted a performance of 133 kWh/m^2 panel area. The modelled output was 5.8 kWh/m^2 per annum (7946 kWh per annum).

Energy performance

Stoke Local Service Centre opened in January 2009. Formal energy monitoring started in October 2009, which gave the building eight months to settle down.

Figure 2 shows the SLSC's energy consumption for the year to September



Left, Figure 3: Summary results of the Building Use Studies occupant satisfaction survey carried out at Stoke Local Service Centre. 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. Benchmarks are represented by the white line through each variable. Be careful to read the directions of the scales and the scale labels.

2010. Total energy consumption for the period was 130 kWh/m^2 per annum. This compares with the design (modelled) prediction of 77.4 kWh/m^2 per annum, and the hybrid *ECON 19* benchmark of 106 kWh/m^2 per annum.

Consumption by the GSHP was 90 kWh/m^2 per annum. The higher consumption, compared with the design prediction of 53 kWh/m^2 per annum, may be due to a high night-setback on the underfloor heating system.

Lighting has come in at 43.5 kWh/m^2 per annum, twice the prediction of 21 kWh/m^2 per annum. The high consumption may be due to the installed power density of the lamps, In the training rooms for example, the lighting load is 8.5 W/m^2 per 100 lux, when this might reasonably be expected to be 3.5 W/m^2 per 100 lux.

Meter readings have shown that the lighting system has defaulted to on, raising questions about the effectiveness of the controls. Carbon Trust researchers also found lighting on in unoccupied rooms due to over-sensitive detectors.

At 18 kWh/m^2 per annum, small power loads have proved to be lower than the design estimate of 32.9 kWh/m^2 per annum, beating the *ECON 19* good practice value of 27 kWh/m^2 per annum.

Annual consumption for the domestic hot water immersion heater came in at 12 kWh/m^2 per annum, or 10 per cent of the total consumption. The estimated solar yield is 6.3 kWh/m^2 per annum, which compares with the design prediction of 4 kWh/m^2 per annum.

The solar thermal system was designed to generate about 50 per cent of the annual demand. Solar energy contribution has been estimated by monitoring the cold water draw-off and the immersion heater demand. As the demand of the immersion heater is much higher than the draw-off, it proved difficult to establish the contribution. The Carbon Trust researchers estimate that around 8 kWh/m^2 per annum is being lost through the secondary circulation.

After the Carbon Trust monitoring came to an end, the SLSC's facilities staff conducted an experiment. The solar thermal was valved off during March 2011, and the water tank was heated solely by the immersion heater. During February 2011 the domestic hot water system consumed 210 kWh/m^3. In March, with no solar thermal input, consumption rose to 346 kWh/m^3.

The photovoltaics are generating 5 kWh/m^2 per annum, close to the software prediction of 5.8 kWh/m^2 per annum. The realised performance ratio is 115 kWh/m^2 of panel area compared with the manufacturer's more optimistic 133 kWh/m^2 per annum.

Despite the energy metering following the recommendations in CIBSE *TM39*, the SLSC's energy metering exhibited serious shortcomings, with data logging showing that the BMS was not matching the consumption measured at the meter. Some pulsed data from the meters is not being recorded.

The second problem is that the BMS can only store a limited amount of data. Without data logs of energy consumption the BMS cannot be used to analyse trends accurately. The data logging was also not frequent enough to establish peak demand against the energy generated by the renewables.

Carbon dioxide emissions

Actual emissions to September 2010 were 64.9 kgCO_2/m^2 per annum against the design target of 40 kgCO_2/m^2 per annum. The *ECON 19* hybrid benchmark was 43 kgCO_2/m^2 per annum. For reference, the most relevant CIBSE *TM46* median benchmark is 50.5 kgCO_2/m^2 per annum

Actual carbon dioxide emissions are one and half times higher than the design expectation, and worse than the notional building which assumes a design standard to 2002 *Building Regulations*. On this basis it is difficult to regard SLSC as a low carbon building, despite its low carbon credentials.

Although there is evidence of wasteful operation, particularly of the GSHP and the lighting, the Carbon Trust assessors believe that the simulation modelling did not appear to closely predict how the building would operate in reality.

It is important to stress that energy consumption in the first 18 months of any building's life should not be taken as representative of its long-term performance. There are many variables. Outstanding defects, delayed commissioning, phased occupation, and

LESSONS LEARNED

Sub-metering
Despite the sub-metering following the requirements of CIBSE *TM39*, the subsequent installation was not ideal. Sub-metering needs to be considered at an early design stage to ensure that all appropriate systems are sufficiently monitored to deliver accurate and useful information. Low and zero carbon technologies need particular care in their metering. Solar thermal and domestic water systems should be metered directly, rather than force the building managers to work out consumption by a process of deduction.

Energy monitoring
Energy monitoring should be discussed with the facilities managers at the design stage, in order to inform the controls specification. The controls must be configured to ensure full transparency of energy use, and accuracy of recording. Standard BMS software cannot be relied upon to deliver the level of functionality required for energy monitoring and targeting. The specification should include commissioning, data-logging frequency, archiving and remote access.

Commissioning
Initial (static) commissioning is not always enough, especially for complex or low energy systems that require fine-tuning after occupation for them to perform sustainably. Seasonal commissioning is needed for controls, ventilation and low and zero-carbon building services.

Heat pump boreholes
The ground pipework for the ground-source heat pump system was installed early in the programme to ensure complications did not affect the construction programme. A blockage, identified during pressure testing, meant that a new bore could be drilled and connected without compromising the build programme.

fine-tuning of systems to suit occupants' needs can all conspire to distort initial energy performance.

Occupant survey results

An occupant satisfaction survey was conducted in February 2011, using the Building Use Studies (BUS) methodology. The questionnaire-based survey covers 46 comfort variables, including design, comfort, lighting, noise, productivity, health and needs. The sample of 33 respondents represented 90 per cent of those who work in the building.

Figure 3 shows the overall picture of the building by the 12 summary variables, compared with a benchmark dataset of similar UK buildings.

Occupants report that the building performs well on design, needs and on its image to visitors. In other areas the building performs close to UK norms: temperature and air quality in summer, lighting and overall comfort and health can be considered typical.

The occupants' comments reflect the statistical results, with positive remarks about the building's design and image, but more critical comments on comfort factors. For example, the underfloor heating is perceived as too warm. Typical comments on the survey were: "Too hot in summer and too cold in winter", "Heating and ventilation in offices and to a lesser degree meeting rooms is very unsatisfactory", and "Large windows let light in but do not keep the building warm in winter or cool in summer."

The scores for lighting overall are good with little glare reported. The ratings for natural light are also good, which is quite rare. Other positive responses related to the bright open-plan nature of the building, the ease of access, and the pleasant working conditions.

Given its mixture of activities the results are relatively good. The main downsides are the wintertime comfort conditions. The building is also regarded as too noisy, but staff are seemingly tolerant for the most part because they understand the building's purpose.

Performance in use

Despite its problem with high energy consumption, the building is performing reasonably well. Howard Hammond, of Stoke-on-Trent City Council property department, admits that the building has taken some time to settle down.

"We were desperate to open by January 2009, but we were rushing to finish the building in the run up to Christmas," said Hammond. "We accepted the building, got it painted, and moved in while we were still trying to commission it, and so commissioning didn't really take place properly."

Support from the project team dissipated very quickly after handover. "It was poor to be honest," said Hammond. "People had moved on to other projects." As a consequence the property team have been re-setting sensors on wind-assisted ventilators, trying to find the most appropriate settings for the underfloor heating, and attempting to resolve the problems with the BMS that won't record all the pulses from the electrical sub-meters.

"We've addressed that with correction factor in the software, so the increments are now the same," said Hammond, "but even the readings weren't the same, as the meters weren't calibrated properly."

Overall the lighting controls for the open-plan areas tend to lead to a default to on. The switches themselves lack any form of labelling and some detective work is needed to determine the link between switches and lamps.

Some of the mechanically cooled rooms changed use after handover, which means that the DX air-conditioning system is being used differently. The system wasn't initially on the Trend BMS, but now a link has been made. The downside of this is that the cooling cannot be turned on and off by the occupants. It won't stay on overnight like it used to, but staff have no control at all, which is unhelpful.

Overall, the library has been a great success in rejuvenating the centre of Stoke. Library visitor numbers have doubled, and people seem genuinely pleased with building.

The article is based on data analysis carried out by Mark Katatumba of Arup, funded by the Carbon Trust. Thanks to BBLB Architects for supplying photographs for this article.