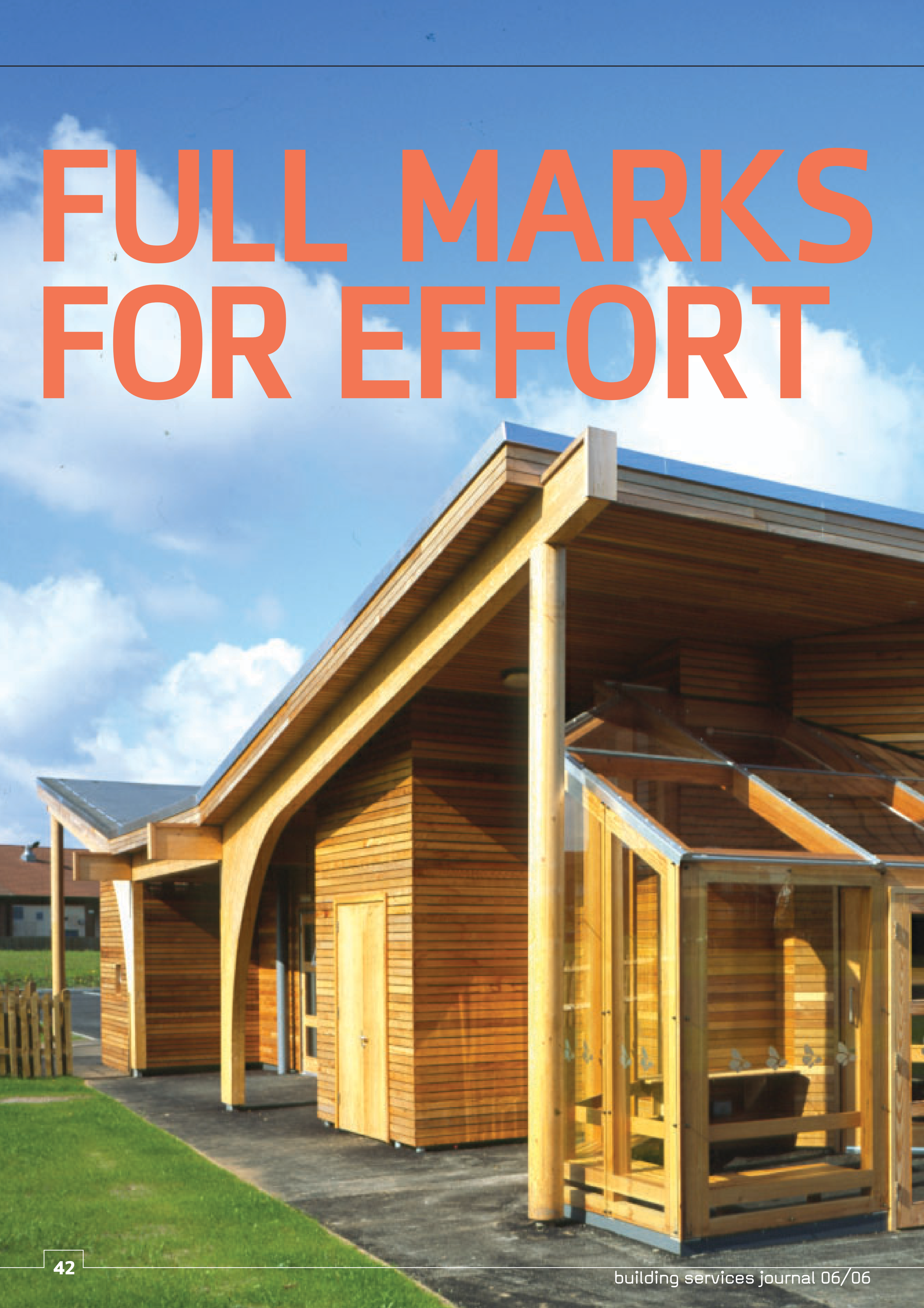
FULL MARKS FOR EFFORT



PHOTOGRAH: ADAM WILSON

Kingsmead Primary School set out to be as sustainable as possible, and its pupils and staff are very pleased with the result. Trouble is, its energy performance could be better. Jason Palmer's **report on this Cheshire project is followed by a discussion of its successes and shortcomings**

Kingsmead School in Cheshire pushes all the right buttons for sustainability: renewable energy, sustainable materials, excellent insulation and rainwater harvesting. In the eyes of pupils and teachers, it's one of the best-loved of the clutch of recently completed UK primary schools. As is often the case, though, there is a catch: the renewable energy systems are less than resilient and its energy performance isn't great.

The school is the fruit of a partnership between architect White Design, main contractor Wilmott Dixon and window supplier Velux. Arup did the concept design for building services, which was translated into detailed design by Mitie Engineering Services.

The designers pitched for low energy consumption married to renewable energy generation from the start, with encouragement and support from their client, Cheshire County Council. The school was completed in July 2004, with time in hand before the school opened to pupils in September.

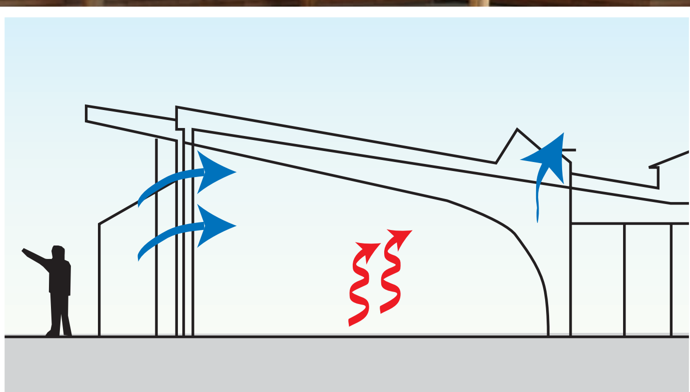
Kingsmead is located on land secured by the County Council as part of a Section 106 agreement with housing developers. The school's footprint resembles a section cut from a tyre (see plan, page 45), with a long concave curve facing north and a shorter convex curve forming the southern facade. A curved corridor runs right through the middle of the building, forming a spine with classrooms to the right (facing north) and the school hall and offices to the left (facing south).

The main structural element of the building is a large glulaminated frame made from timber from a sustainable source. The external walls are timber, while concrete block internal walls divide the rooms, also introducing some thermal mass.

Rain provides entertainment

The roof is inverted so all the rainwater that falls on it can be harvested and used to flush toilets and urinals, reducing the demand for mains water by as much as a third. This also meant the roof required no gutters and fewer downpipes than a traditional roof, saving cost and time to build.

There is an electronic panel designed to allow children to see how much rainwater is being collected over time. This not only provides entertainment for pupils when it is raining hard, but a real-life input into the



ABOVE: The main structural element of the school is a large glulaminated frame of timber from a sustainable source. **RIGHT:** The classrooms are naturally ventilated through windows and rooflights. **FAR RIGHT:** Natural lighting is maximised in the north-facing classrooms

maths and geography curriculum too.

There is also a transparent downpipe running through the school's centre. This may mean a small thermal loss through the pipe in winter, when cold water enters it, but it brings rainwater collection alive to the pupils.

Walls and roof have at least 200 mm of glasswool insulation, which achieves significantly better insulation than the UK building regulations called for (see data box on page 46). High-performance double-glazed windows with low emissivity, clear glass and an argon-filled cavity also provide excellent u-values.

Heating hiccups

The heating system has both a biomass boiler, fuelled by locally-produced woodchip from waste timber, and a condensing gas boiler. The design concept was that the 50 kW biomass boiler (which achieves 80% efficiency and is nearly carbon neutral) would do most of the work, with the 100 kW gas boiler used as a top-up when required.

However, in practice the biomass boiler was used for only two weeks in the first 13 months of operation, and the gas boiler has provided most of the school's heating. An intermittent heating load caused problems with the biomass boiler because the water temperature rose too high and the boiler cut out. Fortunately the gas boiler, connected in parallel to the biomass boiler, was sized to cope with the full heating demand, so the school did not suffer in winter.

The biomass boiler was initially fuelled with wood pellets, which burn hotter than woodchip, are more expensive, and require higher energy inputs to produce. The school switched from pellets to woodchip, hoping this would resolve the overheating problems, but the biomass boiler still isn't working and the gas boiler currently does all the work.

There is appears to be some difficulty in using biomass boilers in well-insulated buildings with low and intermittent heating loads, and this needs to be addressed.

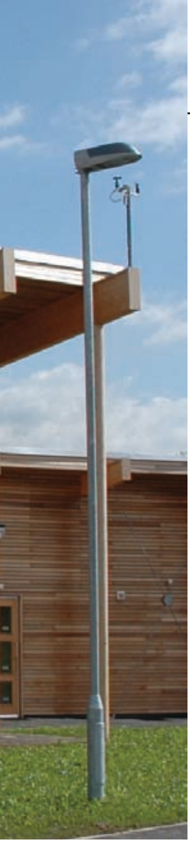
Heating is delivered to classrooms through low service-temperature radiators, which have panels that reach only 43°C, and concealed pipework, so that there is no risk of children getting burnt. The hall has underfloor heating, while offices have ordinary radiators. All the radiators have thermostatic radiator valves.

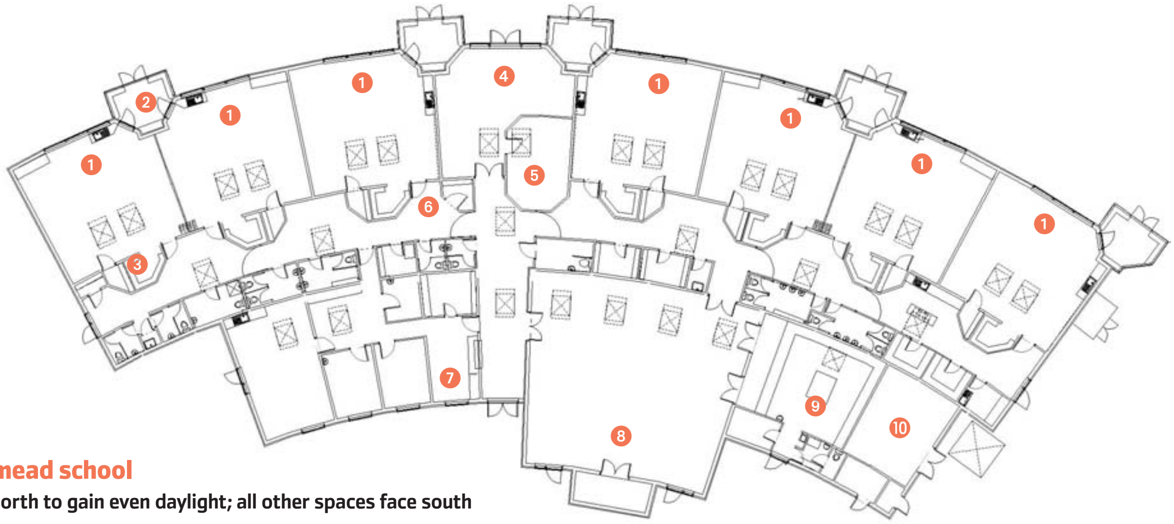
Airing the school

The classrooms are naturally ventilated through windows and rooflights, controlled automatically using the WindowMaster system. In winter, they open a small amount at breaktime and during the lunch hour to bring down CO_2 concentrations without causing drafts for pupils. The windows are also linked to temperature sensors, so in summer they open wider if rooms overheat.

Each classroom has its own unheated 'winter garden' or conservatory, with direct access to the play areas. These provide an 'air lock' or buffer that prevents unwanted heat loss each time someone goes outside.

They also provide flexible space for classes to use as they wish, whether to store dirty outdoor shoes or grow plants in a sheltered envi-





Plan of Kingsmead school

Classrooms face north to gain even daylight; all other spaces face south

1. classroom
2. winter garden
3. cloakroom
4. library
5. quiet room
6. corridor
7. reception
8. multifunctional hall
9. servery
10. kitchen

PHOTOGRAPH: ADAM WILSON

ronment. A drawback of the north-facing orientation is that the winter gardens get little sun – with only one, at the end of the building, getting enough sunlight to ripen tomatoes.

Light work

The architects sought to use natural lighting in all the main spaces, and nearly all of the electric lights are switched off most of the time. Classroom light switches are in banks, allowing teachers to bring on lights in strips if they wish – perhaps only for parts of the class furthest away from the windows or skylights. In addition, the electric lights have a daylight sensor, allowing lights to dim when there is sufficient light coming in from outside.

Very little lighting was on when the school was visited, and overall staff appear to understand and support the low-energy design.

The project team also tried to make best use of solar energy by incorporating solar water heaters and photovoltaics. There are four 2.8 m^2 solar water heaters on the roof, feeding into a single calorifier in the plant room to preheat water for the toilets and kitchen. The manufacturer's estimates were that 4000 kWh/y of solar energy would strike the collectors.

A delivery efficiency of around 50% meant that the system should have saved 2000 kWh of gas a year, or 20% of expected energy demand for hot water. However, the gas boiler heated water even in peak summer of 2005 and the solar heaters still needed some adjustment in February this year.

The PV system, meanwhile, generates electricity and so cuts power drawn from the national grid. The system uses hybrid crystalline and amorphous modules, and has a peak output of 5 kW. At design stage, this system was expected to meet 15% of annual electricity demand, although this estimate appears optimistic, and from February to March 2005 the system contributed 1605 kWh, or about 6% of electricity demand.

There is a building management system (BMS) to help control the various elements of building services and which is also intended to

How embodied energy was reduced at Kingsmead Primary School

Embodied energy (the energy used in a material's manufacture and transport) is equivalent to between 10 and 20 years' operational energy use in a typical school. However, as the operational energy efficiency of schools improves, the up-front embodied energy becomes more significant.

Ordinary kiln-dried softwood has a low embodied energy, about 3.4 MJ/kg. The glulaminated timber used in this school's frame has a higher embodied energy content, about 11 MJ/kg, but still much less than steel (around 38 MJ/kg) or aluminium (170 MJ/kg)[1].

However, mass – expressed in kg – is not the most significant factor in selecting materials, so these values aren't terribly helpful. You can rarely substitute one material for another of equal weight. Moreover, most building materials are used in combination: a timber frame with a timber cladding and plasterboard lining, or masonry with two layers of bricks and a plasterboard lining.

It is often more useful to think of materials in terms of m^2 of facade, and all the components used together. As a rule of thumb, materials that require more processing before they can be used on site have higher embodied energy than those that do not need to be processed.

Kingsmead School probably has about half of the embodied energy of an equivalent school built with a steel frame and timber cladding, or about a third of an equivalent school with a frameless masonry construction.

One of the largest contributors to embodied energy over the whole life of the building are floor coverings, because they are replaced periodically. At Kingsmead bamboo, linoleum and recycled content carpets were used, which reduce embodied energy and improve indoor air quality. Similarly, water-based paints and glues were used instead of solvent-containing products, and a rubber roofing membrane instead of a PVC barrier.

[1]Source: Lawson, B (1996): Building Materials, Energy and the Environment, Canberra

provide information for pupils to use in lessons. However, there have been teething problems with the controls and the school is unable to reprogram it.

Energy consumption

Gas and electricity consumption are both higher than expected, and electricity consumption at more than 70 kWh/m^2 is three-and-a-half times the benchmark figure for primary schools as stated in Energy Consumption Guide 73: Saving Energy in Schools (see figure 1 below). Gas consumption is higher than anticipated because of the problems with the solar water heater and biomass boiler – the project team assumed that most of the energy for space and water heating would come from woodchip.

However, the gas boiler had to step into the breach when the biomass heating system fell over as explained earlier. Contractor Wilmott Dixon and environmental consultant Arup are working to resolve the boiler problems and gas consumption is expected to fall accordingly.

Electricity consumption is higher than expected for three reasons. First, because kitchen equipment has been running during the school holiday periods – and arguably, this was unnecessary.

Second, the school is being used for community purposes in the evenings, which means it has longer-than-expected opening hours and so more lighting is needed in the evening. And third, there is more ICT equipment in the school than is average: a server room, interactive white-boards, portable PCs left to charge overnight and closed-circuit TV, which all inevitably raise electricity consumption.

Water consumption, at 420 m^3 for 2005, is approximately on target (even in the relatively dry year of 2005, when rainwater harvesting was lower than expected), and Keith Bate of Cheshire County Council expects figures to fall even further in the future – specifically because of improved controls on urinals.

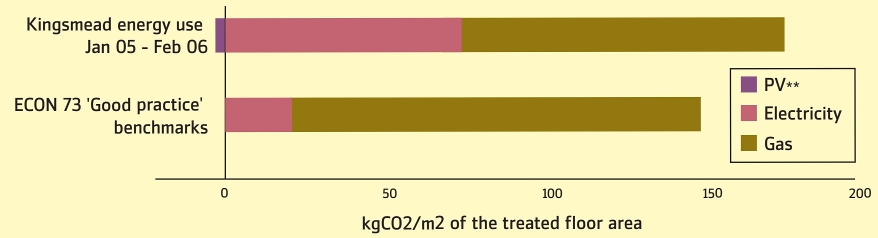
Overall, Cheshire County Council and the school are pragmatic about its performance to date – they accept there are difficulties, in part because it usually takes time for a new building to be fine-tuned to optimum performance, and in part because of innovation (particularly in the case of the biomass boiler). They are working to monitor and resolve the problems, and at the same time learn as much as possible about the technology.

The school provides an excellent working environment. It is warm and fresh in winter, and doesn't get too hot in summer. Teachers and pupils alike are extremely pleased with it and overwhelmingly proud of its environmental credentials, in spite of hiccups with some of the building services – a testament to the resilience of the design.

This was not a cheap school, though, and the cost may put Cheshire County Council off building other schools like it. Nevertheless, some aspects of the school are extremely successful – the timber construction, natural ventilation and daylighting, for example – and these aspects could be replicated in other schools without necessarily incurring the same cost premium. ■

Jason Palmer is a director of Cambridge Architectural Research and compiled this article on behalf of the DfES. Kingsmead School is one of 12 case studies in the forthcoming Building Bulletin on Sustainable School Design.

The roof at Kingsmead is inverted so that all the rainwater can be harvested and used to flush toilets and urinals. Water consumption is on target, unlike the shcool's energy performance which, to date, has been higher than expected



*Assuming 0.19 kgCO$_2$/kWh gas, 0.43 kgCO$_2$/kWh electricity.
**Estimated from four months' data February-March 2005.

TABLE 1: Energy consumption at Kingsmead

Kingsmead Primary School

Local authority client Cheshire County Council
Architect White Design
Structural engineer Integral Structural Design
Environmental engineer Arup/Mitie Engineering Services
Main contractor Wilmott Dixon
M&E contractors Mitie

M&E suppliers
Biomass boiler Talbots
Solar thermal panels Solar Twin
Photovoltaic system Solar Century
PV panels Sanyo

Engineering data
Gross floor area: 1800 m^2
Net treated area: 1296 m^2
Plant rooms: 40 m^2

Occupancy
Classrooms: 63 m^2 for approx 30 pupils

Air permeability test None

U-values

Component (W/m^{2}K)	Kingsmead	Part L (2002)
Walls	0.171	0.35
Windows	1.75	2 (wood/pvc frames)
Pitched roof	0.171	0.2
Floor	0.18	0.25

Structural details:
Slab thickness: 150 mm
Floor-to-ceiling: 3.8-4.4 m

Energy use breakdown (actual)
Gas: 73 kWh/m^2/y
Electricity: 61 kWh/m^2/y
Biomass: negligible
PV generation: 4815 kWh/y (estimate)

Carbon dioxide emissions
Actual: 52 tonnes/y

Costs
Total cost: £2.4 m including fees and furniture
Total net cost: £1333/m^2 (including winter gardens)

Occupant satisfaction survey: what the pupils, teachers and support staff think of the school

Adrian Leaman of Building Use Studies (BUS) carried out an occupancy survey of Kingsmead School in March 2006 as apart of a wider study for the Department for Education and Skills. The results of the survey are shown, right, with benchmarks (the mean for the UK, with upper and lower limits for statistical significance) represented by the black line through each variable.

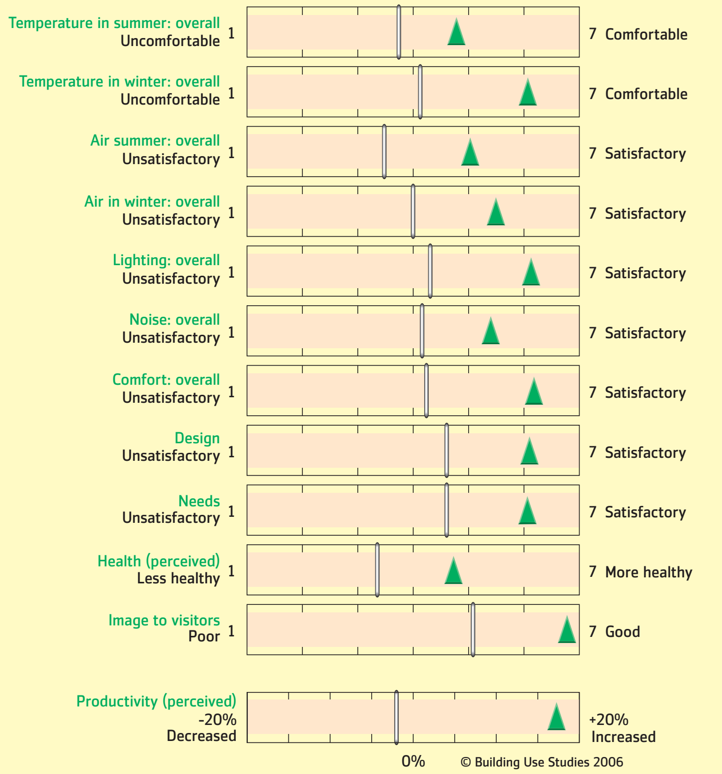
Kingsmead Primary School rates highly from the occupants' point of view. On the basis of Building Use Studies (BUS) ratings and benchmarks, it falls in the top 10% of buildings in the current BUS British dataset, making it one of the best schools BUS has found.

The approach to lighting at Kingsmead refutes the conventional wisdom that classrooms should be south- facing. Here, most classrooms are north-facing, but benefit from a controllable top-light in the deepest part of the classroom spaces. This seems to work well for the most part. The quality of daylighting is good enough to encourage users to keep the lights off and blinds up.

Kingsmead also has one of the best ratings BUS researchers have seen for perceived productivity. Staff say that the conditions in the building significantly contribute to their perceived productivity at work.

This is no surprise given the extremely good thermal comfort scores, attention to detail in the design, and high level of awareness that users have of how the building is supposed to work and be used. The design intent is, for the most part, clearly communicated to occupants.

Kingsmead has most of the features that occupants love in buildings, and they unconsciously respond positively as a result. It is a rare case of a building that performs well on most of the assessment criteria but also has extra qualities which emerge from the combination of design, management and user activities.



WHAT THE EXPERTS SAY


Roderic Bunn: editor of two forthcoming books on sustainable school design


Craig White: architect of Kingsmead and principal of White Design Architects


Adrian Leaman: social scientist and principal of Building Use Studies


George Martin: head of rethinking at Willmott Dixon Construction

PHOTOGRAPHS: RODERIC BUNN

Kingsmead School has attempted to be an exemplar of sustainable school design. In part, the partnering team of architect White Design, consulting engineer Arup and main contractor Willmott Dixon – not forgetting the strong leadership provided by the client, Cheshire County Council and the school head, Catriona Stewart – has achieved its ambition. And as far as its occupants are concerned, it has certainly succeeded (see box, above). Yet, despite these undoubtable successes, there's no getting away from the fact that the school's energy performance could be better.

To discuss the school's successes and failings, and to understand how the school indicates the direction sustainable design should be heading, key players in the design and construction process met to go over the energy and occupancy survey results.

The meeting was attended by George Martin, Head of Rethinking at main contractor Willmott Dixon Construction; Craig White, architect of Kingsmead School and principal of White Design Architects; BSRIA's Roderic Bunn, editor of two forthcoming DfES books on sustainable school design, and social scientist Adrian Leaman, principal of Building Use Studies, whose occupant satisfaction survey method was used at Kingsmead and in BSJ's PROBE studies.

This article is a condensed version of a discussion to be published in the forthcoming Department for Education and Skills book Design of Sustainable Schools - Case Studies edited by Roderic Bunn. The case studies will be published alongside a companion volume *Sustainable Schools – A Design Primer*. Both books are due to be published in summer 2006.