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design of sustainable schools **case studies**

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Special thanks go to all the schools in this guide for making their schools available for analysis.

> “ Schools are there to give children the knowledge and skills they need to become active members of society. Many children are rightly worried about climate change, global poverty and the impact of our lifestyles. Schools can demonstrate ways of living that are models of good practice for children and their communities. They can build sustainable development into the learning experience of every child to encourage innovation and improvement. ”

Alan Johnson, Secretary of State for Education and Skills
September 2006

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Foreword

Parmjit Dhanda

Parmjit Dhanda MP

We need new buildings, yet construction is one of the least sustainable industries in the world. How can school buildings play their part in addressing the challenges of issues surrounding sustainability?

Design of sustainable schools – case studies aims to provide schools and design teams with real-world examples of places that have embraced these challenges.

The government will be investing substantial public funds over 15 years to rebuild and transform the schools estate. Investment in schools will be £6.4 billion in 2007-08, rising to at least £8 billion by 2010-11. This is a once-in-a-lifetime opportunity to provide our children with sustainable school buildings: buildings that use less energy and water; that minimise waste and avoid the use of pollutants; that protect and enhance habitats for plants and wildlife; and that meet local needs. Educational vision remains central to delivering twenty-first century schools and all stakeholders will be involved in the process.

Rather than simply rebuilding new schools as old, DfES is ensuring that stakeholders are involved in the design of their schools. Inclusive briefing, sensitive to pupils, staff, governors and parents, will transform school design to meet wider community needs.

We have set high standards for this next generation of school buildings. All major school building projects must now undergo formal environmental assessment using the Building Research Establishment's environmental assessment method BREEAM Schools and the application of new building regulations should reduce carbon emissions significantly. Local planning policies are also encouraging sustainable development.

The case studies in this book show just what can be done. These sustainable schools are the pioneers and it is important that we learn from their achievements – and their mistakes. The schools have allowed free and open reporting and I commend them for that. Their courage is helping us all to realise the vision of a transformed and sustainable educational system. Read the case studies, learn the lessons and apply them to your school today. And in turn pass on your experiences to others.

Contents


WELCOME
TO OUR
SCHOOL
Exit

Introduction

Our understanding of sustainable development has progressed since 2000, when the Government published its *Strategy for Sustainable Construction: Building a Better Quality of Life*. During 2006, the DfES published its Sustainable Schools consultation paper. The feedback received, together with wider initiatives within the construction industry, will inform the ways in which tomorrow's schools will be designed, constructed and operated to meet local needs, and how their environmental performance will be enhanced.

This guide is designed to be accessible to the whole school community. But it is particularly aimed at expert professionals such as designers and local authority clients. It addresses refurbishment of existing schools as many sustainability techniques used in the design of new schools can be applied to existing schools and vice versa.

The publication is structured in three parts:

Part 1: Emerging themes highlights those messages that were consistently identified at a number of the schools investigated.

Part 2: Detailed case studies of twelve schools.

Part 3: A brief description of the main tools that support sustainable design, many of which have been applied to the case study schools.

All those involved in creating a school need to take their share of responsibility for its design and performance. With climate change now a stark reality, everyone in the community has a responsibility for ensuring that sustainability aspirations are met or even exceeded. It's time to raise the bar on school design. This guide shows you how some schools have met this challenge.

DfES policies are set out in the Department's *Sustainable Development Action Plan* published in March 2006. This will be followed up with a variety of tools, including sustainable schools websites:
www.teachernet.gov.uk/sustainableschools
www.teachernet.gov.uk/sustainabledesign

Emerging themes

Sustainability in schools is highly context-dependent: what works for one school with a particular set of requirements and constraints may not be so successful elsewhere.

This volume of case studies concentrates primarily on schools which have tackled environmental aspects of sustainability. The schools include various features which allow schools to be constructed and operated in ways that do not damage the environment by:

- Reducing our dependency on fossil fuels for heating and lighting
- Encouraging methods of transport to and from school other than travel by car
- Improving school grounds in ways that encourage bio-diversity
- Reducing water demand and identifying sustainable drainage systems which reduce flood risk
- Responsibly sourcing materials, and recycling and re-using materials wherever possible.

Within these broad categories, there are a number of themes which are common to all schools and these are summarised under a range of headings below.

But there is also a strong social perspective to sustainability – a school that does not meet the needs of its community will not be sustainable. The best examples we have found started by finding out what people really wanted and needed. Hence the first heading below covers stakeholder involvement. In some cases, this involvement has resulted in valuable teaching resources that will continue to generate interest in sustainability at those sites. Five of the schools have undertaken a post occupancy evaluation – a formal occupants' assessment of the building's performance – so that lessons learnt could be fed into future projects.

The final perspective on sustainability surrounds costs – measures that are not economic are also unsustainable. It is clear that careful consideration of whole-life costs should identify the most economically sustainable design option, but methods for whole-life costing are currently poorly understood. Some schools have reported that they couldn't afford to do all that they would have liked, while on other projects relatively expensive technologies have been retained for reasons other than their financial return. On the whole, these case studies show that much can be achieved with current funding levels and that sustainable schools are affordable.

Many features that aren't affordable today will become so in the near future. Advances in technology and changing markets are helping to reduce the capital costs of investing in sustainability. Future rises in fuel prices will improve the financial case for investing in energy conservation and renewable energy. The cost-effectiveness is boosted further if the social and wider economic implications of climate change are taken into account.

Compared to most other types of building, schools are extreme environments. They have high and sporadic occupancy levels, often boisterous use of circulation space, and are subject to the ultimate human agents of erosion and accelerated wear: schoolchildren. School buildings need ongoing management and periodic re-commissioning if they are to remain in peak condition. Good design will result in systems that don't require much ongoing attention which school staff can understand, operate and maintain in good working order.

Stakeholder involvement

Sustainability begins with finding out what people need and want in a new or refurbished school. It is tempting to think that sustainability is largely about technical fixes, but it is as much about the way the school is procured and run and how the whole school community is involved.

Schools are complex buildings that house many competing activities and functions within them. There are teachers, parents, pupils, classrooms, canteens and timetables – a great mix and more varied than most buildings.

Sustainability needs to start at the beginning: the educational vision within the School Development Plan sets the background for potential design solutions. Design should start with an assessment of current educational needs and be flexible enough to accommodate future changes in educational practice.

Not only should this include obvious things like pupil numbers, site details and space for storage, but also meeting occupiers' expectations for control and usability of a school's systems, such as lights, blinds and heating, and the integration of information and communications technology (ICT).

A consultative approach to design means engaging early in the design process with parents, children, teachers and other stakeholders. Successful communications depend on engaging the relevant people at the right time, and giving them 'ownership' of the project.

- Sustainability and education for sustainable development need to be integral to both the curriculum and school development plans for a school to be truly sustainable
- Occupant satisfaction surveys of schools suggest that circulation and storage are most commonly overlooked
- Continuity within the design can help to support a project's outcomes. At Kingsmead the client, user, contractors and consultants, all worked together very well. The Local Authority had four client liaison staff and those people didn't change throughout the project. The designers and the contractor are still in contact with the school
- Local Authorities and other client bodies should become an integral part of the team rather than purely gatekeepers of public finance and design standards
- The continuing involvement of the professional team in the months following a school's occupation is important. Sophisticated energy-saving technology will not compensate for hurried commissioning and a lack of fine tuning. This should include heating, ventilation and other building services and the ICT systems.

Getting the 'basics' right

▲ Above
Circulation spaces at the Academy of St Francis of Assisi support natural ventilation and good daylight.

In many ways, sustainable design is no different to good design, and lessons can be learnt from the past. Electrical power and other utilities were not readily available early in the last century so other strategies were developed to light, heat and ventilate buildings. Similarly, materials were locally sourced because transportation was difficult and expensive.

In the case of Bromsgrove Senior School, several basic building options were modelled in the early stages of design so that the basic decisions (layout, orientation, etc.) supported the development of the most sustainable school building.

- Good daylight, acoustics, ventilation and transport links are as important as inspirational design
- Transparent insulation materials can provide diffuse daylight whilst maintaining high thermal insulation. An example is the polycarbonate glazing systems used at Oakgrove and Venerable Bede schools
- Consider how users will operate their windows and blinds to provide daylight and fresh air. This will vary depending on internal and external temperature, lighting conditions, and is crucial in teaching spaces with electronic whiteboards and PC screens
- Building Regulations now require buildings to achieve air-tightness standards, so attention to detailing and careful supervision of construction is essential
- The re-use and recycling of materials are a fundamental part of sustainable construction. For example, the construction of Bradley Stoke involved the use of recycled aggregates in the foundations.

The building as a learning tool

Sustainability features can provide valuable opportunities for learning.

- At Notley Green Primary School there are worktops which are visibly recognisable as being manufactured from recycled products, and viewing panels allowing pupils to see the thermal insulation made from recycled newspaper
- At Anns Grove Primary School, parts of the building were comprised of locally sourced recycled materials: thermal insulation from fabric and roof material from recycled tyres
- Kingsmead Primary School has a perspex drainpipe running through the centre of the school to demonstrate rainwater recovery to the schoolchildren. There is also an electronic display panel to allow pupils to monitor how much rainwater is being collected
- Automatic meter reading and energy monitoring software can provide real-time data for use in mathematics and other subjects.

The headteacher at Kingsmead Primary School, Catriona Stewart, says the school does not hold an environment week or a recycling week, because: "We prefer to do it all the time, and we don't want people to stop doing it after a week".

Throughout their time at Kingsmead Primary School the children learn about their building in the environment through topics. This improves their understanding of how the building works. Years 4 and 5 are taught about the school's sustainable urban drainage system and the rainwater harvesting system. A science lesson about electricity uses a mini solar-panel to show the principles, then explains how part of the school's electricity comes from photovoltaics on the roof. Another lesson about building materials explains why Kingsmead is built from timber, and how this compares to alternative building materials.

In the words of Craig White, the architect of Kingsmead: "I think that rather than simply employing specialists to reduce energy consumption, we should enlist the help of the schoolchildren. When a school like Kingsmead seems to be consuming more energy than it should, we can say to them: 'You can be our ears and eyes to identify where the energy is going'. A five-year old should be able to understand what a balloon of carbon dioxide looks like, or how many raindrops it takes to flush the toilet. Sustainability should be linked into the curriculum."

▲ Above
For sustainability to resonate with pupils, information needs to be presented in a form they can understand: such as how many raindrops it takes to fill a bath.

Low energy design

▲ **Above**
The school's low energy features are used in the curriculum. Here the pupils are learning about the environmental qualities of insulation made from waste textiles.

The energy use of schools can be significantly reduced through passive design measures (heating, ventilation and the provision of daylight), thermal insulation, energy efficient equipment and appropriate automatic controls.

Thermal modelling can be used to optimise energy efficient designs, as was the case at Bromsgrove Senior School and the Academy of St Francis of Assisi. Occupants will need training so that the building can operate as modelled.

At Kingsmead, there is a biomass boiler, sensors on the electric lights, solar power, and an informed client group who saw energy efficiency as part of the educational agenda. The designers also knew what equipment was being installed and set energy targets. However Kingsmead is still missing its energy targets as equipment such as overhead projectors in classrooms and laptop-recharging trolleys are being left switched on unnecessarily for long periods.

- Controls should be suitable for use by the occupants. Not only does this provide them with an opportunity to influence their environment, but building users are more likely to tolerate wider variations in environmental conditions if they have even a modest influence over their local environment
- Installing energy meters and provision of simple monitoring tools enables schools to monitor and fine-tune their operational performance
- Use whole-life costs and try to consider how fuel prices may change in future to prioritise energy efficiency and renewable energy measures. See www.buildingenergyadvisor.com

Renewable energy systems

'Micro-generation' – meeting heat and/or power needs using on-site renewable energy systems – has become a statutory requirement through Building Regulations and local planning policies. But the appropriate use of renewable sources of energy should be part of a comprehensive energy strategy that seeks first to minimise energy use. Oakgrove Secondary School includes passive features and low energy design to meet a challenging target for energy. This low energy design is complemented by the inclusion of renewable energy systems.

The real value of these technologies is that they can provide practical learning experiences. However, the lack of energy data found by the researchers suggests that some schools may be finding it difficult to take full advantage of the opportunity to interact meaningfully with the technologies.

- Consider renewable forms of energy in the wider context of energy efficiency and operational management practices. The installation of wind turbines and photovoltaics in isolation is not likely to contribute meaningfully to a school's energy performance and carbon dioxide emissions
- Showcasing renewable energy technologies can generate interest: engaging teachers and pupils, and encouraging the local community to take responsibility for the environment
- It is all too easy to negate the environmental benefit of a renewable system by leaving equipment switched on.

Energy and ICT

Technologies such as whiteboards, projectors and laptops are highly beneficial teaching aids, but they can vastly increase a school's electricity consumption. Switching-off policies can help considerably, but schools need to manage the energy and environmental effects of their ICT strategies.

ICT requirements can be met in a variety of ways which can be either more or less energy efficient. Energy efficiency should therefore be a high priority for the ICT specification in order to minimise the electrical loads of ICT equipment, network servers, etc. This will also reduce the potential for overheating and the requirement for associated cooling plant. Energy calculations often do not take account of all the new ICT kit in schools.

- ICT classrooms require careful design. Some ICT classrooms have been designed with no windows, many overheat, whilst others have pillars and columns that obscure teachers' and pupils' lines of sight. South-facing ICT rooms can lead to overheating and require shading to prevent occupant problems with glare
- Spaces with interactive whiteboards require the virtual exclusion of sunlight when the whiteboards are in use, and measures to control glare from electric lighting
- Blinds should also be simple to operate so that daylighting can be optimised for more-traditional teaching, and blinds should not overly restrict access to fresh air through openable windows.

▲ Top
The use of wood as a heating fuel at Weobley Primary School has reduced the carbon emissions associated with energy demand.

▲ Above
Electronic whiteboards are vital teaching aids, but their projectors consume high amounts of electricity. This is very environmentally damaging, especially when a school has lots of them, and they are left on for long periods.

▼ Below
The concave rear of Kingsmead Primary School faces south, with the convex elevation of the classrooms facing mostly north. This makes best use of daylight in classrooms without problems of glare. The classrooms are also isolated from the busy main road.

Completed
August 2004

Floor area
1,296 m^2 (gross internal)

Pupil numbers
250

School hours
07.30 – 18.00 h

Maintenance
On-site maintenance manager

Local authority client
Cheshire County Council

Architect
White Design

Structural engineer
Integral Structural Design

Environmental engineer
Arup/Mitie Engineering Services

Main contractor
Willmott Dixon

M&E contractors
Mitie

Energy use breakdown
Gas: 103 $kWh/m^2/y$
(adjusted for local temperature)
Electricity: 72 $kWh/m^2/y$
Biomass: negligible (but designed to meet 60 percent of the heating load)
Photovoltaic generation:
4,815 kWh/y (estimate)

Carbon dioxide emissions
Predicted: not calculated, but aimed to be of at least 40 percent less than a typical primary school

Actual: 49 $kgCO_2/m^2/y$
(52 tonnes/y total)

Costs
Total budget: £2.37 million (£1,815/m^2 in 2003) including fees, furniture, energy and water collecting features, and equipment

The County Council secured additional funding of £475,000 from DfES (Working Environment for Teachers), North West Development Agency and Department for Trade and Industry to address sustainability issues

Kingsmead Primary School

Kingsmead Primary School is attempting to demonstrate the virtues of low energy design and renewable energy solutions.

Summary

The headteacher at this primary school feels strongly about environmental issues, and this translates to a genuine effort to respect the environment. The school is very attractive inside and out, using materials of low embodied energy within a timber frame.

The designers of the school aimed for low energy consumption married to renewable energy generation. Although the energy performance has yet to live up to expectations, the design team and Cheshire County Council are attempting to resolve the teething problems.

Staff and pupils are extremely pleased with the school and overwhelmingly proud of its environmental credentials. This is being emphasised in the curriculum.

Primary
Middle
Secondary
Academy

▶ Right
Detail of the glue-laminated timber frame during construction.
Photograph ©White Design Associates.

▶▶ Far right
All timber for the school was obtained from sustainable sources. The windows are under the operation of a computer system for purging during teaching breaks.
Photograph ©White Design Associates.

Project details

Kingsmead Primary School was completed in July 2004, with time in hand before the school opened to pupils in September that year.

The school is close to the entrance of the site, which serves two purposes. First, service connections and the access road were kept as short as possible; second, the school provides a barrier to the road, creating a private zone for play areas.

The school has a curved corridor running east-west which acts as the main circulation space. Classrooms run along its north aspect, with the school hall and offices along the south side. North-facing classrooms help provide consistent light without overheating in summer, and there are also rooflights fitted with motorised solar blinds to allow solar gain when it is needed in winter, but help keep it out in summer.

The school's main structural frame is made of glulam timber (laminated wood glued together in layers to make long beams). This timber was obtained from a sustainable source. The external walls are also of timber (sourced, as was all the timber, from a sustainable source).

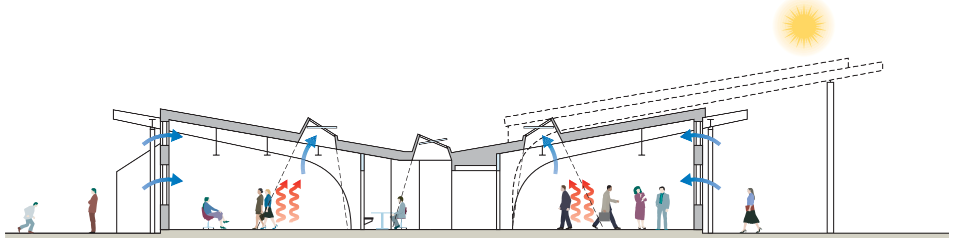
The concrete block internal walls are not load bearing. This provides flexibility in changing the room layouts and improves the ease with which the walls can be removed and broken down into their component parts, either for recycling or for re-use in other buildings.

The roof is inverted so that rainwater can be easily gathered into a central store and used thereafter for the flushing of toilets and urinals. This measure was estimated to reduce the use of potable water for non-potable purposes by around 30 percent.
As an added bonus, this meant the roof required no gutters and fewer downpipes than a conventional roof. This saved cost and reduced the build programme.

An electronic display panel enables the pupils to see how much rainwater is being collected. This provides entertainment for pupils when it is raining hard, and provides educational material for maths and geography lessons. The data can also be used to tackle complex mathematical problems, such as the calculation of yearly averages. A minor frustration is that the monitor resets when the power goes off or when the school suffers a storm, so it is difficult to know the total amount of rainwater collected by the system.

A transparent downpipe runs through the centre of the school to make the collection of rainwater real to the pupils. The penalty is a small thermal loss through the pipe in winter when cold water or snow-melt enters the school.

▶ Top right
The school's main structural frame under construction in 2004. The frame is made of glulam timber (laminated wood glued together in layers). *Photograph ©White Design Associates.*



▶ Bottom right
The primary school is natural ventilated, with some computer control of windows to prevent the build-up of carbon dioxide. Note the inverted roof, designed to capture rainfall for the water harvesting system.

Insulation

The school's walls and roof have at least 200 mm of glass wool insulation, made partly from recycled glass. This thickness of glass wool means that the thermal performance of the envelope (the U-value) is significantly better than the requirements of the 2002 UK *Building Regulations* (see table below).

High performance double-glazed windows also provide excellent U-values. The glazing used in these elements has low-emissivity, clear glass, and the cavity is argon-filled to improve its thermal performance.

Heating systems

The heating system has a biomass boiler, fuelled by locally-produced woodchip from waste timber, and a gas-fired condensing boiler. The system was designed so that the 60 kW biomass boiler (which achieves 80 percent efficiency and is nearly carbon neutral) would do most of the work, with the 100 kW condensing 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. Consequently, the condensing 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 condensing boiler was sized to cope with the building's full heating demand, so the school did not suffer during winter cold spells.

The biomass boiler was initially fuelled with wood pellets, which burn hotter than woodchip.
The pellets also require higher energy inputs to produce than woodchip. The school hoped that changing from pellets to woodchip would resolve the overheating problems, but even in Spring 2006 the biomass boiler still wasn't functioning properly, and the gas boiler served the full load.

U-values of building components (all W/m²K)	Achieved at Kingsmead	*Building Regulations* (2002)
Walls	0·171	0·35
Windows	1·75	2 or 2·2
Pitched roof	0·171	0·2
Floor	0·18	0·25

◀◀ Far left
An electronic display panel enables the pupils to see how much rainwater is being collected.

◀ Left
Each classroom has a small winter garden that connects the playground to the classrooms. They also act as thermal buffer zones.

◣ Below
North-facing classrooms help provide consistent light without overheating in summer, and there are also rooflights fitted with motorised solar blinds to allow solar gain when it is needed in winter, but help keep it out in summer.

Passive solar design

Each classroom has its own unheated winter garden, with direct access to the play areas. These gardens act as thermal buffers that reduce heat loss from the classrooms as children go to the play areas. They also provide a flexible, sheltered space for each class to store outdoor shoes or grow plants.

The architects sought to get natural light into all the main spaces, and consequently nearly all the electric lights are off most of the time. Classroom light switches are in banks, allowing teachers to bring on lights in strips if they wish – such as for parts of the class furthest away from the windows or skylights. In addition, the electric lights are linked to daylight sensors, which enables lights to dim when there is sufficient daylight.

The design team tried to make best use of solar energy by incorporating solar water heaters and photovoltaics. The solar water heaters pre-heat the hot water for the toilets and kitchen. The design is based on the solar panels providing 20 percent of the school's domestic hot water

	KWh/m^2/y		kgCO$_2$/m^2/y*		
	Electricity	Gas[†]	Electricity	Gas[†]	Combined
Kingsmead consumption 2005	72	103	29	20	49
Kingsmead photovoltaic generation 2005**	4	–	–	–	–
Top 25 percent of primary schools[††]	25	113	11	22	33

* Assuming 0·19 kgCO$_2$/kWh gas, 0·43 kgCO$_2$/kWh electricity.

** Estimated from four months' data February to May 2005.

[†] Gas use adjusted for local temperature.

[††] Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003.*

requirements over the course of the year. However, the solar heaters still needed some adjustment in February 2006 – the gas boiler heated water even in peak summer of 2005.

The system uses hybrid crystalline and amorphous photovoltaic modules, and delivering a peak output of 5 kW. At the design stage, this system was expected to deliver 15 percent of the school's annual electricity requirement. This estimate appears optimistic, as from February to March 2005 the system contributed about 6 percent of electricity.

Energy consumption

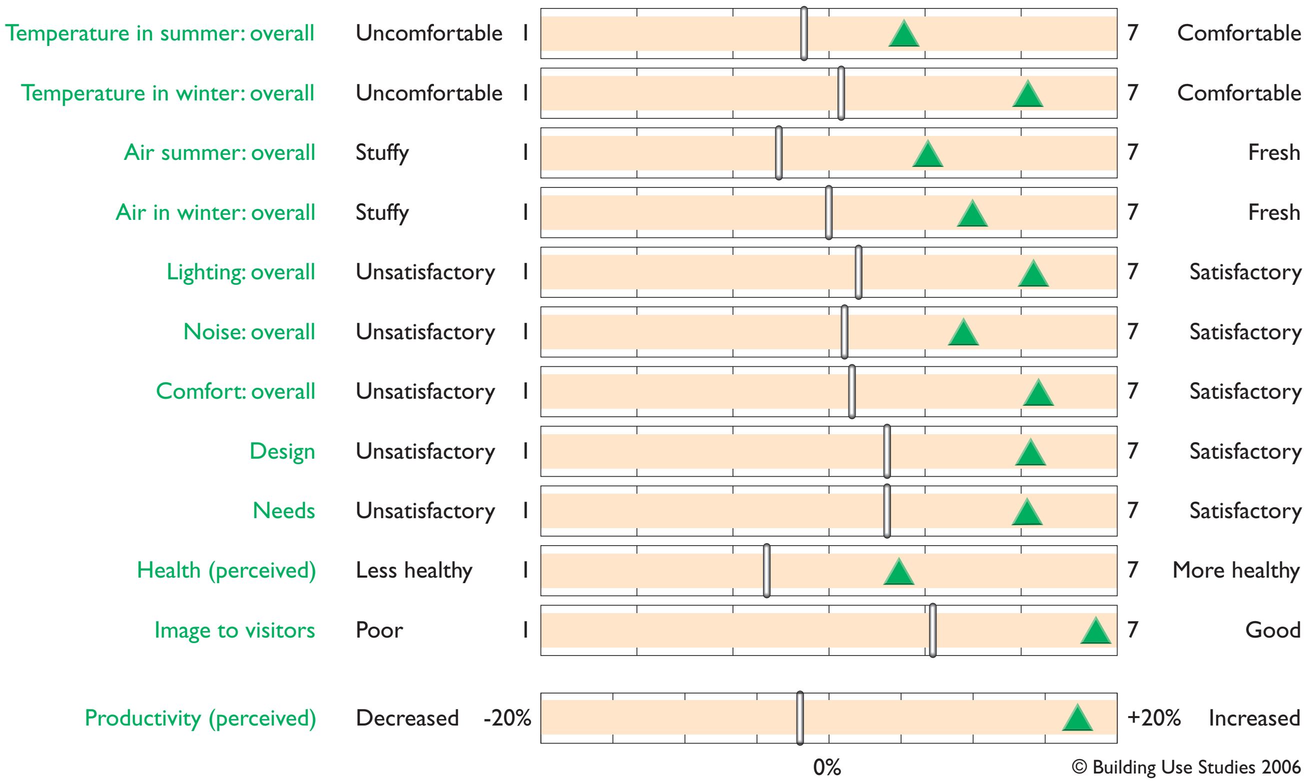
Gas and electricity are both higher than expected. Electricity consumption, at more than 70 kWh/m^2, is nearly three times the benchmark figure for primary schools. Gas consumption is high because of the problems with the solar water heater and biomass boiler – the project team assumed that most of the energy for space and water heating would come from burning wood chips. However, the gas boiler has had to step into the breach when the biomass boiler failed to perform. Gas consumption is expected to fall once the problems with the wood-chip boiler are resolved.

Electricity consumption is higher than expected for three reasons. First, because kitchen equipment has been running during holiday periods. Extract fans, freezers and refrigerators have all been left running, arguably unnecessarily. 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. Third, there is a lot of information technology in the school, such as a server room, interactive white-boards and CCTV.

What this means to you

- Bear in mind water use as well as energy. A school usually pays both for the supply of water and for its disposal as sewage
- Be wary of over-complicated building management systems: there should be sufficient sensors on the system to inform decisions, but not so many it becomes unmanageable
- Be wary of new sustainable technologies that your project team hasn't used successfully in the past
- Make sure installers of new technologies aren't cutting their teeth on your school; and if possible speak to other LEAs with experience to share
- Think about using the school buildings in lessons – there may not be meters to show rainfall at your school, but there are probably meters for gas and electricity consumption
- Tie lessons into pupils' own experiences, perhaps using aspects of your school building

Occupancy satisfaction scores for Kingsmead Primary School



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These are summaries of some of the variables used in the Building Use Studies occupant assessments of five schools covered in this book. But what do the symbols mean?

▲ Green triangles represent mean values significantly better or higher than both the benchmark and scale midpoint. In other words, a good score.

● Amber (orange) circles are mean values no different from benchmark. In other words, a typical score.

◆ Red diamonds are mean values worse or lower than benchmark and scale midpoint. In other words, a poor score.

Be careful to read the directions of the scales and the scale labels. Perceived productivity is a measure of how the staff feel the school contributes, positively or negatively, to their productivity. It is not an absolute measure.

| Benchmarks are represented by the line through each variable. The location of the benchmark varies for each variable. The benchmarks are derived from British, Australian and International studies of schools, depending on the context.

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 percent of buildings in the current BUS British dataset, making it one of the best buildings BUS has found[1].

Occupants also seem to tolerate the school's faults. For example, it is perceived as too hot and still in summer.

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. However, some commented that 'it feels a little dark' and say that the contrast between relatively dark classrooms and the brightness in the hall can be too great at times.

Kingsmead is one of the best ratings BUS researchers have seen for perceived productivity. Staff are saying that the conditions in the building significantly contribute to their perceived productivity at work[2]. This is no surprise given the extremely good thermal comfort scores, attention to detail in the design, and users' high level of awareness 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 which occupants love in buildings, and they respond positively as a result[3].

Kingsmead School 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. Obviously, it is important that the basic design works reasonably well, fulfils its purpose and looks good. However these are not enough by themselves.

In the case of Kingsmead, the client is committed to making the building work, and the design team and contractors are willing to carry out health checks over and above the normal handover requirements, so that all parties are pulling together. This is particularly important where innovative features are present and the school staff are not blessed with large budgets to sort things out if they go wrong.

A further vital factor is the attitude of the school governors and staff to the project. At Kingsmead, everyone embraces a wholehearted approach to environmental responsibility, led with vigour and good humour by the head and staff, but also communicated simply and clearly to all who use the building – children, parents and visitors alike. BUS has not found a better case where the energy-efficiency maxim 'make performance visible' has been put into practice.

The outcome is not just value in the economic and environmental senses, but the creation of a virtuous circle of improvement which in turn influences and changes attitudes and behaviours in a broader educational sense. This not only applies to pupils' development, but also to parents' attitudes.

These emergent properties are extremely hard to pin down quantitatively, and often depend on people and management strategies as much as the physical building for their success. This also implies that they can change also for the worse over time as people move on and reasons for doing things are forgotten or neglected.

1 This covers building types such as offices and higher education buildings as well as schools.

2 A note of caution. The actual statistic is plus 17·5 percent improvement. We prefer not to quote this directly because it is subject to the usual caveats, such as small sample sizes and possibly higher standard deviations. If quoted out of context, this will be misleading.

3 For further coverage of productivity-enhancing features see Leaman A and Bordass W, *Productivity in Buildings: the Killer Variables*, chapter 10 of Clements-Croome D (ed), Creating the Productive Workplace, E&FN Spon, 2000. Download from www.usablebuildings.co.uk

Completed
April 1998

Pupil numbers
240 (including a nursery)

School hours
1,368 hours a year

Maintenance
One caretaker

Local authority client
Hereford County Council (was Hereford & Worcester County Council)

Architect
Hereford & Worcester County Council in-house team (Dermot Galvin)

Structural engineer
Building Design Partnership, Manchester

Environmental engineer and cost consultant
Hereford & Worcester County Council in-house team

Main contractor
E Manton Limited, Birmingham

Carbon emissions
Predicted: 150 tonnes per year
Actual: Unknown

Costs
The funding for modifying the school building with high levels of insulation and other energy saving features was provided from normal budget of Hereford & Worcester County Council.

The heating system cost €271,000 (around £400,000) in 1997. European Regional Funding provided €125,400. Matched funding was contributed by the DTI and from Hereford & Worcester County Council.

Total net cost: within DfES budget of £620/m^2 (excluding grant aid for wood-burning boiler system)

◀ Left
Wood chips are delivered by lorry to a semi-basement silo that is connected to the school's boiler house.

▼ Below
The school is a classic example of 1990s solar design, with cross-ventilation aided by the clerestorey windows set in a waveform roof.

Weobley Primary School

Carbon-neutral heating systems are possible if the local authority and school design team are willing to work with local suppliers of wood fuel.

Primary
Middle
Secondary
Academy

Summary

Weobley Primary School is a primary and nursery school for boys and girls aged 3-11.

In the mid-1990s, Hereford & Worcester County Council set out to replace Weobley Primary School's 70-year old timber and asbestos shacks. The Council adopted an environmental action plan based on the principles of Local Agenda 21 and the recently published BSRIA *Environmental Code of Practice*[1].

During the initial stages of design, the Council was approached by the DTI and the Rural Development Commission who were looking for a project to demonstrate the use of wood as a heating fuel. The aim was to kick-start a rural wood-chip supply industry while reducing CO_2 emissions from school heating systems. Thanks to a committed and motivated in-house design team, Weobley Primary School has delivered its sponsors' objective.

Project details

At the heart of the scheme is an automated wood-fuelled boiler that uses 150-300 tonnes/year of wood-chips. These are provided from locally sourced woodland thinnings and short-rotation coppiced poplar and willow. All the wood is grown within a 10-mile radius of the school and a local company ensures the supply of wood chips from a co-operative of local farmers.

The wood chips are delivered twice a week and stored in a concrete silo. The supply to the boiler is fully automated: the wood chips are raised up from the silo by hydraulic rams, a screw lift and a stoker, and then fed into the boiler. The exhaust gases are cleaned before they are exhausted through a low-level chimney.

The small amount of ash produced by the process of combustion is used to fertilise the school garden. The school caretaker undertakes routine maintenance of the boiler, with an annual maintenance inspection performed by Nordist, the company that installed it.

The 350 kW wood-fired boiler operates for about 600 hours a year. The system is fully automated to provide heat according to demand, with fuel-use meters used to measure the rate at which the wood is being burned.

The system runs the underfloor heating system before the primary school opens in the morning, then switches to heat the radiator system at an adjacent secondary school during the school day. Hot water is pumped from one site to another depending on which boiler is running.

The backup boiler in the secondary school is only needed at the beginning and end of each heating season when the demand for heat is intermittent or when it is needed as as a potential top-up supply during periods of peak demand.

◀◀ Far left
The wood chips are raised up from the silo by hydraulic rams, a screw lift and a stoker.

◀ Left
The wood chip boiler serves as an educational resource for the school, enabling the pupils to understand the role of the local economy in providing low carbon-sources of energy.

In use performance

While Weobley's success has been achieved by the design team's focus on a renewable, energy-efficient heat source, the designers reduced the school's heating requirements by specifying highly insulated floors, walls and roof to ensure that heat is not lost through the fabric of the building. Heavyweight interior blockwork also gives the school thermal stability.

The design team estimated that the school would produce 78 tonnes less carbon dioxide per year than the norm for schools of this type, which average around 228 tonnes. This equates to a 34 percent reduction. As wood is the heating fuel source, the carbon emissions are equal to that absorbed by the trees when they are growing. The school's heating system can therefore be considered CO_2 neutral (leaving aside any fossil fuels consumed in processing and transporting the wood chips.)

The use of daylight and natural ventilation has also helped to minimise the school's energy requirements. All the classrooms have a south-facing aspect to optimise daylight, with the risk of glare and overheating being reduced by an overhanging roof to south-facing windows, along with a shade-giving pergola that incorporates deciduous species and vines in planters. As architect Dermot Galvin explained: "With schools you have to get that balance: you want solar gain but don't want the glare and overheating associated with it".

Materials

The choice of materials for the building were also given a lot of consideration. The design team specified a high proportion of local, recycled, recyclable, natural and non-toxic materials.

"In 1996 you had to do a lot of research to find materials that were sustainable," recalled Dermot Galvin. "One invariably found that such materials weren't always competitively priced. It's much easier now that sustainability is becoming mainstream."

The materials specified by the designers included:
- Locally-made bricks
- Timber window frames
- Reprocessed plastic damp-proofing
- Recyclable clay roof-tiles
- Recyclable aluminium glazing bars (for clerestorey windows)
- Guttering and roof sheeting for the fuel-store roof
- Warmcell insulation, (recycled newsprint) used extensively in the walls and roofs
- Rubber and timber flooring
- Water-based paints.

◀◀ Far left
Sustainable design need not be obvious: the designers opted for timber window frames, recyclable clay roof-tiles, recyclable aluminium glazing bars for clerestorey windows, rubber and timber flooring, and water-based paint.

◀ Left
User controls are properly labelled and clear in what they do. This enables the occupants to control their ventilation needs. However, the same cannot be said of the heating system, which is computer controlled. Windows are often opened for cooling while the heating is left running.

Low energy building services

The instructional element of the school's design is visible in its heating system, which is used to teach pupils about energy use. The school has undoubtedly raised the profile of wood-fuel technology and the use of biomass as a credible carbon-neutral source of fuel. "By the end of the project the teachers were very enthusiastic, and prepared to open up their school to hold awareness-raising events," said Galvin. "The teachers were also proud of a school that they can incorporate into the curriculum."

Internally, the school's electric lights are controlled by an electric lighting control system that controls the output of the lamps by detecting levels of daylight. Motion sensors turn lights off after a period of detected inactivity. The teachers can manually override these systems if they need to.

A 2003 Ofsted Report said that Weobley Primary School was "a high quality purpose-built accommodation that has had a considerable impact on the facilities for learning".

Reference

1 BSRIA *Environmental Code of Practice for Buildings and Their Services*, COP 6/1999 BSRIA. ISBN 0860 22 5240

Further reading

Ashley S, 'Branch Lines To Weobley', *Building Services Journal*, February 1999. ISBN 1365-5671.

What this means to you

- Work closely with the local community when considering sustainability strategies
- Work within the bounds of what is achievable, and don't procure what you can't afford, or can't manage
- Solicit local expertise when putting together a brief for a school
- Seek contributions and support from central government, and keep abreast of government-led strategies and policies to reduce energy consumption
- Think beyond the property boundaries of a new school when considering innovative and low energy ways to provide heating – but ensure the result is easy for users to control
- Appreciate how investment in sustainable design can help to raise the profile of the school both nationally and within the local community
- Use links with local industry to demonstrate to schoolchildren the relationship between what they learn and what goes on in the local community

Occupancy satisfaction scores for Weobley Primary School

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These are summaries of some of the variables used in the Building Use Studies occupant assessments of five schools covered in this book. But what do the symbols mean?

▲ Green triangles represent mean values significantly better or higher than both the benchmark and scale midpoint. In other words, a good score.

● Amber (orange) circles are mean values no different from benchmark. In other words, a typical score.

◆ Red diamonds are mean values worse or lower than benchmark and scale midpoint. In other words, a poor score.

Be careful to read the directions of the scales and the scale labels. Perceived productivity is a measure of how the staff feel the school contributes, positively or negatively, to their productivity. It is not an absolute measure.

| Benchmarks are represented by the line through each variable. The location of the benchmark varies for each variable. The benchmarks are derived from British, Australian and International studies of schools, depending on the context.

On the basis of the occupant survey (February 2006), Weobley School comes in the top decile (top 10 percent) of the Building Use Studies (BUS) dataset[1] – a very good result.

The building has a high forgiveness score: occupants give good overall ratings for aspects like temperature and ventilation, but mark the school down on aspects like stuffiness. In other words, they like the building and are usually prepared to tolerate its faults.

Most needs seem to be well met, and occupants say that they like the design and the overall image. Space provision was not particularly generous, but the use of space seems ingenious, with circulation spaces effectively doubling up as break-out teaching areas or preparation areas. The downside was that, in some instances, ready access is more difficult when the circulation spaces are being used for other purposes. This often forces pupils and teachers to take alternative routes through the school and its grounds.

Lighting scores were relatively good. However, scores for ventilation, and in some respects temperature, are not so good. The building is prone to overheating in summer. The headteacher says that this is down to "a failure on the part of staff to follow correct procedures in getting good air flow", but arguably the design shouldn't place this onus on the users.

The survey results indicate that the school is perceived as being too quiet – rare for a school. All classrooms have doors, which may contribute to this. The headteacher perceives this as a feature rather than a bug.

Weobley School's notable green feature is the boiler fuelled by wood chips.[2] The boiler supplies hot water for the underfloor heating in the primary school and the radiator system in the adjacent secondary school, with the oil-fired system in the secondary school theoretically acting as a back-up.

Despite this green technology, Weobley School has no energy metering for its buildings, so it is impossible for the primary school to know its exact energy costs. The primary school pays one fifth of the joint utilities bill with the secondary school. A formula has been arrived at which makes a best estimate of the relative consumption of the two buildings based on the age of the building, and the relative floor space.

There is no incentive for either school to reduce energy costs, nor any exact understanding of what they actually are. Is the wood-chip boiler, despite its perceived over-capacity and intermittent functioning, making a real contribution to reducing emissions, or not? It was impossible to know. On that basis, Weobley can't lay claim to be a green building until the boiler has been properly assessed.

Weobley School also has no control over its building management system. The BMS is totally remote. This means that there is no on-site control of the heating, and that cooling is often achieved by opening windows rather than by shutting down the heating.[3]

As with many schools, electronic whiteboard projection technology dominates classroom teaching. Given the attention that has been given in the past to the calculation of daylight factors in classrooms, and the provision of daylight, this technology may have a big effect on occupant satisfaction.

The south-facing roof was thought by the headteacher to be a lost opportunity for solar water heating, or photovoltaic electricity generation.

1 The rating uses the BUS Summary Index. Buildings are put in order on the summary index from the highest ranking to the lowest.

2 Wood chips were supplied from the immediate locality, but the source may extend to the Pershore area of Hereford and Worcester, thereby raising transport and logistics costs.

3 Pumps had been discovered running undetected during two summers.

Completed
Phase 1: September 1999
Phase 2: September 2004

Pupil numbers
351 (maximum of 180 in each phase)

Floor area (gross)
Phase 1: 1,044 m^2
Phase 2: 626 m^2

School hours
06.30 – 18.00 h

Maintenance
One caretaker

Local authority client
Essex County Council

Architect
Phase 1: Allford Hall Monaghan Morris
Phase 2: Bryant Harvey Partnership

Structural engineer
Phase 1: Atelier One
Phase 2: Hindley & Associates

Environmental engineer
Phase 1: Atelier Ten
Phase 2: Integrated Building Services

Cost consultant
Phase 1: Cook & Butler Partnership
Phase 2: Geoff Picket

Main contractor
Phase 1: Jackson Building
Phase 2: Rose Builders

M&E contractors
Phase 1: Essex Mechanical Services /Ruddocks
Phase 2: Burwell Mechanical Services /North Essex Electrical

Contract
JCT 80

Approximate energy use
Gas: 81 kWh/m^2/y
Electricity: 67 kWh/m^2/y

Carbon dioxide emissions
Predicted: 36 tonnes per year (based on energy targets for Phase 1)
Actual: around 44·2 kgCO$_2$/m^2/y (78·3 tonnes/y total)

Costs
Phase 1: £1.2 million (£1,149/m^2)
Phase 2: £1.48 million (£2,364/m^2) including external works

Funding
Essex County Council's capital programme

▼ Below
Essex County Council wanted to achieve a sustainable school within their usual budget for a primary school.

◢ Below right
Phase 1 has a triangular footprint, with classrooms all facing south-east, and brises soleil helping to limit solar gains.

Notley Green Primary School

A tale of a primary school built over two phases, with different approaches to sustainable design based on in-use experience.

Summary

Catch sight of this school as you cycle past and you'll probably want a closer look. Its complex multi-pitch roofs planted with sedum and cedar-clad walls make it one of the most unusual new schools in the country.

In plan view the school seems even stranger. Notley Green Primary School comprises two separate but very similar buildings, constructed five years apart. Phase 1 of the school was completed in 1999 to serve the new settlement of Great Notley. The village's expansion led to a second phase, added in 2004.

Despite both phases having a triangular footprint, they were designed and constructed by different teams. Among other things this enabled the Phase 2 design team to learn from the successes and failures of the earlier phase. Hence there are differences in internal arrangements, and the choice of materials and heating systems.

- 🟫 **1** Foyer
- 🟦 **2** Staff rooms
- ⬜ **3** Classrooms/teaching areas
- 🟪 **4** WCs and cloakrooms
- 🟨 **5** Stores
- 🟧 **6** Kitchen
- ⬛ **7** Library
- ▨ **8** Plant room
- ⬜ **9** Hall
- 🟦 **10** Wet play
- 🟥 **11** Specialised teaching spaces
- 🟩 **12** Circulation

Primary
Middle
Secondary
Academy

◀◀ **Far left**
Electrically-operated shading on lower windows of Phase 2 contrast with fixed brises soleil on Phase 1.

◀ **Left**
These recycled worktops from Smile Plastics speak for themselves: how better to encourage pupils to recycle?

Project details

The consultants for both phases were chosen through open competition, but rather than the prospective design teams being asked by the client to spend a long time working up tentative designs at risk, they were asked to make a submission about their practices and their approach. This meant the designers were not committed to a design early on, which can happen when an architect wins on the basis of a design competition.

Phase 1 has a triangular floor plan and comprises six classrooms, the school hall, an internal courtyard and two open-plan library areas. It was designed by architect Allford Hall Monaghan Morris and environmental engineer Atelier Ten.

Phase 2, which is two-thirds of the area of Phase 1, introduced another six classrooms, with a smaller hall and a cellular library. This was designed by architect Bryant Harvey Partnership and environmental engineer Integrated Building Services. They continued some themes from the original building, but dropped others.

The original triangular footprint didn't lend itself to extension, so while Phase 2 is a separate triangular building, it is rotated clockwise by about 45°, to create a new central focus point for the school between the two buildings.

The walls and roof are made from Masonite beams, injected with Warmcell insulation (made from recycled newsprint). Outside walls vary in thickness from 270 to 330 mm, and have no vapour barrier, which means they breathe and help to expel moisture without losing heat.

Problems have been reported in trying to clean down the linseed-based paint used in the hall in Phase 2. It has marked badly, in a short period, and the marks do not wash off.

The wall insulation achieves better insulation than required by the *Building Regulations* in 2002. The first school features a glass panel to enable pupils to see the insulation. Like the recycled work-surfaces inside, this advertises the school's use of recycled materials to the staff and schoolchildren. There were some initial problems, such as rodents trying to eat the recycled newspaper insulation.

The roofs of both buildings at Notley Green Primary School were planted with sedum, and the school is known throughout Essex as the grass-roof school.

The roof supplier reassured Essex County Council that no irrigation was needed for sedum. However, while this might be true in other parts of the country, Essex is the driest county in the UK, and the un-watered sedum began to die during the first occupied summer, to be picked off by birds keen to use it as nesting material.

The school has therefore installed a leaky-hose irrigation system to the steepest parts of the roof, switched on manually when the weather is dry, and set to come on for half-an-hour each day. This water consumption is probably small, but so far unmeasured.

▶ Right
The design team for Phase 2 built on the concepts established for Phase 1: timber beams for the walls, a sedum roof, and cross-ventilated classrooms with generous glazing. However, a curved façade to the classrooms was preferred for Phase 2.

◢ Below right
Bamboo used for the hall in Phase 1 lifted in the first year of occupation, so the school went for a more conventional timber floor for the hall in Phase 2.

Phase 1 has classrooms that are open to the corridor (there are no doors). It also features paired classes so that teachers can perform team-teaching between classes. There is very easy access between neighbouring classes. Phase 2 has wider corridors that incorporate space for coats.

Classrooms in Phase 2 are more conventional, in that they have doors to the corridor and sliding doors between paired classrooms. However, Phase 1's two banks of glazing to the south are retained in Phase 2, as are the north-lights that protrude through the green roof.

A triangular footprint created some space-planning difficulties, especially in Phase 1. Its triangular kitchen and kitchen store make for slightly impractical workspaces, and the visitors' entrance area feels uncomfortable and cramped. Although classrooms themselves are conventional rectangles, other teaching areas and offices are irregular, which means shelving is difficult to access.

◀◀ Far left
High and low-level glazing facing south-east, coupled with north-facing clerestorey lights, ensure excellent daylighting in classrooms when the blinds are open.

◀ Left
An exposed part of the wall shows the pupils how the school uses recycled materials for insulation.

◣ Below
The corridors are wider and curved in Phase 2, with space for coats and bags. Rooflights mean that circulation areas in both buildings have good daylighting.

Environmental systems

Both phases have conventional condensing gas boilers for space heating needs. Phase 1 has underfloor heating in all rooms – Essex County Council's first use of underfloor heating for many years. Unfortunately, the experience was less than positive.

Control issues, possibly coupled to inadequate commissioning, meant that some rooms were cold initially. The problems may have been to do with the limited understanding of slow-response heating systems by the school's maintenance staff, who were accustomed to using radiators. Controlling underfloor heating is different.

Although the heating problems in Phase 1 were resolved before work started on Phase 2, the school and County Council jointly decided against underfloor heating in all but the second hall. Even here (where the school specifically asked and paid for underfloor heating), Essex insisted on a backup heating system as a failsafe in case the underfloor heating proved unsatisfactory. This seems costly and unnecessary, and will require extra facilities management.

All classrooms in Phase 2 have radiators with thermostatic radiator valves and low-temperature pipework. Ultimately, the client put controllability above usable wall space the second time around. Both Phase 1 and Phase 2 of Notley Green Primary School are almost entirely naturally ventilated. There are manually opening windows to the north and south of classrooms, providing good cross-ventilation in summer. Trickle vents in the glazing appear to be successful in preventing stuffiness in winter.

▶ **Right**
The double-glazed windows are made from softwood, with aluminium outers for improved durability. Internal blinds keep down unwanted glare.

Daylight and electric lighting

The classrooms have two banks of windows facing south-east to south-west – one high and one low – and high level northlights that pierce through the roof to provide extra daylight without solar gains.

Phase 2 classrooms have larger northlights than Phase 1: 1,000 mm high compared to 600 mm high in the original building. This improves daylighting when (as seems common) blinds are drawn on the south side.

Electric lighting consists entirely of high-efficiency T5 fluorescent tubes and compact fluorescent, all controlled using simple local switches.

Renewables and BREEAM

Atelier Ten looked into a series of renewable technologies as part of their work on Phase 1, but the County Council was reluctant to increase capital costs above their standard formula for costs per pupil. Ultimately, the application of renewable energy came down to the length of payback periods required to recoup the investment.

The Phase 1 designers examined the potential for solar thermal panels, photovoltaics, a wind turbine, and biomass heating, but these were not installed. Nevertheless, their detailed report to the Essex County Council served to raise awareness and understanding of what was possible at what capital cost.

Notley Green Phase 2 was assessed using SEAM (the Schools Environmental Assessment Method, a forerunner to BREEAM Schools). It achieved a Very Good rating. A BREEAM assessment has not been undertaken for the school.

◀ **Left**
Blinds are down in the ICT room, to prevent glare, but this forces the use of electric lights.

Sustainable materials

The school hall in Phase 1 of Notley Green Primary School used Plyboo bamboo flooring. Bamboo grows quickly, and absorbs lots of CO_2 in the process. The school felt that this bamboo was less durable than alternatives (some parts lifted and had to be re-glued), so maple flooring was used instead for Phase 2.

Warmcell insulation made from recycled newspapers was used in the walls of both phases, and one section in Phase 1 is exposed through a Perspex sheet so that pupils can see the insulation.

Marmoleum lino (made from linseed oil, wood flour, pine resin, jute and limestone) was used as a flooring material to avoid pvc-based vinyl. This did not age well in the Phase 1 building. The school was uncertain about the right cleaning products to use on Marmoleum (there is a special product from Forbo called Monel, which was specially developed for this flooring).

Some fitted worktops in the classrooms are made from a recycled plastics product, which wears its environmental credentials on its sleeve: the plastic bottles used in manufacture are still visible in the worktops. This looks attractive, is very popular with pupils, and a tangible example of how materials can be recycled.

A linseed-based eggshell paint was used for both phases, and together with other natural materials, this means the build up of toxins in the internal atmosphere is much lower than most schools.

There have been maintenance issues with the paintwork in some parts of Phase 2: the paint used is not easy to clean, and it has marked in the second hall. Simply repainting with ordinary gloss paint would counteract the specially constructed breathable walls, which have no vapour barrier.

Health and safety issues

Health and safety concerns include a pupil injured by running into an open window from Phase 1. For some reason the restrictor was not engaged and the window was open wider than it should have been. Specifying cobbled concrete as a paving material to deter pupils from running close to the windows actually had the opposite effect: the unusual, uneven surface was a challenge to pupils, and made them more likely to run near the windows.

Brises soleil for the lower windows in Phase 1 presented similar health and safety concerns, so motorised external awnings were specified for Phase 2. This is more flexible than the original brises soleil, because shading may be retracted when the classroom needs more daylight, and the awning may be adjusted to project up to 2·5 m from the window to keep out low angle sunlight.

The awning is attached to a wind-speed sensor, so that in high winds it retracts automatically, which should prevent damage in a storm. However, movable external elements usually increase the maintenance burden.

▶ Right
In Phase 1, classrooms without doors have suffered noise from adjacent classrooms. Phase 2 classrooms have sliding doors to each paired classroom.

Energy analysis

There was no airtightness test for either phase. Although there were formal targets for energy consumption by end use for Phase 1, the exercise was not repeated for Phase 2.

In practice, indicative energy consumption figures exceed the targets and are somewhat disappointing (in the region of 81 kWh/m^2/y for gas, and around 67 kWh/m^2/y for electricity). Carbon dioxide emissions are therefore greater than expected when Phase 1 was designed.

Both gas and electricity use are higher than they should be because of the long school day (06.30 to 18.00 h). This is more than 50 percent longer than anticipated when Phase 1 was designed, and inevitably increases the use of lighting and heating. Electricity consumption is also relatively high because classroom blinds are usually down, with lights left on.

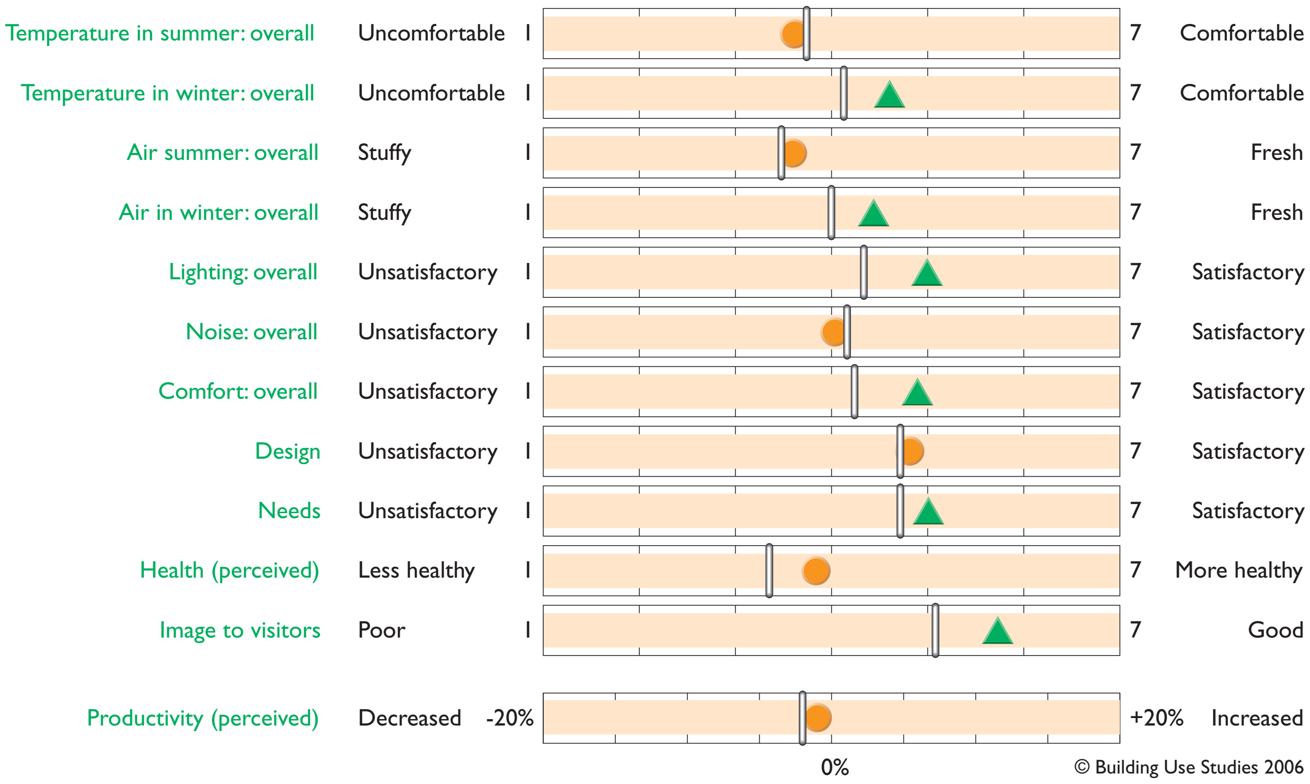
In addition, the school's temporary classrooms (which lack the high insulation of the main buildings, and probably have less efficient lighting) also increase energy consumption. The school plans to remove these classrooms in the future, and there should be an improvement in energy efficiency as a result.

Overall the school hits many of the right buttons on sustainability: benign materials with low embodied energy, good daylighting and insulation, and straightforward controls on building services.

What this means to you

- Be wary of designs that allow pupils to drop belongings into inaccessible places, like slotted decking
- Consider maintenance as well as environmental performance when considering the use of chemical-free materials
- Ensure that the design of a school is not primarily defined by an architectural motive – this can cause a confusion of ends and means
- Encourage designers to consider recycled products for their environmental benefits, and to show pupils why reclamation and recycling are important
- Client and local authority leadership and vision is central to the development of a design brief that seeks to address sustainability issues
- Recycled and reclaimed construction materials offer good opportunities for covering sustainability in the curriculum
- Ensure that the right balance is struck between privacy and openness in classroom design. Classrooms can be too quiet as well as too noisy

Occupancy satisfaction scores for Notley Green Primary School



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| Benchmarks are represented by the line through each variable. The location of the benchmark varies for each variable. The benchmarks are derived from British, Australian and International studies of schools, depending on the context.

The occupant survey results show that Notley Green Primary School[1] falls in the top 40 percent of the Building Use Studies (BUS) dataset[2] – a reasonably good outcome.

On the ten study variables used to give a simple overview of the school's performance, all ten scores were either better or no different from the scale midpoint and/or benchmark.

The forgiveness score was also high, indicating that occupants will accept some dissatisfaction when taking account of the overall performance of the building.

The main weaknesses were ventilation (especially in summer when it is perceived as too hot, stuffy and smelly) too much natural light for some people, with others affected by glare from the sun and sky. The latter is partly because the blinds are not effective enough, and there is not enough user control over heating, cooling, ventilation and lighting.

Other problems were noise from adjacent classrooms, especially where the classrooms have no doors[3], ambient noise from music and physical education classes in the new block, and through-traffic in corridors that adversely affect pupils' concentration.

The BUS researchers noted that the irregular shape of rooms (a consequence of the triangular plan), has created a cramped reception with no space for visitors, space limitations in classrooms, a lack of lighting control in classrooms (affecting the effectiveness of interactive whiteboards) and inadequate provision for administrative offices. There has also been a doubling-up of functions. For example, a dedicated medical room is used for photocopying, and a dedicated washing room is also used for meetings.

There was some criticism of the practicalities of storage, but overall the design was reasonably well liked and met staff needs. Notley Green Primary School has many sustainability features and the staff were well aware of its credentials. There is also evidence that building is used as an example in environmental studies teaching.

Notley Green has a triangular plan form so that the base of the triangle faces south, in theory maximising exposure to the sun – classrooms open onto a south-facing playground. Notwithstanding the benefits of this approach (for example, the playground is usually relatively bright, warm and sunny), the BUS researchers found that the plan form imposes space limitations in an already space-constrained setting.

Many rooms are not square, so that seating arrangements are affected at corners (one chair will clash with another) and it is not possible to maximise the use of space for storage because the space left over tends to have odd shapes.

Top-hung windows on the ground floor had also to be governed to open no more than 100 mm because of the hazard of children running into the open frames.

Notley Green Primary School is another example of a school that had little idea of its relative performance from an energy and environmental point of view. For example, there had been no gas bill for three years, and the school had received a credit for £20,000 in 2005, presumably for previous over-payments.

As with three out of five schools studied for this series of case studies, the school has no management system in place to control or reduce energy and water costs, and therefore no means of putting energy monitoring and targeting into practice.

This was one of several symptoms that the school had not been given advice on how to run the building effectively, a further pointer that a comprehensive professional aftercare service must be put in place during the handover period for the school to get the best from ostensibly sustainable features.

1 This is a summary of findings from an occupant survey by Building Use Studies of Notley Green School Braintree, Essex in March 2006.

2 The rating uses the BUS Summary Index.

3 Classrooms in the Phase 2 part of the school have doors.

◀ Left
The connection between the extension and the 1970s SCOLA-built steel-frame building.

▼ Below
The high thermal mass of the south-facing façade helps to regulate the school's internal temperature. Note the fixed solar shading and Western Red Cedar boards.

Floor area
2,640 m^2 (1,800 m^2 new extension, 550 m^2 refurbished)

Pupil numbers
375 (partial occupancy)

Client
Worcestershire County Council

Architect
ECD Architects

Services consultant
Whitby Bird

Environmental engineer
Energy for Sustainable Development

Cost consultant
MDA, Bristol

Main contractor
Harper Construction

Educational design consultant
Graham Parker

Form of contract
JCT 80

Energy use breakdown
Gas: 45·2 kWh/m^2/y
(adjusted for local temperature)
Electricity: 59·1 kWh/m^2/y

Carbon dioxide emissions
Predicted: Unknown
Actual: 33·9 kgCO$_2$/m^2/y
(90 tonnes/y total)

Final project cost
£1.5 million (net)

Birchensale Middle School

Birchensale Middle School has been refurbished and extended along sustainable design principles.

Project details

Birchensale Middle School in Redditch is a refurbishment and extension of an existing 1970s SCOLA-built steel frame building. In September 2002, the school successfully doubled its size from 300 to 600 pupils by integrating the original structure with a new building.

A particular concern of the design team was the integration of the new accommodation with the existing school building. The objective was to find the best way of improving the energy performance of both school buildings.

The design involved attaching 10 new classrooms to the south façade of the existing school. In the act of providing extra teaching accommodation, the designers were able to upgrade the thermal performance of the building envelope.

Environmental design

A number of education and sustainability specialists were involved in the development of the brief. ECD Architects developed the feasibility study by testing the ways in which the energy performance of both the new and existing buildings could be improved.

Thermal and daylight modelling was used to develop the three-dimensional shape of the classrooms and the positioning of the windows. This led to features such as a glass wall, which provided increased levels of natural daylight, with external shading louvres on southerly facades to help to reduce direct solar gain in summer.

Despite the addition of 1,800 m^2 of new accommodation, the higher insulation standards for the building envelope meant that no additional boilers were required.

Ventilation is by openable windows, with trickle vents fitted on all new windows. The only room which uses mechanical ventilation and cooling is the IT suite. This is located internally, and of necessity is equipped with mechanical refrigeration and lighting controls based on presence detectors.

The lighting switches in the classrooms have been designed to encourage children to think about how much electric light is needed. Each switch-plate is etched with a cloud and sun: pressing the cloud switches on all lights, while pressing the half-cloud symbol will bring on half the lights.

The school Bursar, Patricia Duncan, said that children recognise that these switches relate in some way to energy efficiency. "If they hit the switches long enough they get what they want" she said. "But there is no immediate connection between what the symbols say and what the switches actually do."

Birchensale's heating energy figures are exemplary – annual gas consumption per square metre is less than half that for similar schools. However, the school uses twice as much electricity as the benchmark taken from the top 25 percent of existing schools, which means that overall CO_2 emissions are no better than the benchmark.

◤ Top left
Stepped lighting controls have been provided that are intended to encourage pupils to reduce the use of electric lighting when daylight is adequate.

▲ Top right
The window controls in the new classrooms seem robust and in reasonably good condition.

◀ Left
Thermal and daylight modelling was used to develop the three-dimensional shape of the classrooms and the positioning of the windows.

▲ Above
The blinds serving the sports hall's high-level windows have been blown out of their runners by strong draughts.

	$KWh/m^2/y$		$kgCO_2/m^2/y$[*]		
	Electricity	Gas[†]	Electricity	Gas[†]	Combined
Birchensale consumption 2005	59	45	25	9	34
Top 25 percent of secondary schools[††]	28	115	12	22	34

[*] Assuming 0·19 $kgCO_2$/kWh gas, 0·43 $kgCO_2$/kWh electricity.

[†] Gas use adjusted for local temperature.

[††] Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003*.

Electricity use climbed steadily in the five years following completion of the extension and refurbishment, by an average of four percent per annum. There may have been increased electrical equipment (notably computers) as the school became more established, and/or increased pupil numbers, both of which increase electricity use.

Gas use increased by an average of 1·5 percent year-on-year for the first four years, and then fell back below the first year's consumption. It finished 2005 at more than six percent below the five-year average consumption, suggesting improved energy management.

Cost analysis

Creating a school which responds well to curricular issues while pursuing an environmental agenda was not easy to do on a tight budget. The refurbishment and new build at Birchensale was funded partly by County Council capital and partly from Department for Education and Skills (DfES) capital receipts.

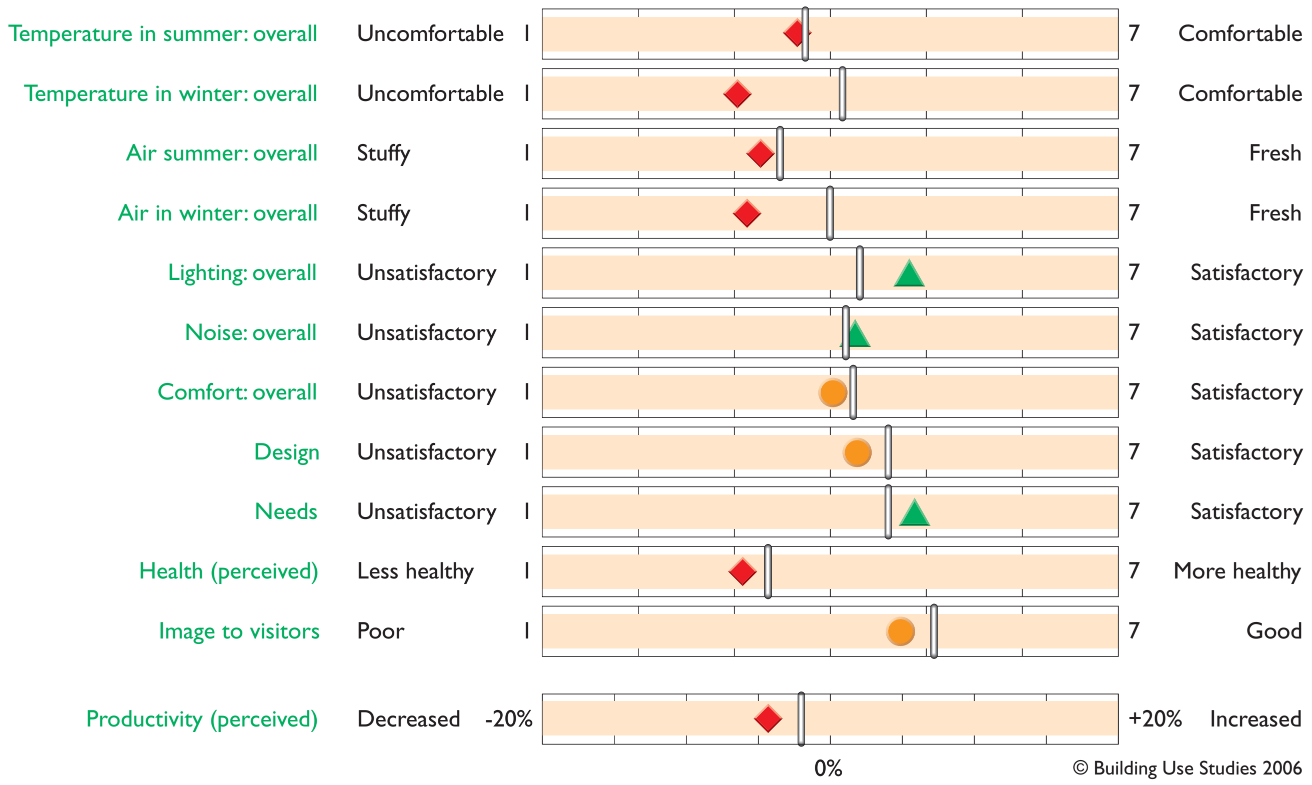
County architect Iain Paul believes that although the building is highly sustainable, some features have been left out to save money. For example, initial designs focused on a wooden frame of Parallam beams. These were replaced in the final design with a much less environmentally-friendly steel frame. However, the design did incorporate recycled and renewable materials that were chosen for their low embodied energy and low maintenance.

Western Red Cedar boards are used as cladding on parts of the façade. Internal materials include natural-fibre carpets and natural-finish timbers, while recycled plastics are used in the reception area and for signage throughout the school.

What this means to you

- Extending a school may be a better option than replacement
- Attempts to reduce a school's carbon dioxide emissions requires the setting of energy targets during design
- Improving the school's insulation may obviate the need to upgrade boilers and heating systems
- Reducing the embodied energy of construction materials needs to take into account the whole-life costs and environmental costs, not just capital cost
- Ensure your opinions are solicited on the degree to which you can override automatic lighting controls
- Ensure that openable windows and internal blinds are robust and usable

Occupancy satisfaction scores for Birchensale Middle School



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These are summaries of some of the variables used in the Building Use Studies occupant assessments of five schools covered in this book. But what do the symbols mean?

▲ Green triangles represent mean values significantly better or higher than both the benchmark and scale midpoint. In other words, a good score.

● Amber (orange) circles are mean values no different from benchmark. In other words, a typical score.

◆ Red diamonds are mean values worse or lower than benchmark and scale midpoint. In other words, a poor score.

Be careful to read the directions of the scales and the scale labels. Perceived productivity is a measure of how the staff feel the school contributes, positively or negatively, to their productivity. It is not an absolute measure.

| Benchmarks are represented by the line through each variable. The location of the benchmark varies for each variable. The benchmarks are derived from British, Australian and International studies of schools, depending on the context.

The occupant survey results show that Birchensale School falls in the bottom 30 percent of the Building Use Studies' (BUS) dataset[1] – on the face of it a relatively poor score. However, Birchensale Middle School is an older building with a newer extension and the assessments relate to the whole school, not just the extension. As most of the buildings in the benchmark dataset are new, some generosity should be given interpreting the results. Note that the assessments relate to the whole school, not just the new extension.

Given the drawbacks of its age and image, Birchensale Middle School is still better than benchmark for variables such as furniture, cleaning, lighting, needs and space in the building.

At the time of the survey (February 2006) the school had 375 pupils, but was not at full capacity. The survey found the school was a pleasant, calm, cheerful environment, seemingly well managed with very co-operative staff. The main problems are thermal: too hot in summer, with perceptions of stuffiness and stillness, and too cold in winter.

Coldness in winter (for example, in the art and music rooms) seemed to be the most serious problem. This problem was in the older part of the building.

In terms of the school's green credentials, staff were not aware that the building could be thought of as green. As a result they had not incorporated any aspects of the building's performance into any environmental awareness teaching, nor did they seem particularly proactive on, for example, the management of energy consumption. However, an area of the school grounds has been landscaped and improved, some of it with local help as a community garden.

In June 2000, the design team for the extension to Birchensale Middle School was assisted under the government-funded post-occupancy project, PROBE[2]. As a result of recommendations made by the PROBE research team, the school was able to supply the DfES study team with metered data for gas and electricity for a five-year period from 2000.

While this has proved valuable in determining the success of the school's ventilation and lighting control strategy, and consequential CO_2 emissions, the school has had little capability to act on the information gathered, because: "No-one seems to be exactly aware of how systems worked and what they were for".

Birchensale Middle School is a classic case of occupants not being able to adjust the heating controls because the latter are under an automatic building management system. As a result, areas of the corridors are too hot, but staff can't do anything about it.

In the new classrooms, there were requests for lighting override switches. The automatic lighting system is manual on/automatic off, but users still like to override these automatic functions.

The window controls in the new classrooms seem robust and in reasonably good condition, although one or two handles had failed. At the time of the study, trickle ventilators were in use with about 30 percent of them open.

In the sports hall, the high-level window blinds with manual winder controls had failed. One day when the high-level windows were opened (under electronic control), draughts blew the blinds out of their runners, rendering them uncontrollable. Most of these failed blinds have been left in the down position.

As with other schools in this study, the arrangement for heating, ventilation and lighting of the sports hall seemed to operate on separate control regimes from the rest of the school's system. It was not possible to test systematically whether the newer classroom areas were perceived as better or worse than the old classrooms.

[1] The rating uses the BUS Summary Index. Buildings are put in order on the summary index from the highest ranking to the lowest.

[2] Birchensale School PROBE Intervention Study, *Building Services Journal* June 2000, p 49-52 and April 2001, p 42-44.

▼ Below
The school's entrance faces south, with most classrooms facing east or west. Solar shading on this elevation and projecting roofs help to reduce solar gains on the first floor. *Photograph © Sally-Ann Norman.*

◢ Below right
The ground floor plan of the school.

Completed
Partial handover September 2003
Practical completion December 2003

Pupil numbers
900 (design)

Floor area
Gross: 7,400 m^2
Net: 6,300 m^2

School hours
08.00 – 20.00 h

Maintenance
Two caretakers

Local authority client
Sunderland County Council

Architect
Napper Architects, Newcastle

Structural engineer
Connell Mott Macdonald

Environmental engineer
R W Gregory

Cost consultant/quantity surveyor
Gardner & Theobald

Main contractor
Allenbuild

M&E contractors
Rotary Northern

Energy use breakdown (estimates based on utilities costs)
Gas: 67·6 kWh/m^2/y
(adjusted for local temperature)
Electricity: 22·6 kWh/m^2/y

Carbon dioxide emissions
Estimated energy consumption at concept design stage: 150 kWh/m^2/y (40 kgCO$_2$/m^2/y)
In-use estimate (based on utilities costs): 23·0 kgCO$_2$/m^2/y

Costs
Cost per square metre: £1,757/m^2
Total construction cost: £13 million (including external works, fixed furniture, and ITC infrastructure)

Venerable Bede Secondary School

A new school on a hilltop provided an opportunity for using ground-coupled cooling and wind-assisted ventilation systems.

Primary
Middle
Secondary
Academy

Summary

This Church of England school in Sunderland was built at the top of a hill on the site of a former quarry. The headteacher of this new school was appointed at the same time as the design team, and attended nearly all of the design meetings.

Most of the school has simple natural ventilation and underfloor heating. Supply air for the main hall and dining hall is drawn through two tubes buried beneath the school's courtyard. By drawing on the year-round stable temperature of the ground, these tubes are able to pre-condition the supply air.

Twelve wind-assisted ventilation chimneys, located on the school's roof, handle the school's ventilation extract. The school was not subject to energy modelling or targeting during the design process because the client didn't ask for it.

The school was designed for 900 pupils, but initially just two year-groups are in occupation, which made the school's late completion easier to handle.

Project details

The designers and contractors were appointed through competitive tender. There was no written brief apart from DfES-recommended floor areas. The contract was run under a traditional JCT 80 contract, which meant that the design team led the project and saw it through to completion. Napper Architects thinks this may have been an advantage in their pursuit of sustainable design.

The school has a straightforward layout of two teaching wings either side of central communal accommodation. This layout was chosen for its daylighting potential and to enable the school to be extended without excessive disruption. The school's one single-storey area also has a structure designed to accommodate new classrooms on the roof. This may serve a sixth form if funding becomes available.

◀◀ Far left
Actuator-controlled openable Velux windows bring daylight into the first floor circulation space.

◀ Left
The landscaped lagoon has been used as a teaching resource for pupils but is locked most of the time because of safety concerns.

◣ Below
Fixed solar-shading and opening windows help trim peak temperatures in the corridors, but the lighting controls mean lights come on even when the sun is shining.

A bright, airy entrance foyer with full-height glazing on one side leads into the main corridor. This corridor benefits from good daylighting through actuator-controlled openable Velux windows.

Most corridors are fully glazed on one side, with solar shading on the first floor to limit solar gain in summer. Some glazing panels in the corridors and main hall use Okalux light diffusing insulating plastic glazing. This has a translucent capillary slab covered with glass-fibre tissues in the cavity to give a uniform light transmittance into the room.

Corridor lighting has passive, infrared movement-sensors, which seem effective. Lights default to off and only come on when someone walks through the corridor. It is difficult to combine movement and daylight sensors, but there may have been an argument for using daylight sensors or timer controls, because although daylighting in the corridors is excellent, the electric lights come on unnecessarily during the day.

Classrooms have simple lighting switches in three banks, with daylight sensors on the perimeter zone to prevent unnecessary lighting. Energy efficient compact fluorescent lamps have been used throughout.

Classrooms face east and west. Although there is adequate daylighting, blinds are often closed at teachers' request – sometimes so they can use the interactive whiteboards and sometimes to prevent pupils from being distracted.

Classrooms and corridors have suspended ceilings throughout. The designers suggested exposing the soffit in some rooms to help keep down summer temperatures, but the client rejected this idea on aesthetic grounds.

Although the school was built before the DfES issued guidance on acoustics (*Building Bulletin 93*), the school has sound-absorbent pin boards and acoustic ceiling tiles in classrooms, and double-thickness studwork walls between classrooms. The walls for the music practice rooms on the lower ground floor are formed of blockwork laid sideways on, backed up by heavyweight acoustic doors.

▶ Right
The central courtyard was to have more ambitious planting and less paving, but the headteacher was concerned about maintenance. The air-conditioning condensers in the foreground testify to the growth of ICT in secondary schools.

Wind energy

The school's exposed site takes the brunt of winds coming off the North Sea and would therefore have been perfect for a wind turbine. Sadly, no funding was available for renewable energy at the outset, but initial building work provided basic infrastructure for a turbine – making subsequent installation less disruptive. The school has since secured funding for a turbine, although it had not been installed by March 2006.

The downside of a windy site is that cold winds can penetrate the building fabric. Although the school did not feel draughty when visited, it's a pity that it was not subject to an airtightness test.

Heating and ventilation

The school's underfloor heating system is fed by two 350 kW boilers. The heating uses a mixing system to maintain a flow setpoint of 50°C necessary for the underfloor system. It would have been more efficient to heat to the desired temperature from the start – possibly a missed opportunity for improving efficiency.

The underfloor heating is self-regulating, in that colder classrooms draw more heat from the floors (designed for a floor temperature of 24°C). Zoning on the heating controls enables rooms to be heated outside of normal school hours.

Temperature sensors in every classroom are linked to the building management system (bms). However, there are reports of uneven temperatures between classrooms. The school staff are frustrated by not having control over the bms, which is only accessible by the engineers or by the City Council officers.

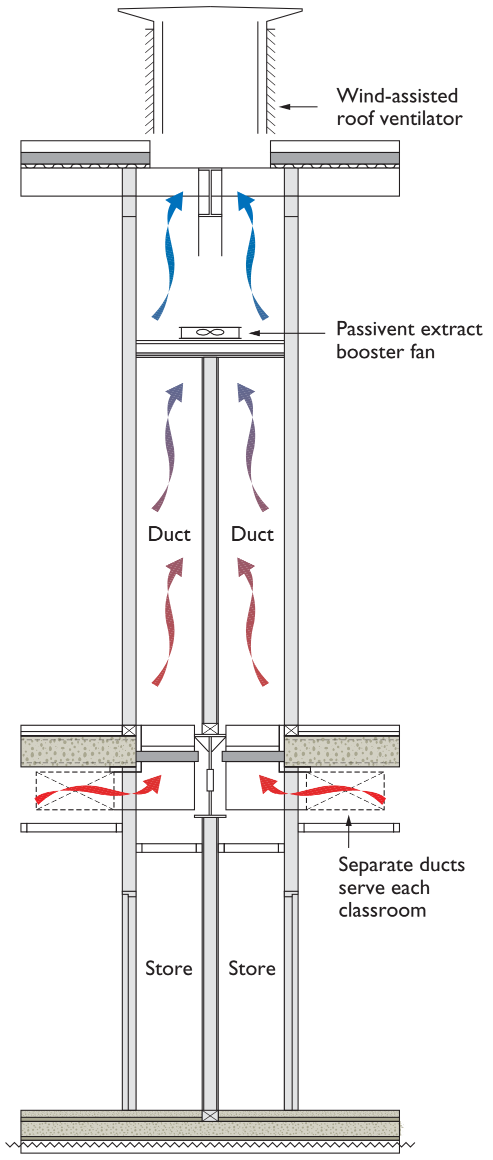
Each classroom has a ventilation grille in the ceiling leading to the wind-assisted ventilation chimneys on the roof (see figure overleaf). An insulated damper in the ceiling ductwork opens automatically when classrooms warm above the setpoint of 22°C. The stack effect of warm air rising means that air leaves the classrooms without any mechanical input.

If the classroom rises above 25°C – likely on warm summer days – a slow-running booster fan is triggered to increase the extract rate through the stacks, which helps to increase the draw of fresh air through the building.

If a teacher wants more ventilation in a classroom, there are two options: one or more of the windows can be opened, and/or a ventilation booster button on the wall can be pushed to bring on the fan in the chimney. Unfortunately the booster button is ambiguously marked 'ventilation override', and staff are not sure whether this makes the fan come on or go off.

◀ ◣ Far left and below
Twelve rooftop wind-assisted ventilators provide air to classrooms.

◀ Left
A similar form of natural ventilation is used for the main hall and the dining hall. The supply air is drawn in through earth tubes buried 2 m beneath the courtyard.



Earth-coupled ventilation

Supply air for the main hall and dining hall is drawn in through earth tubes buried 2 m beneath the courtyard, at which depth ground temperature is stable at about 13°C. These tubes serve to pre-condition the incoming air so that it is raised or lowered by approximately 1°C depending on the season.

The earth tubes are of 800 mm diameter, 20 m long polyethylene tubes. The benefit of this earth-coupled ventilation is that the halls are less likely to overheat when they are fully occupied in summer.

Circular rooflights in the dining hall and clerestorey lights in the main hall have motorised blinds so the rooms can be blacked out easily when required.

Four rooms with information and communications technology (ICT) are mechanically ventilated, as are a handful of classrooms on the lower ground floor where natural ventilation wasn't practicable. The ICT rooms are also mechanically cooled (which was found to be running when the school was visited during half term).

Water conservation

The school couldn't use the main sewer to discharge storm water, and this prompted the designers to introduce a landscaped lagoon on a plateau at the lower part of the site. This lagoon encourages wildlife and has been used as a teaching resource for pupils. It has a timber access platform, but is locked most of the time because of safety concerns.

There are no notable attempts to reduce water consumption or to harvest rainwater at the school. Although greywater recycling was suggested during the design, it was dismissed as complicated and not very important.

Water bills show that the school uses about 700 m^3 a month in term time, at a cost of around £1,000. Surprisingly, water use only falls by about a quarter during the holidays – perhaps because the local community also uses the school.

	$KWh/m^2/y$		$kgCO_2/m^2/y$*		
	Electricity	Gas	Electricity	Gas	Combined
Venerable Bede estimated consumption	23**	68***	10	13	23
Top 25 percent of secondary schools†	28	115	12	22	34

* Assuming 0·19 $kgCO_2/kWh$ gas, 0·43 $kgCO_2/kWh$ electricity.
** Estimate based on electricity cost 2005-2006
***Estimate based on two years' gas cost 2004-2006, adjusted for local temperature.
† Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003.*

Energy performance

Environmental engineers R W Gregory estimated during concept design that energy consumption would total 150 $kWh/m^2/y$, but this estimate seemed to be based on gut feel rather than any formal calculations. There was no effort to set energy targets by end-use even late on in the design process.

Energy consumption at Venerable Bede appears to be substantially less than early estimates. Although meter readings are not available, Sunderland County Council collects data on the cost of energy in schools (not kWh consumed) and this provides an approximate estimate of gas and electricity use at Venerable Bede Secondary School (see table).

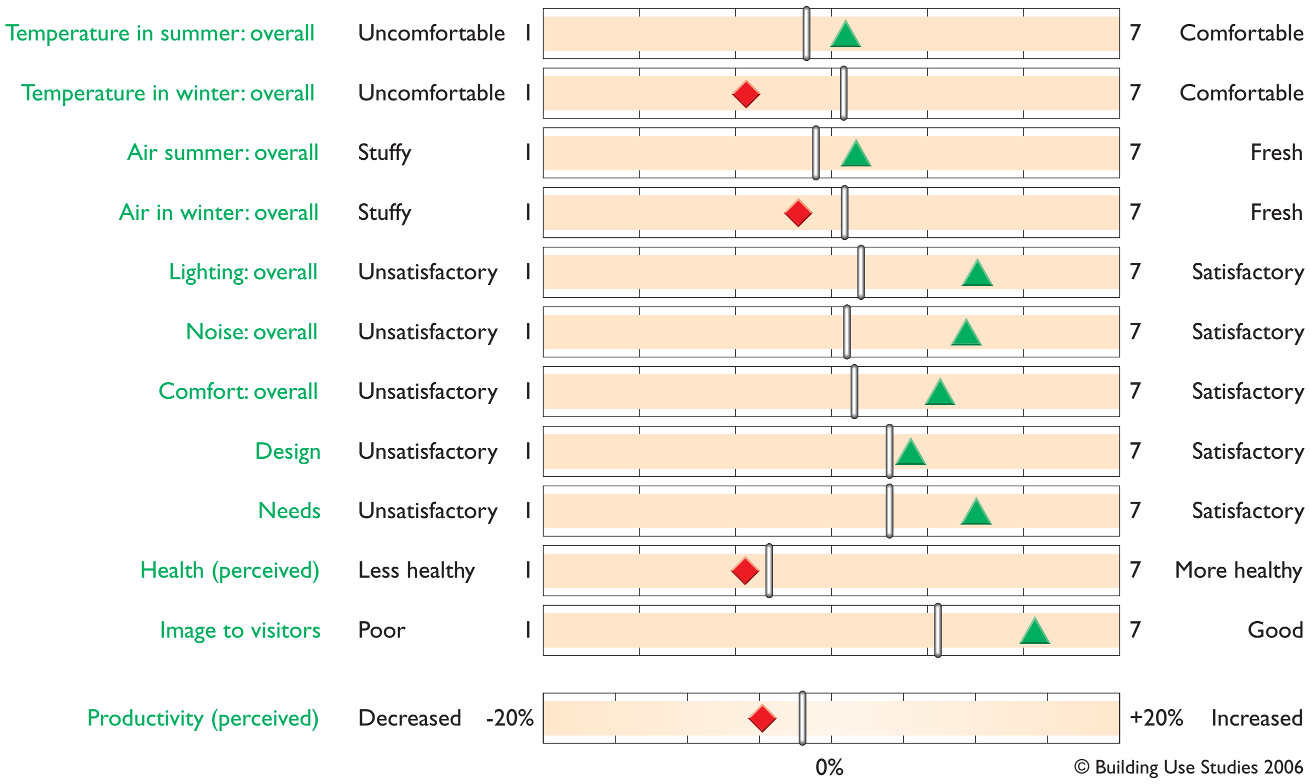
The school beats the performance of the top 25 percent of existing English secondaries for both gas and electricity consumption (somewhat surprising given there is no obvious effort by the school to manage energy use), although it uses more gas than the most efficient schools. Tighter control of energy (and especially trying to reduce unnecessary heating and cooling when facilities are unused) could probably take the school into the best 10 percent nationally.

Daylight and natural ventilation mean that Venerable Bede Secondary School offers an environment that is conducive to teaching. Energy use is fair (although it could be reduced further).

What this means to you

- Be prepared for major construction work to run late and make contingency plans
- Get involved with the design and build team before and after handover – you can learn from each other
- Don't procure what you can't manage. Go for simple and robust technology, and set energy proper targets
- Not investing in greywater and rainwater recycling can be a missed opportunity, particularly as the cost of mains water rises
- Do not wrest control of building systems from the end-users in favour of a deterministic controls regime; automatic controls and management systems need to be adjusted on site to meet local needs
- Teachers are in a good position to advise designers on occupant controls and to insist on controls that are functional and well labelled
- Make sure the design team enable the teaching staff to intervene over the control of lighting, heating, ventilation and noise. Understand the implications of computerised systems that are not controlled by the school

Occupancy satisfaction scores for Venerable Bede Secondary School



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| Benchmarks are represented by the line through each variable. The location of the benchmark varies for each variable. The benchmarks are derived from British, Australian and International studies of schools, depending on the context.

On the basis of the occupant survey, Venerable Bede School comes in the third decile (the top 30 percent) of the Building Use Studies (BUS) dataset, a good outcome. Staff were prepared to tolerate some of the perceived faults, as they mostly liked the design of the school and the image it presented.

Summertime comfort ratings were good, but there were more detailed criticisms of temperature and air quality, such as dryness of the air in both summer and winter.

Ratings for design (whether staff liked the design overall) and needs (whether needs were met) were good.

However, despite reasonably generous space provision overall and – at the time of the study – operating short of full student capacity[1], there were still shortcomings with the provision of storage. “It’s well laid out, but there’s not enough storage,” said one respondent.

This finding is common in BUS studies of schools, and seems to hold almost irrespective of whether or not space standards are good. For example, finding hired storage containers in the playground, as here, is a common occurrence in English schools of all types.

Although Venerable Bede School could justifiably claim to be green from its features list[2], there was little evidence that the building was operating in this way. School staff said they had no control over heating, so they could not change the settings in the building. This meant, for example, that there would be occasions when the building would be “unbearably hot” when the underfloor heating system had been running out of proper control[3].

Another respondent said: “The system works fine, then all-of-a-sudden it gets boiling hot. It’s so hot it sets the alarms off.” The school also gets too cold in places, to the extent that the school has had to buy additional heaters.

The school says that the controls manufacturers will not come back on site to fix what the school and local authority think is a software problem. The software runs to programs set by the contractors. The school thinks that this standoff occurred during a period when the school was not finished on time, and contractors were still on site when the school was being used.

This is a classic example of where good environmental intentions break down when there is no professional aftercare after handover.

Consequently the school has “no idea of the true energy costs”. A problem developed when the billing was transferred from the City of Sunderland to Npower, the utilities company. The school thinks that form-filling procedures were never completed properly at the outset, because the contractors provided incorrect information to the utilities company. The upshot was that the school received a bill for £70,000, subsequently reduced to £16,000. Npower came to cut the power off two weeks before BUS researchers carried out the occupant study.

The school also had no idea of how much energy a school like Venerable Bede should be using because no energy modelling or targeting had been carried out at the design stage. This was not automatically provided as part of the design package, despite the avowed green intentions and credentials.

The combination of these factors means, of course, that the school does not have any means – control, billing or management – to reduce its energy costs and emissions, nor any understanding of how its performance compares with yardsticks.

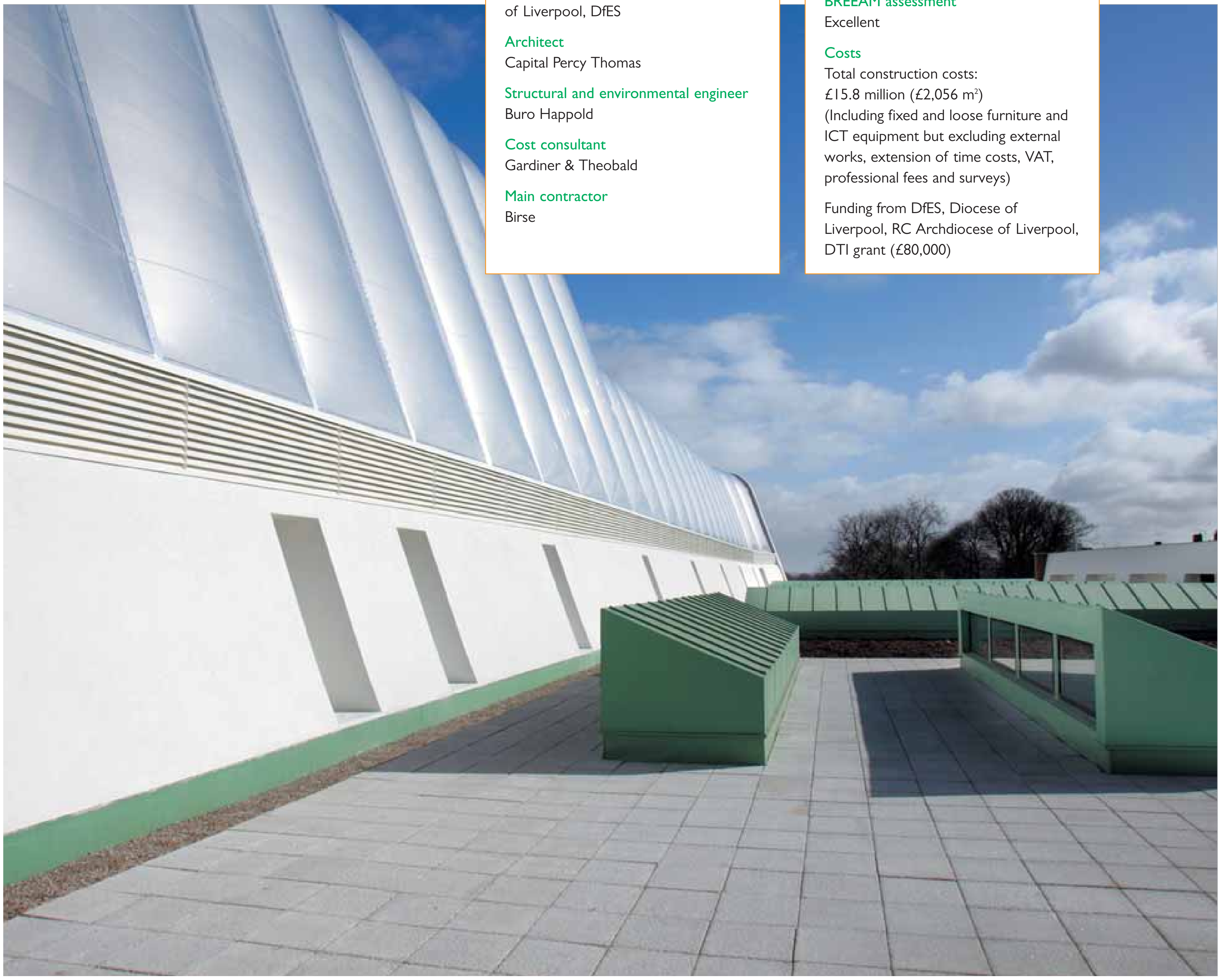
BUS researchers asked how easy it was for the school staff to understand how to run building systems. They said that they had been “swamped by technical information at handover”.

[1] Full capacity was expected to be reached in September 2006.

[2] For example, earth tubes to assist cooling, buried in the courtyard and passive ventilation chimneys set to operate at 22°C.

[3] After half term, for example.

▼ Below
The air-bag construction also endows the atrium roof with good properties of thermal insulation.



Completed
Partial completion September 2005, practical completion March 2006

Floor area
7,704 m^2 (gross)

Pupil numbers
900 when full (530 in March 2006)

School hours
08.15 – 18.00 h

Maintenance
One premises manager, two full-time assistants

Clients
Diocese of Liverpool, RC Archdiocese of Liverpool, DfES

Architect
Capital Percy Thomas

Structural and environmental engineer
Buro Happold

Cost consultant
Gardiner & Theobald

Main contractor
Birse

M&E contractor
Smith Group

Landscape architect
Fira Landscape Ltd

Indicative energy use breakdown
Gas: 138 kW/m^2/y (estimate based on first seven months data, adjusted for local temperature)
Electricity: 73 kW/m^2/y (estimate based on first six months data)

Carbon dioxide emissions
Predicted: 94 tonnes/y
Estimated actual: 57·6 kgCO$_2$/m^2/y (437 tonnes/y total)

BREEAM assessment
Excellent

Costs
Total construction costs:
£15.8 million (£2,056 m^2)
(Including fixed and loose furniture and ICT equipment but excluding external works, extension of time costs, VAT, professional fees and surveys)

Funding from DfES, Diocese of Liverpool, RC Archdiocese of Liverpool, DTI grant (£80,000)

Academy of St Francis of Assisi

A deprived area of Liverpool has been provided with a dramatic and innovative academy with low energy aspirations.

Summary

This academy for 900 pupils was jointly sponsored by the Anglican and Catholic Churches in an attempt to raise educational standards in a deprived part of Liverpool. The site is quite tight, with no playing fields, as its boundaries are defined by Victorian buildings on one side and housing on the other.

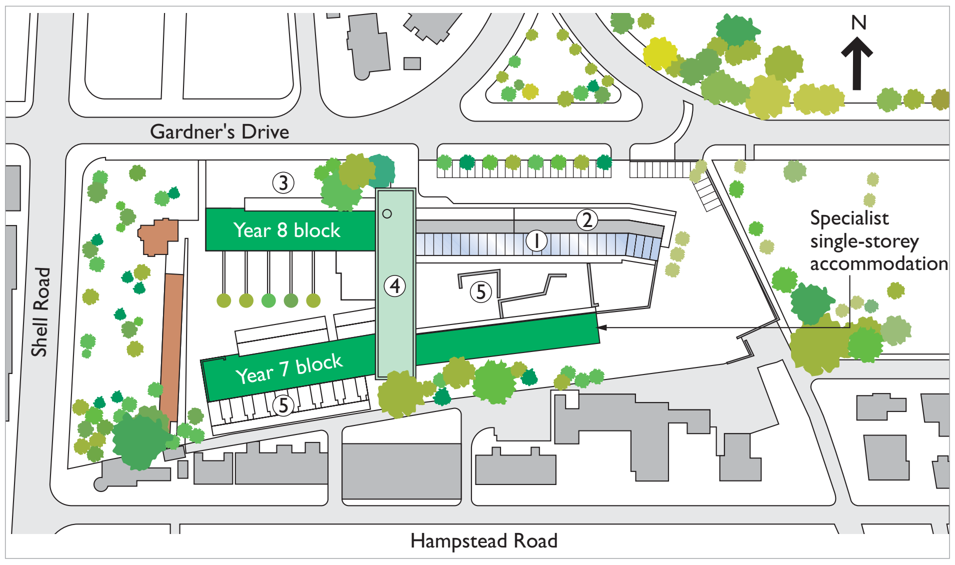
The environment is at the centre of the school's teaching philosophy, and the curriculum is using the building and its surroundings to improve pupils' understanding of the natural world. The building itself has natural ventilation, rainwater harvesting, and lots of tree planting. The designers have also avoided the use of potentially damaging materials.

Project details

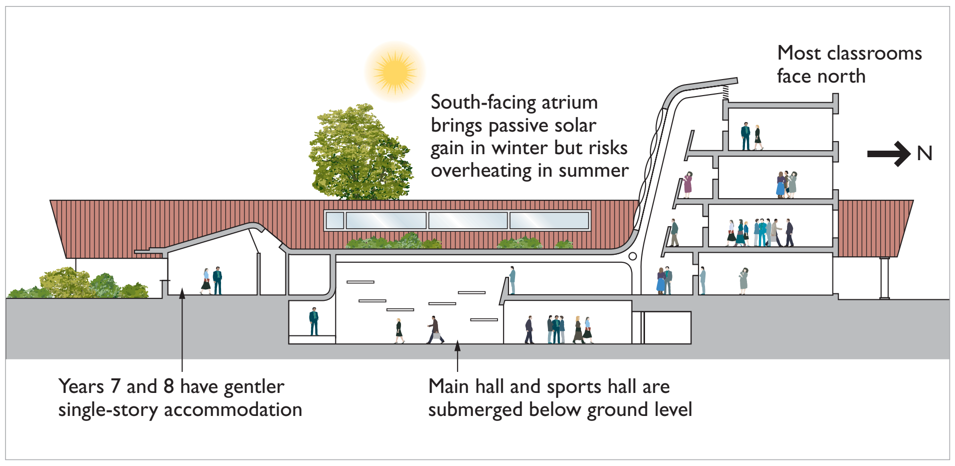
A two-page brief was produced at the bid stage, which emphasised the client's desire for the school design to respect the environment.

The building's form has reflected the one and two-storey buildings on the edge of the site, and in so doing has avoided being an oppressive monolith to houses on the other side. However, this conflicted with the requirement for 45 classrooms, plus a sports hall and main hall, all of which had to be located on a small site.

The solution was to build up and down: there are five storeys, and the two halls are underground. The roofs step down from four storeys to one storey, and inconspicuous, sky-coloured materials have been used to soften views of the tall parts of the school.



1 Solar atrium
2 Three/four storey teaching accomodation
3 Private gardens for years 7 and 8
4 Two-storey accommodation with photovoltaics on roof
5 Underground halls with outdoor classrooms above



◣ Left and below
The so-called solar funnels bring a small amount of reflected daylight into the underground areas of the academy.

The client's desire to give younger children their own space and some independence from the rest of the school – to ease the transition into high school – led to a very different form of building for Years 7 and 8. Here, the pupils stay put while the teachers rotate between classrooms. These year groups also have their own gardens.

A roof constructed of inflated ETFE foil (Ethylenetetrafluoroethylene – akin to bubble-wrap on a large scale) has been used to cap the roof of the school's atrium. ETFE is transparent to ultra-violet light and is chemically inert, thus preventing it from degrading under the influence of sunlight.

The air-bag construction also endows the roof with good properties of thermal insulation compared to glass. Values around 1·3 W/m^{2}K are possible depending on the number of foil layers. Even so, the translucent ETFE cushions that face south bring the same risk of solar gain as do south-facing windows.

▶ Right
All of the classrooms have external views, and many look out onto highlights of the school's design as here with the sedum roof.

▶▶ Far right
Classroom ventilation consists of no more than rotating louvres in the windows. Occupants are viewed as participants in maintaining a comfortable environment.

The south-facing cushions have been treated with an opaque paint to improve the shading co-efficient, but considerable heat gains may still occur: modelling carried out by the environmental designer, Buro Happold, showed that the top of the atrium could reach 30°C in summer.

One possible weakness in the design is that the manually-openable louvres at the top of the atrium are a long reach from the balcony – around 2 m – which means the occupants have to fly-fish with a long rod to open or close them. Had more money been available, these louvres would have been motorised.

Lighting

The project team put a lot of effort into introducing daylight into the school, both through windows and (for areas away from the perimeter or underground) light funnels that bring in reflected light. The windows seem to achieve the desired effect – at least for desks near the building façade – but the light funnels make a very small contribution to the lighting load.

In part, the problem with the light funnels comes from the limited area of glazing. Relatively dark colours chosen for some of the funnels do not help.

On paper, the average daylight factor for a classroom in the main block is 4·5 percent (where a 5 percent daylight factor is reckoned to provide adequate natural light most of the time in daylight). Science labs – which are deeper – achieve a daylight factor of 3·6 percent, and Year 7 and 8 classes manage a very impressive 7·8 percent.

Lighting controls are very simple single switches in most classrooms. This means teachers have to bring on all the lights, or none. Admittedly, when lights can be switched on in banks, teachers in many schools do turn on all classroom lights without a thought, but perhaps more flexible controls could have saved electricity.

About 70 percent of classrooms have passive infrared (PIR) sensors to turn off lights when they are unoccupied. Services engineer Ivan Chan explained that more sophisticated lighting controls would have been used throughout if more funds had been available.

As some lights in the corridors and atrium seem to be left on during the day, perhaps the investment in passive infrared sensors would have been better spent on daylight sensors in public areas known to have good daylighting.

Most classrooms face north, which allows the use of generous glazing ratios without risk of solar gain. Thermal modelling for the classrooms indicated that they would fall within the *BB87* limit of less than 80 h above 28°C.

◀ Left
Three contrasting construction materials have been used at the academy: brick for the lower elevations, deeper projecting copper-clad elements, and timber.

◣ Below
The manually-openable louvres at the top of the atrium are around 2 m away from the balcony which means the occupants have to use a long rod to open or close them.

Low-energy services

Energy efficiency was high priority from the beginning. Rather than automate everything, the architect and engineers decided to allow staff and pupils to take control of their environment. This could be argued to be an educational outcome of a building like this: a stand against buildings that automatically adjust to conditions and second-guess occupants' needs, which can leave people feeling helpless.

The school is predominantly naturally ventilated, with all classrooms and corridors provided with rotating glass louvres. Craft and science rooms have additional mechanical extract to maintain air quality, while underground areas and the dining room have mechanical supply and extract, with heat recovery via a simple run-around coil. The heat recovery is estimated to be around 50 percent efficient, and specific fan power (according to the system manufacturers) is reported as being 1·42 W/litre/s, well below the 2 W/litre/s required by the *Building Regulations*.

The supply air enters and leaves classrooms on one side only. They are fairly deep classrooms – 9·5 m on the ground floor – but early indications are that the ventilation is sufficient. To the headmaster's knowledge there have been no complaints.

Central mechanical cooling has been provided for two information and communications technology rooms and an informal cyber-cafe. The design engineers specified a variable refrigerant flow system with heat-recovery, which can operate in heating and cooling modes. This system was chosen as there could be occasions when internal areas would need cooling when areas on the perimeter of the building would require heating. The maximum cooling capacity is 70 kW.

	KWh/m^2/y		kgCO$_2$/m^2/y*		
	Electricity	Gas†	Electricity	Gas†	Combined
St Francis of Assisi 2005-2006**	73	138	31	26	57
Energy model result, tender stage (combined gas and electricity)	-	-	-	-	12
Top 25 percent of secondary schools††	28	115	12	22	34

* Assuming 0·19 kgCO$_2$/kWh gas, 0·43 kgCO$_2$/kWh electricity.

** Estimate based on seven months' data August-February 2006.

† Gas use adjusted for local temperature.

†† Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003.*

Energy analysis

The environmental engineer Buro Happold carried out energy modelling at an early stage using the *Building Bulletin 87*[1] spreadsheet. This suggested that annual energy consumption would be around 12·24 kgCO$_2$/m^2/y, (beating the top 10 percent of English secondary schools).

- Heating: 1·60 kgCO$_2$/m^2/y
- Hot water: 1·39 kgCO$_2$/m^2/y
- Electrical: 9·26 kgCO$_2$/m^2/y
- Total: 12·24 kgCO$_2$/m^2/y

Indicative estimates of actual energy use, based on meter readings for the first six months, are recorded in the table. These are substantially higher than the modelling – getting on for five times the CO$_2$ calculated at tender stage.

There are clear reasons for this high energy consumption. First, the building initially is not as airtight as it could be, and some remedial work is needed to improve its airtightness. Success would see the heating load fall significantly.

Second, commissioning of the heating system is incomplete, so again there should be a saving in gas consumption. Third, some of the heating set-points (which regulate when radiators come on and go off) are incorrectly set. For example, the sports hall set-point was 18°C, when it should have been 16°C.

Overall, the high energy use should settle down once the school is free of the construction team and can focus on tightening up energy use. The key point to draw from this is that modelled estimates of energy consumption in a new school are unlikely to be met in the first year of occupation, and the building will require fine tuning on an ongoing basis.

Renewable energy

Two renewable sources of energy have been used: photovoltaics and solar thermal panels. So far, their contribution has not been accurately measured.

A 24 kWp photovoltaic array has been installed on the roof of the two-storey core building. This was intended to meet 10 percent of the school's small-power needs (a small proportion of the school's total energy use). This smaller building is overlooked by the atrium, so pupils can see its solar cells and sedum green roof.

◀◀ Far left
The huge photovoltaics installation comprises 144 modules, which were designed to meet about 10 percent of the school's small power needs.

◀ Left
The students are able to monitor the output from the 144 photovoltaic modules.

◣ Below
The school is five storeys high, although you wouldn't guess that from outside. The sports hall and main hall are buried underground.

Embodied energy

The school has a lot of concrete, and that means its embodied energy is high. Copper also involves high energy use in manufacture, as does the aluminium used in windows. However, energy in use is normally reckoned to outweigh embodied energy by a factor of ten (although better energy efficiency in use means that the high embodied energy becomes more significant as a percentage of the building's total carbon footprint).

Water efficiency

Rainwater harvesting off the 700 m^2 roof of the main building feeds into a 15,000 litre tank beneath the courtyard at the rear of the school. This is used to flush toilets in the main buildings and the Year 7 wing. The rainwater collection and use is displayed in the entrance foyer for all to see.

Low-flush WCs (using 6 litres per flush) and waterless urinals help to cut mains water use. Based on the first quarterly water bill, the school will use around 630 m^3 of water a year, or about 1,200 litres per pupil.

◀◀ Far left
Light wells and light funnels are effective at bringing daylight into the lower storeys, although the light funnels only make a very small contribution to the school lighting needs.

◀ Left
These light funnels in the sports hall, despite providing some connection with the outside add little to daylight levels and could become a maintenance headache.

Sustainability in the curriculum

The architect, White Design, provided an input into how the school could incorporate environmental issues into the curriculum, and all heads of department were given ideas about teaching sustainability. The headmaster believes it goes further than the curriculum: "Administration, catering, and the grounds – everything about the school looks to sustainability. We're not there yet, and we still have work to do, but we will address sustainability throughout."

The school has established eco-councils for each year group to tackle environmental issues. Members of the eco-councils have learnt so much about the building that they now act as tour guides for visitors to the school.

Overall, Academy of St Francis of Assisi is a Jekyll and Hyde building: stunningly good-looking outside, but with brutally tough aspects inside (such as bare concrete walls).

Perhaps aesthetics were higher up the agenda during design than the environmental side, but the result shows that a school can attempt a sustainable performance without looking like a woolly jumper.

[1] *Building Bulletin 87: Guidelines for Environmental Design in Schools*, DfES 2003

What this means to you

- Don't be afraid of using innovative materials. They can be durable and help make a building more comfortable, as well as adding drama to your school
- Consider what facilities you could use if your building work runs late. How would you deal with transport issues?
- Utility bills and CO_2 emissions for a new school can initially be higher than the design targets – but these can be driven down by diligent fine-tuning
- Set aside a sum in the project budget to enable the design team to help with fine-tuning during the early stages of occupation. Make this a separate contract from remedial work
- Look for opportunities to use the school and its grounds in teaching biology, geography, science and design and technology
- Make sure your views on manual controls versus automatic controls are heard. Controls for occupants can be liberating, but they can also be a distraction for teachers and pupils

Completed
Partial completion September 2005, final handover October 2005

Pupil numbers
300 in first phase, 1,500 total

Floor area (first phase)
Gross: 5,835 m^2
Net: 5,603 m^2

School hours
08.00 – 16.00 h

Maintenance
Two premises managers

Local authority client
Milton Keynes Council

Architect
Architecture MK

Structural and environmental engineer
White Young Green

Cost consultant/quantity surveyor
NTN Partnership

Main contractor
DC Builders

Form of contract
Prime cost (open book accounting for all contractors)

Indicative energy use
Gas: 40·3 kWh/m^2/y
(estimate based on six months' data)
Electricity: 35·3 kWh/m^2/y
(estimate based on four months' data, adjusted for local temperature)

Carbon dioxide emissions
Predicted: 10·35 kgCO$_2$/m^2/y
(60 tonnes/y total)
Estimated actual: 21·4 kgCO$_2$/m^2/y
(125 tonnes/y total)

BREEAM rating (bespoke method)
Excellent

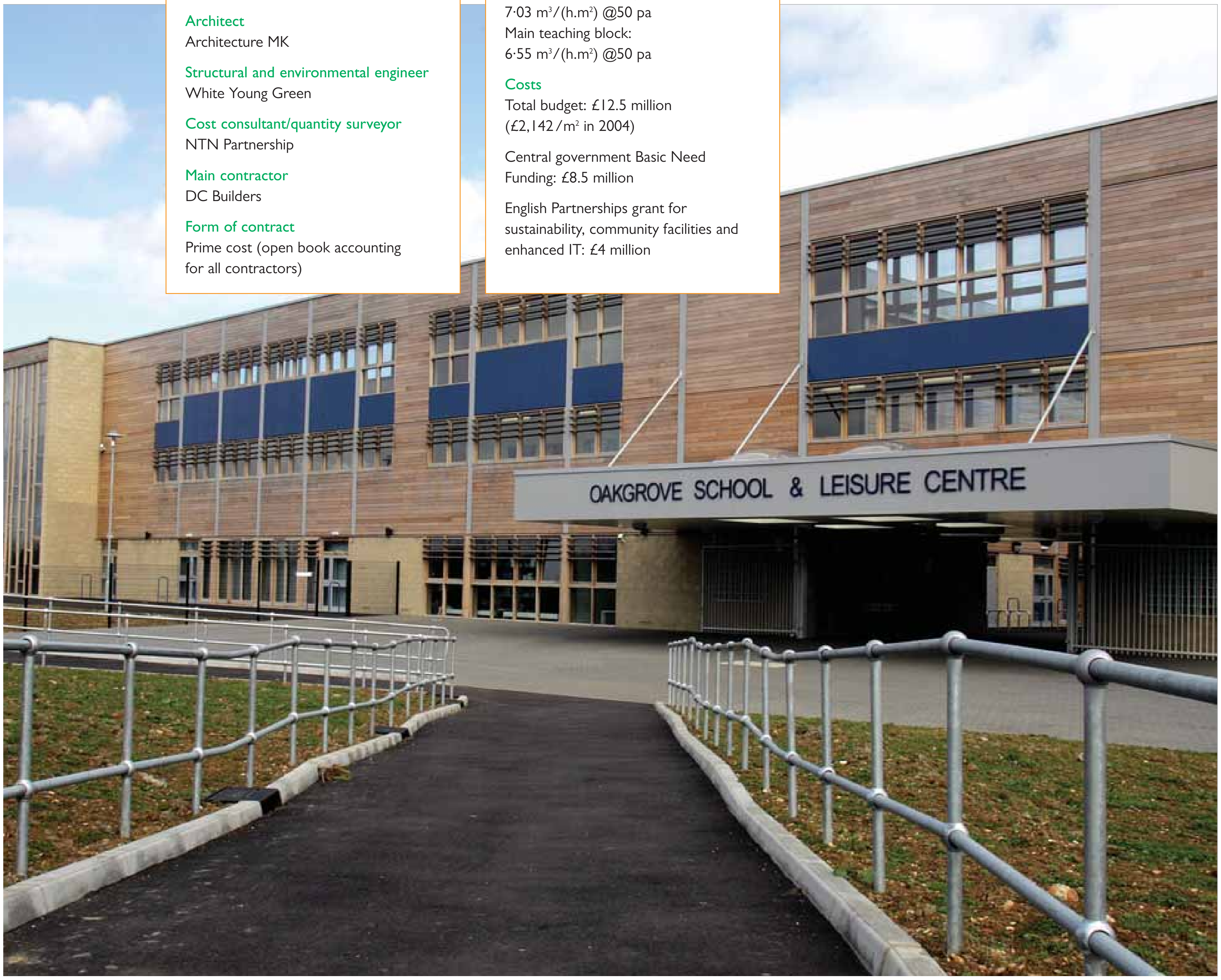
Air permeability
Leisure centre/library block:
7·03 m^3/(h.m^2) @50 pa
Main teaching block:
6·55 m^3/(h.m^2) @50 pa

Costs
Total budget: £12.5 million
(£2,142/m^2 in 2004)

Central government Basic Need Funding: £8.5 million

English Partnerships grant for sustainability, community facilities and enhanced IT: £4 million

▼ **Below**
The Panelvent sheathing used on external elevations of Oakgrove School is made from wood waste and forest trimmings. It contains no glue, bitumen or preservatives.



Oakgrove Secondary School

Heat pumps, recycled newsprint insulation and environmentally sustainable materials help make Oakgrove School an exemplar of its kind.

Summary

Excellent community access, low embodied energy and minimal harm to the environment were the key drivers behind this secondary school in Milton Keynes. Completed in October 2005, the school was built with durable finishes, all Forestry Stewardship Council-registered timber, and some recycled materials.

The designers have pushed all the right buttons in relation to cycling facilities, rainwater recovery, low carbon materials, sensitive landscaping and innovative heating systems. The result was an excellent rating under the BREEAM environmental assessment scheme.

- 1 Main entrance
- 2 Foyer
- 3 Staff rooms
- 4 Classrooms/teaching area
- 5 WCs
- 6 Stores
- 7 Kitchen/servery
- 8 Offices
- 9 Plant room
- 10 Hall
- 11 Reception
- 12 Changing rooms
- 13 Squash courts

◀◀ Far left
All classrooms face south. Simple roller blinds control glare effectively while external brises soleil deal with solar gain.

◀ Left
Glass-block walls at the backs of the classrooms bring a little extra light from the corridor into the classrooms.

◣ Below
The wall-mounted towers contain passive stack ventilation systems. In the foreground, wind-assisted ventilators serve the squash courts, sports hall and community facilities.

Project details

Milton Keynes is one of the fastest-growing cities in the country, with about 70,000 new homes expected to be built in the city by 2031. Oakgrove Millennium Community is part of this growth, and this secondary school, the first phase in a 1,500-pupil school, will serve the new development.

Sustainability was explicit in the council's brief, which said that the school should achieve a BREEAM rating of Excellent. A Section 106 agreement meant that a shared-access leisure centre would be built in parallel with the school, which meant that community involvement and social aspects of sustainability were significant drivers in the design.

The school was completed very quickly – 12 months' design and only 12 months on site (a full year faster than the norm for a secondary school in Milton Keynes). The school was handed over one month later than intended, in October 2005.

Construction details

The school is of steel frame construction with prefabricated timber cassettes within the frame. Panelvent sheathing forms the outer face of the cassettes, with Western Red Cedar cladding pinned onto it.

Holes were drilled into the walls from inside to inject Warmcell insulation (made from recycled newspaper) into the 150 mm cavity.

Offsite prefabrication of the timber cassettes may not have saved any money, but it certainly improved quality and saved a considerable amount of time on site. In particular, the wall construction eliminated the need for wet trades, a major contribution to meeting the accelerated programme.

▶ Right
The fluorescent fittings in the daylit linking corridors are controlled automatically. Better control of this type of lighting should reduce the school's energy consumption.

Materials

All timber used in the school is registered under the Forestry Stewardship Council (FSC). The Panelvent sheathing used on external elevations is made from wood waste and forest trimmings. It contains no glue, bitumen or preservatives.

Tarkett floor coverings are used throughout (Tecsom carpet tiles and Tarkett iQ vinyl), which were the only materials with A-ratings under the BRE's *Green Guide* when the school was built. Matting in the entrance areas is a hardwearing product made from recycled lorry and bus tyres.

The roof membrane is FDT's Rhepanol, which was considered the greenest material available at the time. The flat-roof parts of the building have timber rather than steel frames – a significant saving in embodied energy.

On the pitched roof, the architects specified Marley Eternit tiles, which again received an A-rating from the BRE.

BREEAM assessment

Oakgrove School pre-dated *BREEAM Schools*, but it was assessed instead using a bespoke set of criteria based on the Exemplar Designs for Schools requirements and some elements of BREEAM for Offices.

The design team looked at a wide range of different options for meeting the desired rating, and presented these options to English Partnerships, which had agreed to pay the extra costs.

In addition to the mixed-mode ventilation and ground-source heat-pump system, an outdoor teaching area, cycle storage, rainwater harvesting, and benign materials all helped to win BREEAM credits.

An unexpected outcome of adhering closely to BREEAM checklists was that the project team was unable to improve on the sustainable timber specified for the external cladding. Although the new source appeared to be from a better-run forest, it did not have the paperwork from the Forestry Stewardship Certification necessary to earn the BREEAM credit.

This is significant because the designers explained that "in order to get the excellent, you really need every point". In their view, getting a Very Good rating is possible through good design alone, whereas the environmental technologies required to meet an Excellent rating come at a high financial cost.

The design team had to identify the most cost-effective credits and make a case to English Partnerships for extra resources. The team estimated that the extra cost of achieving an Excellent rating was around £1.2 million, or £200/m^2. For comparison, the total cost of mechanical and electrical services in Phase 1 of the school was about £2.4 million.

◀◀ Far left
The designers persuaded the leisure centre client to avoid mechanical cooling for the shared-use gym. This can be retro-fitted if it proves necessary.

◀ Left
External brises soleil should prevent classrooms from getting too hot in summer. The 30 m^2 of solar collectors are used to generate hot water for the heating system.

Airtightness

Timber subcontractor Wood Newton had most of the responsibility for meeting the airtightness target imposed by the architect – a challenging 5 $m^3/(h.m^2)$ at a pressure differential of 50 Pascals (twice as good as required by the 2002 *Building Regulations*).

Wood Newton made sure there were two seals on every panel, and three seals on every window. In addition, a typical section of the prefabricated façade was tested for permeability at the BRE.

The airtightness test was carried out in two parts, with the main teaching block with cycle storage beneath achieving 6·55 $m^3/(h.m^2)$ at 50 Pa, while the remainder achieved 7·03 $m^3/(h.m^2)$ at 50 Pa.

Environmental systems

The classrooms rely partly on natural ventilation and partly on fans to provide fresh air. On the supply side, classrooms have trickle vents above the windows providing around three litres of air per second per pupil – enough to meet minimum background ventilation requirements – while openable windows can add another four to eight litres of air per second per pupil.

Some of the extract air from the classrooms air is supplied into the corridors via transfer grilles, while the rest leaves the building (driven by stack-effect forces) through one of seven, large ventilation chimneys.

Fans in the chimneys are controlled using a combined CO_2 and temperature sensor at the back of each classroom. If the CO_2 concentration reaches 1,500 parts per million (ppm) in the occupied area, or if the temperature edges above 23°C, then the fans come on to assist air movement through the building.

Environmental engineers White Young Green carried out thermal modelling to calculate the required number of openable windows, based on likely peak temperatures and the amount of ventilation required to dissipate heat. The position and number of brises soleil on the windows were also optimised – there are fewer louvres in the brises soleil on the ground floor than on the first and second storeys.

▶ **Right**
Second storey classrooms are larger, so they need smaller opening windows to dissipate heat. Kalwall backlights provide daylight without the penalty of large thermal gains or losses.

Heating systems

The design team initially considered supplying all space heating from a ground-source heat pump, based on a closed-circuit borehole system. As the total heating load of around 200 kW would have required an extremely large heat pump, the engineers took advice from a manufacturer that advised that it would be more cost-effective to install electric heat-pumps to meet the base load, along with some gas boilers to help during very cold weather.

Hence the system relies on heat pumps satisfying 120 kW of heating, and three 60 kW condensing gas boilers, the latter being powerful enough to meet the whole heating load. This resulted in a significant cost saving, without making a big difference to CO_2 emissions.

The heat pumps take heat from thirty 120 m-deep boreholes, where the ground temperature is a consistent 10-12°C all year round. Compressors and condensers in the heat pump use this energy to generate water at 45°C, which in turn is used to heat the building. The installation (which will only serve Phase 1 of the school) cost £150,000.

The argument against using electric heat pumps is that it makes little sense to use a high-grade source of energy like electricity for a low-grade purpose like space heating. Although twice as much CO_2 is produced using a kilowatt of electricity compared to a kilowatt of gas, the system at Oakgrove claims a coefficient of performance of 4·5. If this can be sustained throughout the year, the efficiency gains more than outweigh the penalty of using electricity.

Heat-pump performance factors are highest when there is a small temperature difference between the ground source and the heat used in the building. This normally means heat pumps are most efficient when linked to underfloor heating, which requires low water flow temperature.

At Oakgrove, however, heating in most areas is delivered through conventional radiators as they give a faster response time for intermittently occupied spaces, although there is some underfloor heating in the sports hall and community facilities.

Approximately 30 m^2 of solar collectors are used to generate hot water, located on the south-facing pitch of the community centre roof. There is space available alongside them to retrofit photovoltaic (PV) panels to offset the school's dependency on main electricity if the economics of using PVs improves.

◀◀ Far left
There is space to store at least 200 bicycles in this undercroft. The timber columns are of Red Laurel for greater durability.

◀ Left
Recycling is a fundamental part of the school's operation.

Daylighting

South-facing classrooms with a ratio of 40 percent glazing to wall have good daylighting, so much of the time electric lights are not necessary. External brises soleil should prevent it from getting too hot in summer, but the real test will only come during a complete occupied summer.

Large northlights mean that second floor laboratories benefit from good, even daylighting all year round. The Kalwall composite panel used to build these northlights has specially-formulated fibreglass to give far better thermal properties than double-glazing (the U-value is just 0·56 W/m^{2}K).

Electric lighting

At Oakgrove School the classroom lighting has simple on/off switching married to occupancy sensing where lights turn off automatically if sensors detect no movements for, say, 15 minutes.

This requires careful design. For example, at Birchensale School (q.v.) teachers and pupils carrying out quiet study are forced to wave their arms around to keep the lights on.

In addition, lights nearest to the windows are controlled by daylight sensors, which vary the output of the perimeter lights according to daylight levels.

Energy analysis

White Young Green carried out detailed energy analysis using the *Building Bulletin* 87 spreadsheet, with a breakdown of expected energy consumption by final use. The analysis indicated that the school could achieve 10·4 kgCO$_2$/m^2 – less than a third of the energy consumption of the top 25 percent of English schools (see table).

In its first six months of operation, Oakgrove appeared to be performing exceptionally well (although not as good as the design estimates). Indicative estimates suggest that gas use is less than half an average school (principally because of the electric heat-pumps), while even electricity use is at the lower end of what might be expected for a secondary school.

	KWh/m²/y		kgCO$_2$/m²/y*		
	Electricity	Gas	Electricity	Gas	Combined
Indicative Oakgrove consumption	35**	40***	15	8	22
Top 25 percent of secondary schools†	28	115	12	22	34
Design targets for Oakgrove using *BB87* spreadsheet	18	20	7	3	10

* Assuming 0·19 kgCO$_2$/kWh gas, 0·43 kgCO$_2$/kWh electricity.

** Estimate based on four months' data, November 2005-February 2006, adjusted for local temperature.

*** Estimate based on six months' data, September 2005-February 2006.

† Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003*.

There is often potential for tightening up energy use in the first year or two, and so it is at Oakgrove – even with such a positive start. The daily electricity consumption profile from half-hourly meters suggests that services are being used at weekends – possibly due to heating coming on unnecessarily. There is also a constant base-load of about 16 kW that seems high, and it may be possible to trim this back by limiting the unnecessary use of lighting, fans and pumps.

Electricity and gas consumption will rise once the leisure centre opens to the public at the end of March 2006 because of increased lighting and shower use. Rainwater harvesting means that the whole roof of the school and leisure centre is used to collect rain for flushing toilets and, if necessary, for irrigating the playing field.

School staff have very limited experience of monitoring and managing energy consumption. It will be interesting to watch how energy consumption develops at the school over the next few years.

Overall, Oakgrove does well on all fronts: staff and pupils seem happy with their facilities, community access is excellent, it has sensitively chosen materials, and energy consumption so far is one the lowest of any new school in the country. It came at a price: at least a 10 percent premium over an ordinary school. It was intended that the school would have high standards for sustainability and additional funding was made available, including measures which did not have an economic return.

What this means to you

- Search out funding opportunities that allow your project team to go further than normal on the sustainability agenda
- Energy consumption in practice is more important than design targets. Information can be obtained from utilities bills that can be compared with DfES energy benchmarks
- If there are doors leading directly between classrooms, make sure they have acoustic treatment so that noise from one doesn't disturb the other
- Evidence of sustainable materials and technology can be used in the school's design to illustrate environmental issues to pupils
- Ensure your views on lighting controls, and ways of controlling glare, on whiteboards for example, are heard during the design process

Type of school
Primary

Accommodation
Five classrooms, administrative accommodation, playgrounds and grounds

Pupil numbers
150

Gross floor area
904 m^2

Client
Kent County Council

Form of contract
JCT 95

Cost
£1.2 million

Completion
2001

Architect
Philip Payne, Mouchel Property Services

Structural engineer
Mouchel Property Services

Cost consultant
Alan Harwood

Main contractor
R J Barwick

M&E contractor
Kent Property Services

Specialist consultants
Reed bed design: Melvin Rutter

Maintenance
Mouchel Parkman and Andy Radcliffe

▼ **Below**
The school is constructed from a Masonite timber-frame, with a breathing wall and brick cladding at lower levels and larch cladding at high level.

Brenzett Church of England Primary School

This county council-funded school in Romney Marsh didn't set out to be sustainable, but the architect and headteacher had other ideas.

Primary

Middle

Secondary

Academy

Summary

Brenzett is a small village in Romney Marsh, Kent. The new primary school has been built on the playing fields of an existing Victorian school, which has since been converted to housing. The new school was procured by traditional means and completed in 2001. It caters for 150 pupils, and covers an approximate gross floor area of 904 m^2.

The brief from Kent County Council consisted of a schedule of accommodation incorporating five classrooms, administrative accommodation, playgrounds and grounds. Mouchel Property Services (the privatised property services department of Kent County Council) won the contract to construct the school.

The original brief did not refer specifically to sustainability, but sustainable features were subsequently worked into the brief by the project architect (a self-confessed novice in sustainable building) at the request of the headteacher.

Investigation by the architect, Philip Payne, identified an affordable timber-frame construction with a breathing wall design (a masonite I-beam system with recycled newspaper insulation). This was able to meet the client's requirement while staying within the project's budget.

🟩	1	Main entrance
🟦	2	Staff rooms
⬜	3	Classrooms/teaching area
🟪	4	WCs
🟨	5	Stores
🟧	6	Kitchen
🟫	7	Offices
▨	8	Plant room
⬜	9	Hall
🟥	10	IT space
⬛	11	Library

◀◀ Far left
Genersys donated eight solar panels to the school. These boost the school's hot water needs.

◀ Left
The school received a grant of £1,000 from Dungeness power station to fund a 300 W wind turbine. This is used in the curriculum.

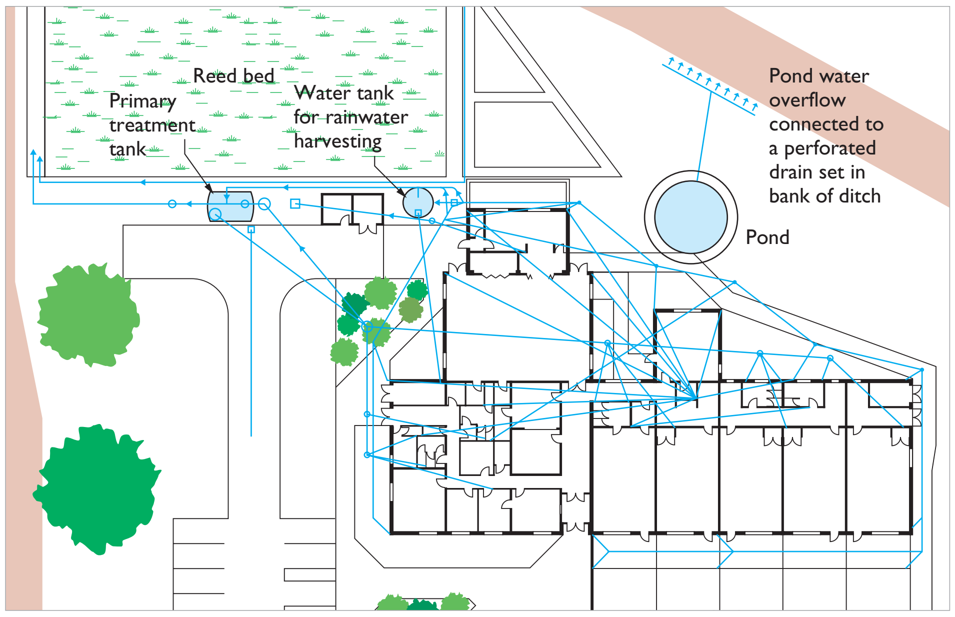
◣ Below left
Brenzett Primary School gathers and stores rainwater. This is used for flushing the school's toilets. The blue lines show the recovery pipework.

Construction

The adoption of an affordable, off-the-shelf, environmentally benign method of construction opened up opportunities for a design concept that embraced an efficient fabric, healthy construction materials and good daylighting and ventilation. The sustainability agenda subsequently addressed water management and use of solar energy.

Window and doors use a system known as Ecoplus. These elements are constructed from carefully sourced timber and are said to have exceptional thermal efficiency (a centre-pane U-value of 1·1 W/m^{2}K.) The system also proved to be cheaper than aluminium alternatives.

The window and door system embodied a number of benign materials, including non-toxic, boron-based treatment and natural oil-based wood finishes. These prevent off-gassing and remove the health hazards associated with conventional wood preservatives and paints.



Water systems

A rainwater harvesting system was installed to collect all surface water. The main 25,000 litre water tank is located underground, with water pumped as required to high-level storage in the school roof. The surface water is used to flush the school's 6 litre flush toilets. Other water-saving features include push taps, and a Saniflow system that flushes the urinal when a tap is being used.

The rural location of the school and a lack of existing drainage made a reed-bed filtration system for the school's foul water (also known as grey water) a viable solution. As well as performing an engineering function, the reed bed also forms part of the nature garden and is therefore a teaching resource. As well as the reed beds, the school has a pond, a watercress bed, two herb gardens and general planting. This provides lots of teaching material.

▶ Right
The reed bed that filters the school's foul water forms part of the school's nature garden and is also a teaching resource.

Energy from renewable sources

Genersys donated eight solar thermal panels to the school on the basis of a plan to monitor the energy output and then to offer such systems on the basis of metered output. The school's hot water (generated by high-efficiency condensing boilers) is supplemented by hot water from the solar panels.

The school also received a grant of £1,000 from Dungeness power station to fund a 300 W wind turbine. The intention was to use the power generated to run a computer that would collate data from the turbine – such as the power it generates at measured wind speeds – so the pupils can learn more about energy from the wind.

Cost analysis

The school was one of six in Kent that has been subject to a comparative study with respect to their whole-life cost, quality, and sustainability. This study was undertaken to enable Kent County Council to develop a strategy for schools procurement that could demonstrate best value for money.

Brenzett Primary School was the most expensive school in the study, both in terms of capital cost and whole-life cost. This was partly due to the proportionately high cost of providing a hall in a relatively small school.

With all the sustainability features included at Brenzett it is perhaps surprising the construction costs were greater by only about 25 percent. When compared with the usual overall costs (including the site preparation, contingencies and preliminaries) this reduced to about 15 percent. Yet this extra cost did not merely purchase an environmental statement, but a quality school, with a superior learning environment and lower energy and lifecycle costs. In terms of design quality, Brenzett Primary School received the highest score, which indicates a high quality educational environment.

The Council's study also reported that the school was regarded as a showcase of sustainability, with "a bright and flexible teaching environment". It is also one of only two schools that comply with the latest natural ventilation requirements of *Building Bulletin 87*, although it was built before *BB87* was written.

Ventilation and solar gain were major issues in the cost study. These have displaced heating as the main indoor environment issue for schools, particularly as the requirements for thermal insulation in the *Building Regulations* have improved. Some of the schools in the Council's study were found to be overheating due to limited ventilation. In one case, external sun shading had been removed from the specification to save capital cost. In order to cope with the overheating conditions some of the schools in Kent County Council's study were reported to be propping open fire doors to enable ventilation.

◀ **Left**
A typical classroom. Benign materials are used to treat the windows and doors, such as non-toxic, boron-based treatment and natural oil-based wood finishes.

◣ **Below left**
The user controls for the Velux windows are clear in what they do and visibly connected to the window mechanism.

Lighting and ventilation

The daylighting at Brenzett is very effective. The classrooms have Velux rooflights, which can be motored open for additional ventilation. This is done under the control of the caretaker who has access to a master switch.

Roof-mounted, wind-assisted ventilators ventilate the library and computer rooms. This technology is a good way of ventilating areas of high heat gain when mechanical ventilation is not desirable or affordable. The roof ventilators at Brenzett rely on wind pressure on the leeward side to draw air up and out of the building while air is supplied into the occupied spaces on the windward side.

Simple mechanical ventilators ventilate the toilets. These are fitted with low speed, low-energy fans to assist airflow.

▶ Right
All foul water is treated in the school's reed bed. The school's push taps are also connected to a system that flushes urinals when a tap is being used.

Materials

The school is constructed from a Masonite timber-frame, with a breathing wall which retains heat while controlling humidity. Timber-framed windows with non-toxic boron timber treatment were specified to prevent the off-gassing and health hazards associated with conventional wood preservatives and paints.

Transport

As the school is in a rural area, it was estimated that the majority of the pupils would be dropped off by car. A green travel plan was developed for the site as a planning condition. The school also has a dedicated bus service, with the drop-off point located directly outside the school.

Management issues

There was an ongoing involvement by the mechanical engineers during the defects period. The handover documentation includes operating instructions, although there is little by way of information for the non-technical person. There does not appear to be any assessment of energy or water consumption.

What this means to you

- Ensure that investment in energy saving devices such as wind turbines and solar panels can be monitored for their true contribution to the school's energy needs
- Appreciate the value of specifying school materials and finishes for their health benefits
- Ensure that the brief and the consultants' contracts include money for the ongoing assessment of energy and water consumption
- Involve the teachers' views on the practicality of design options before assuming that they will perform as the designers intend
- Carry out occupant surveys of existing teaching accommodation and use the results to inform the brief for the replacement school. Favour proven public domain and empirical survey methods over bespoke methods
- Ensure that consultation with teachers and governors is carried out formally. They are the ones who have to live with the school
- Ensure that your views on aspects of usability, manageability and maintenance are used to inform the selection of ventilation and daylighting systems
- Consider how sustainable features, such as reed beds for the cleaning of foul water, can be used to enhance the curriculum
- Do not under-estimate your influence on improving the sustainability credentials of a new school

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Completed
March 2006

Pupil numbers
210 (plus 52 in nursery)

Gross floor area
1,952 m^2

School hours
09.00 – 17.00 h

Maintenance
One caretaker

Local authority client
Sheffield City Council

Architect
White Design

Structural and environmental engineer
Carl Bro

Cost consultant
Turner & Townsend

Main contractor
Willmott Dixon

M&E contractor
Emcor

Contract
Partnering (White Design/
Willmott Dixon)

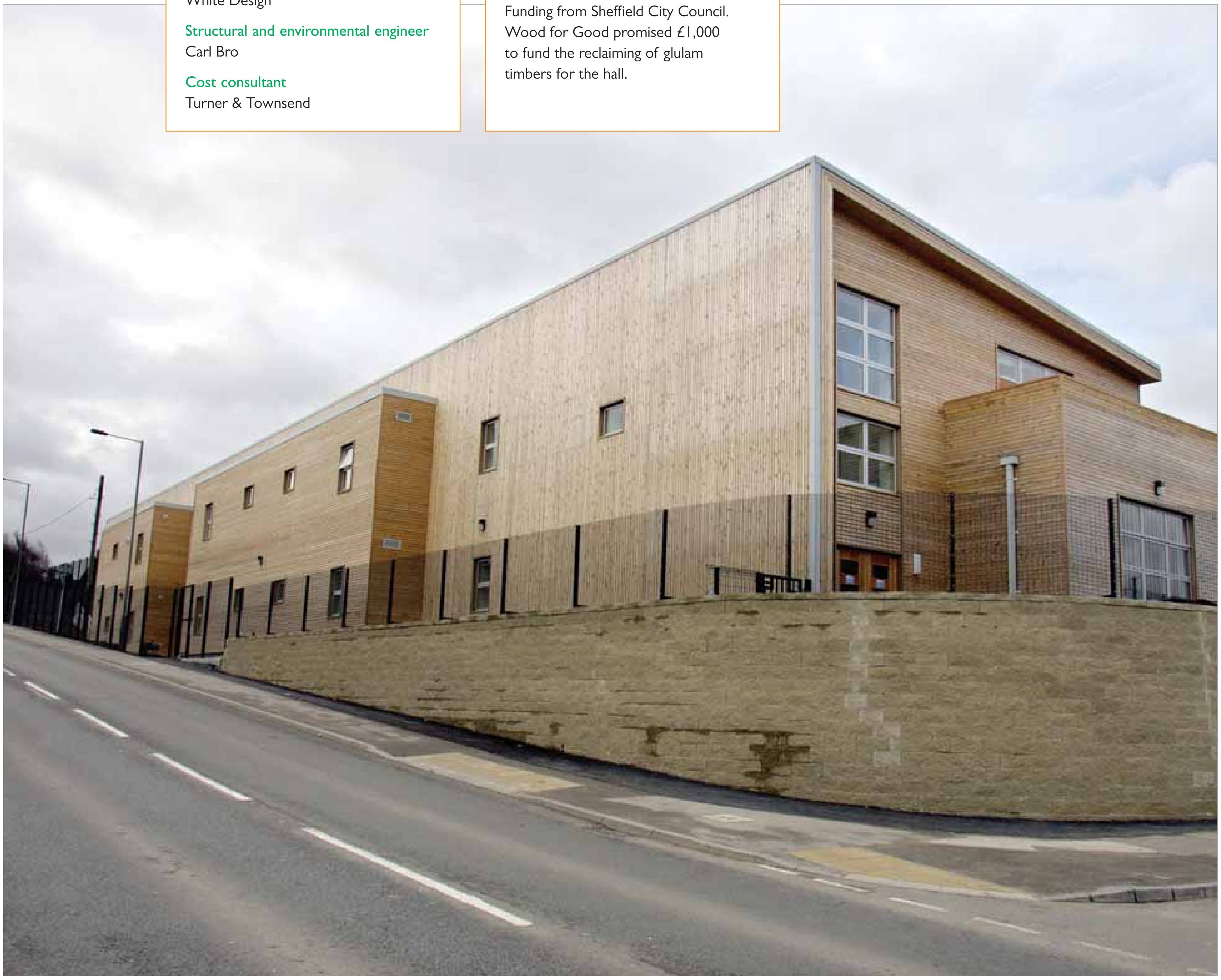
Energy use breakdown
Unknown

Carbon dioxide emissions
No detailed energy analysis or targets.

Costs
Total budget: £3.9 million
(£1,998/m^2 in 2005).
Funding from Sheffield City Council.
Wood for Good promised £1,000
to fund the reclaiming of glulam
timbers for the hall.

▼ Below
Anns Grove Primary School is clad in UK-sourced cedar that comes with the backing of the Forestry Stewardship Council.

◢ Below right
The compact, two-storey plan was a clear response to the site, with the main hall on the second floor. There is a notable absence of external solar shading for the south-west facing classrooms.



Anns Grove Primary School

A primary school with a requirement for low embodied energy bristles with simple, robust and low CO_2 construction materials.

Summary

Low energy consumption was a clear priority for the designers of Anns Grove School. It was built on the playground of the school it replaced: a listed building which could not be converted to meet the needs of contemporary education. The new school is very well insulated, naturally ventilated, and relies on automated controls. There is no mechanical cooling.

Materials with low embodied energy featured high on the design team's list of priorities. Architects White Design managed to find pre-used, recycled and locally-sourced materials for many components. Most of the construction team were local to the area, and therefore the designers and builders alike sought to do their best.

Despite the low energy aspirations of the design team, no detailed energy analysis was undertaken or targets set.

◀◀ **Far left**
Daylighting is good in the classrooms. Fairface blockwork and exposed soffits provide a high thermal mass and help to trim summer temperatures.

◀ **Left**
Light wells increase daylight. Those on the ground floor double as ventilation shafts, so that warm air from the ground floor passes up through natural buoyancy into the first floor.

Project details

In the summer of 2003, Sheffield City Council ran an RIBA competition to appoint an architect. Sustainability was part of the Council's written brief, and White Design was appointed in part because of its environmental credentials.

The school's headteacher and the chair of the board of governors pushed hard to make the school as sustainable as possible. Although there were some sacrifices to meet budgetary constraints, the fundamentals survived: highly insulated fabric and glazing, good controls and robust design.

The compact two-storey plan was a clear response to the site: the school turns its back to a busy road to the north-east, with classrooms all facing south-west towards the Grade 2 listed old school.

The construction is of conventional load-bearing blockwork for the classrooms and a combined steel and timber frame for the hall and library.

Construction materials

The architect managed to find a source of UK-grown cedar with which to clad the building. A supplier in Haverford West, South Wales, supplied the timber which has full certification from the Forestry Stewardship Council (FSC). It was installed by a local joinery.

In a departure from the norm for primary schools, the hall is on the first floor, with the dining room and kitchen beneath. Another unusual feature of the layout is the generous timber balcony adjoining the main hall.

A recycled roofing material made by Firestone (the tyre manufacturer) was used throughout. This material is a rubber-based by-product of tyre manufacturing that is usually sent for landfill.

Part of the frame for the hall and dining room is made from reused glue-laminated (glulam) timber. Some of the glulam beams were reclaimed from a school demolished in Hull. Anns Grove School also has a reclaimed bell tower.

Corridor carpets with at least 75 percent recycled backing were made by C&A (a firm that collects carpets for recycling).

For the classrooms, Architect White Design specified blockwork containing a high proportion of pulverised fuel ash. For the school hall, the architect also specified Masonite timber I-beams that have low formaldehyde content. Pre-fabricated Tradis panels were then specified which are filled with recycled newspaper as insulation. Together, this form of construction gave u-values that met *Building Regulations'* requirements at the same time as achieving very low embodied energy.

In a rare combination of economic, social and environmental sustainability, the project team specified Inno-therm, a recycled insulation product made from waste textiles. Anns Grove represents the first major use of the product in the UK.

▶ Right
Discreet ductwork integrated above storage cupboards allows stale air to pass from the classrooms to the corridor.

◢ Below
The main hall has a sprung timber floor. High performance Velfac 200 windows help to minimise winter heat loss.

Inno-therm has a thermal conductivity of 0·037-0·039 W/mK, which is as good as Rockwool. Inno-therm has been used in all roofs and walls except those for the main hall and library. The insulation is 230 mm thick in the roofs, and 140 mm thick in the walls. This means U-values are better than those prescribed in the *Building Regulations*.

Inno-therm offers advantages over other insulation products when it is installed: no specialist equipment is needed, it cuts easily, and it is safe in use (no masks or gloves are needed). At the time of writing the UK manufacturers are awaiting approval from the British Board of Agrément.

At a cost of £6-£6.50/m^2, Inno-therm compares favourably with other sustainable insulation such as sheep wool.

Daylighting

Inside, the 12 classrooms have large windows giving approximately a 50 percent glazed ratio. Classrooms on the first floor have high ceilings and large Velux windows. Classrooms on the ground floor also have good daylighting. There was no formal daylight modelling, but this does not appear to have been a handicap.

The ground floor classrooms have suspended ceilings to house acoustic material and lights, but there is a large gap (around 0·8 m) around the sides to allow air to reach the ceiling, which acts as a thermal heat-sink in summer. First-floor ceilings have timber cladding with acoustic material hidden discreetly behind. The hope is that high ceilings and cross-ventilation will keep the rooms cool.

Large glazed areas that face south-west suggest a risk of summer overheating, but computer modelling showed that this would not be a problem during term-time (with peak temperatures only occurring in July and August). The real test will come when the school is fully occupied.

◀ **Left**
The main hall is on the second floor. Given the extensive roof area, it was a missed opportunity not to collect rainwater for toilet flushing.

◣ **Below**
An unusual feature is the generous timber balcony adjoining the main hall. This doubles as an external teaching area.

Design for manageability

The school's natural ventilation system relies on WindowMaster controls to precisely regulate opening windows and rooflights. This means that effective ventilation is not dependent on staff or pupils taking responsibility for opening and closing the windows – they can concentrate on teaching or learning and let the windows look after themselves.

There are automatic windows at high level to introduce fresh air at high level and allow mixing above pupils' heads so they do not feel draughts. Typically the windows open only a little, between 20-30 mm, which means that temperatures should not fluctuate wildly.

The WindowMaster system takes into account the speed and direction of the wind. Wind-pressure sensors on the facades allow the window openings to respond to changing wind conditions and thereby maintain a stable internal environment.

The actuators are almost silent, so that opening windows do not distract pupils or staff. They can be set for different amounts of ventilation, typically 3-8 litres of air per person per second. Manually openable windows have been provided for extra ventilation.

Discreet ductwork integrated above storage cupboards allows stale air to transfer from the classrooms to the corridor. This is acoustically treated so that noise should not pass between the corridor and classrooms.

The corridors also feature light wells that double as ventilation shafts, so that warm air from the ground floor passes up through natural buoyancy into the first floor, and ultimately (in summer) through opening Velux windows above the shafts.

A value engineering process resulted in the axing of rainwater harvesting and a biomass boiler. The WindowMaster natural ventilation system also came under scrutiny. At £45,000, plus upwards of £15,000 for cabling, the system was not cheap, but it still worked out to more cost-effective than a mechanical ventilation system.

▶ **Right**
The school's low energy features are used in the curriculum. Here the pupils are learning about the environmental qualities of insulation made from waste textiles.

Sound insulation

Acoustic performance is something the project team took seriously. An acoustic consultant was employed in the design stage and checked that recommended reverberation times were achieved in all areas post-completion. Suspended ceilings on the ground floor include acoustic tiles, while the corridors have fabric-based acoustic panels (which can double as pinboards).

There is some risk of road noise affecting the smaller rooms facing the road (intended as a buffer for the classrooms) in summer, when the windows are open, but computer modelling suggested that road noise will be minimised by the small window openings. On the dry day the school was visited, noise from the road was not a problem.

Heeley Development Trust is keen to convert the original school into an adult education centre. This would make the school part of a broader education campus.

Overall the school has excellent insulation and glazing, and first-rate controls to look after the natural ventilation. It has no obvious visible indication of its sustainable credentials – no turbines, photovoltaics or conspicuous green roofs, and water recovery has been omitted – but most of the pieces are in place for low energy consumption and a very pleasant school environment.

What this means to you

- Be prepared for major construction work to run late and make contingency plans
- Acoustics are important in schools, and noise can make it hard for pupils to concentrate, but this concern should not force acoustics to dominate other aspects of design
- Energy targeting and monitoring is important in reducing CO_2 emissions
- Encourage architects to source materials locally and consider wider social and economic objectives in procurement
- Value engineering should not be cost cutting under another name. Government grants and industry sponsorship should be investigated before simple, robust systems like rainwater recovery are abandoned
- Teachers are in a good position to insist on functional, well labelled and easy to use controls
- Make sure your views are solicited over the control of systems. Automation can work well if it can be altered based on occupant feedback
- Sustainable schools like Anns Grove have great value to the curriculum

Completed
June 2005

Floor Area
Gross: 1,780 m^2
Net: 1,180 m^2

Pupil numbers
400 (Humanities block maximum occupation)

School hours
08.30 – 17.40 h (Mon-Fri),
09.30 – 15.30 h (Sat)

Maintenance
One energy/maintenance manager, one site electrician, one site plumber

Client
Bromsgrove School

Architect
Buttress Fuller Alsop Williams

Structural engineer
Shire Associates

Environmental engineer
Gifford & Partners

Cost consultant
Faithfull & Gould

Main contractor
Chase Norton

M&E contractors
Electrical: Goodwin & Price
Mechanical: L Darby & Sons

Energy use breakdown
Gas: unknown

Electricity: unknown
Early design target: primary energy 60 kWh/m^2

Carbon dioxide emissions
Predicted: 32 tonnes CO_2
Actual: Unknown

Fabric airtightness test
Achieved: Better than 10 m^3/(h.m^2) at 50 Pascals

Costs
Construction cost: £2.7 million (£3.9 million including consultants' fees, furniture and VAT)
Cost: £1,517/m^2 (construction only)

▼ Below
The humanities block at Bromsgrove Senior School is a textbook example of passive solar design, with stack-assisted ventilation via a central street running along the spine of the building.

◢ Below right
The ground floor plan for the humanities block and Bromsgrove Senior School. There are 20 classrooms, each of around 50 m^2, plus an ICT room and six offices.

Bromsgrove Senior School, Humanities Block

Sustainable design doesn't have to mean high tech bolt-on renewable energy features. Keeping things simple can also show dividends.

Summary

Bromsgrove Senior School is an independent school founded in mid-16th century. Over the last ten years the school has undergone a £26 million construction programme, with most of the money going into new buildings. In the words of the Director of Property Services John Rogers: "Sustainable, creative building design is part of our task of creating well-rounded pupils".

For this reason the school was receptive to the idea of low energy design when it procured a new humanities block. It was looking for a building with presence and which would provide first-rate accommodation and low running costs.

Architect Buttress Fuller Alsop Williams and environmental engineer Gifford & Partners collaborated to produce a mixed-mode building with simple environmental systems and controls. Materials are of high quality, but largely traditional and hardwearing. The result is an extremely attractive facility.

Project details

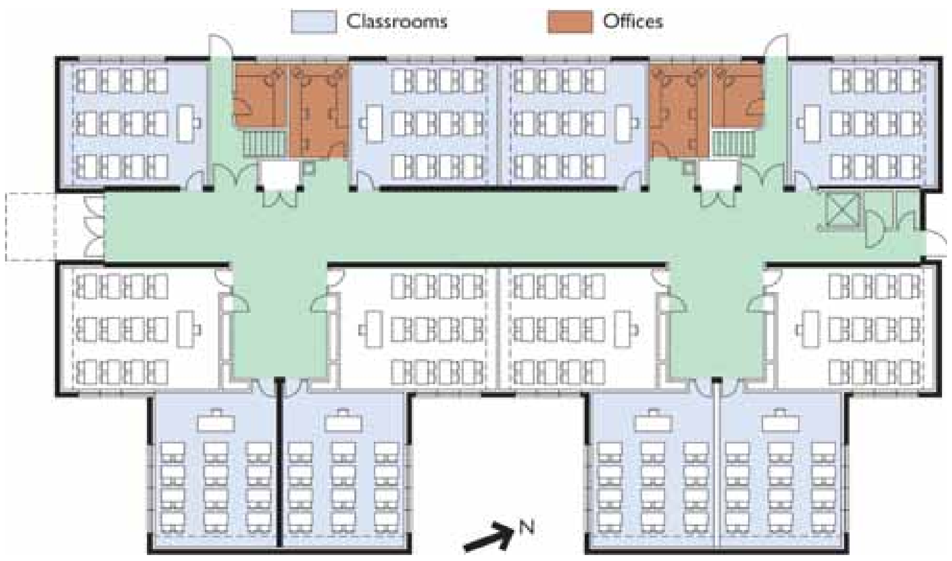
The client was very hands-on – and genuinely interested in what the project team achieved. A written brief informed the competition to appoint an architect, followed up by a second competition to choose a contractor. This was a two-stage tender, which allowed the contractor to make an early input into the design process.

A conventional JCT 80 contract was used, although – unusually – the main contractor was persuaded to accept a guaranteed maximum price.

School site

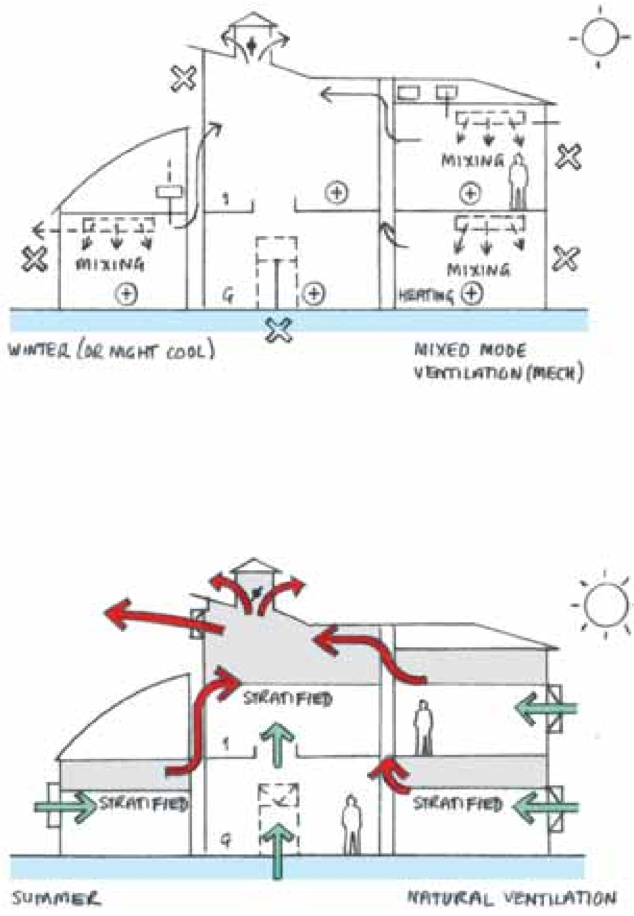
Most of the teaching buildings are located close together on the school's 40-hectare grounds. Choosing the site for the humanities block was straightforward: it was close to the central teaching area, had good access to a road and was able to be isolated from other parts of the school for health and safety reasons. There were also services nearby.

The architect and engineers were appointed in the summer of 2003. Underground services discovered



◀ Left
The building's form clearly follows its function, with the roofline aiding the wind-assisted ventilation strategy.

◣ Below
The humanities block has a mixed mode approach to ventilation, with different modes of operation depending on the season.
Sketches copyright Gifford & Partners.



during the ground works made the early work on site more difficult (and created problems for the main contractor in achieving the guaranteed maximum price). Nevertheless, to the school's delight, the building was actually handed over five weeks early, and a little under-budget.

The building is easy to read from outside: 20 classrooms and six offices are arranged in two parallel wings and connected by a partially glazed street. It has space for displays or artwork, has excellent finishes, and oozes quality.

A planning restriction on height and housing to the west of the site meant that the architect had to deal tactfully with privacy issues. For this reason, west-facing office windows on the first floor have opaque glass and blinds.

Classrooms face east and west, and are all single-aspect. Windows are generously proportioned (around 40 percent glazing ratio for the facades with windows), and daylighting in classrooms is adequate – the average daylight factor for classrooms being 2·5 percent.

There is some overshadowing from neighbouring buildings, and some loss of light through the glazing system, which uses (retractable) interstitial blinds.

Noise was an issue during design. The project team employed an acoustic engineer and applied the DfES design guidance on noise. All classrooms have three walls of pinboards and slotted plasterboard ceilings which have absorbent material. There is also acoustic insulation in builder's work ducts. The ground floor has an insulated, floating-screed floor to deaden impact noise and prevent it being heard in the street.

▶ Right
Classrooms are all accessed via a partially glazed street. Clerestorey windows mean that there is good daylight even on gloomy days, but the lights are still left on.

▶▶ Far right
Despite attention to energy-saving lighting and ventilation, the school's ICT rooms are still equipped with cathode-ray tube screens rather than low energy flat screens.

Environmental services

The environmental engineer Gifford was keen to avoid bolting-on technology, instead concentrating on the building physics and on getting the basics right. Early in the design process the engineer presented a series of different options for servicing the building, with estimates of how much energy each option would imply in terms of kilograms of carbon dioxide per square metre.

Like all of Bromsgrove School's recent buildings, the humanities block is linked to the centralised building management system. At the time of writing the school was experiencing problems in the way the link was established. The school cannot monitor energy consumption in the building (even its bills for gas and electricity are estimates).

Although the bms is configured to record room temperatures and boiler functions, one of the sensors appears to be malfunctioning. When the school was visited, data was not being recorded.

The school does not currently carry out monitoring and targeting for its buildings, although the Carbon Trust carried out an energy review at the school in February 2006.

All heating is provided through underfloor heating, fed from two condensing gas-boilers in a first-floor plant room. Each manifold for the underfloor heating has its own wall-mounted temperature sensor to control how much hot water is delivered to different areas.

Ventilation

The building operates in two ventilation modes (see figures opposite). In summer, all but the toilets are naturally ventilated. There are large opening windows in the classrooms for incoming air, which passes through the classrooms and into a large builder's work duct in one side of the classrooms. Air goes on into the circulation area, and finally leaves the building through stacks in the roof. The height of the stacks helps to draw air through the building.

A particular concern was sufficient ventilation in winter. In many naturally ventilated schools, the desired ventilation rate is not achieved because cold drafts deter teachers and pupils from opening the windows. As a result, carbon dioxide levels in the classrooms rise, the rooms become stuffy, and it is difficult for pupils to concentrate.

◀◀ Far left
Careful attention was paid to the design of the openable windows.

◀ Left
The windows have interstitial blinds to control glare. In winter, air enters and leaves classrooms through louvres above the windows.

In the humanities block, the designers have provided each classroom with local mechanical ventilation to ensure that CO_2 levels remain low enough for pupils to concentrate. Small fans are controlled manually by a switch by the light switches. Like the lighting, the mechanical ventilation is connected to movement sensors that cut off the fans after 15 minutes if the classroom is not occupied.

Supply air grilles at the backs of the classrooms bring air into the classroom, while the gap between the suspended ceiling and the concrete slab above acts as a passive return path. Stale air from the room passes through a high efficiency heat recuperator to pre-heat the incoming air.

Lighting controls

Classrooms have simple lighting switches in three banks. Although the single-position switches are not labelled, they allow people to turn lights on but not off – the off function being handled by motion detectors that switch off the lights if no movement is detected after about 15 minutes. There is some scope for improving lighting controls in the street, which do not have daylight or movement sensors and are left on irrespective of daylight levels.

Lighting efficiency is very good, with very efficient metal-halide display lamps on the ground floor, compact fluorescent lamps on the first floor, and T5 lamps in the classrooms. The installed lighting density is 10 W/m^2, with an average of 75 lumens per circuit Watt (excluding display and external lighting).

Energy consumption

The engineers recognised that the increased use of computers in schools would result in high electricity consumption. They made the point that the use of information and communications technology (ICT) should be considered as part of a broader low energy strategy.

This does not appear to have been wholly successful: one ICT room is inappropriately located in a small room with a low ceiling, and many computers use traditional old-style cathode-ray tubes (CRT) instead of more efficient flat-screen displays which would reduce energy consumption and heat gain in the space.

Although the school is replacing 250 CRT monitors with flat screens in summer 2006, the school also provides 175 laptops for use in the humanities classrooms. This profusion of ICT presents a challenge for reducing electricity consumption.

▶ **Right**
One of the 20 classrooms. In winter, supply air enters at the back of the classrooms through ceiling mounted diffusers.

The early design target was to achieve a total primary energy consumption of 60 kWh/m^2/y – an ambitious target. However, it is not possible to assess how close the humanities block is to meeting the target because of inadequate metering and monitoring. (A small mechanical DX cooling system for the ICT rooms, installed by the client, probably pushes the block above the target.)

The designers carried out a short assessment of the viability of renewable energy in the humanities block. They came up with the notion of a watershed between efficient, simple servicing – implying a cost-effective design – and a capital-intensive approach involving forms of renewable energy, such as a biomass boiler or photovoltaics. The engineers proposed various renewable energy solutions, with their likely benefits and risks, but they were ruled out by the client on cost grounds.

This is not Bromsgrove's first experience of natural ventilation, but it may be its most successful – at least in terms of the number of staff complaints received. It is unfortunate that hitches with the building management system mean that energy data is unavailable, as the humanities block appears to be delivering the expected performance with little obvious waste of energy.

What this means to you

- Ensure that the building management system is set up to provide useful information, and that school staff know how to use it
- A clear, detailed and explicit brief will usually lead to a good building
- Concentrate on the basics first, keeping the design simple and avoiding unmanageable complexity
- The limitations of natural ventilation in schools, particularly in winter, can be overcome by sensible use of mechanical systems acting in a mixed-mode configuration
- Centralised building management systems are logical in theory, but in practice can hinder local energy metering and monitoring in individual buildings
- Ensure that your views on what constitutes usable and manageable controls, particularly for lighting, are covered in the design brief
- Ensure that your views on labelling of light and ventilation switches are understood by the design team
- The capital and running cost of energy metering and measurement can be used to enhance the curriculum

Completion date
July 2005

Floor area
Gross: 8,927 m^2
Net: 7,682 m^2

Pupil numbers
Time of study: 185
Design total: 950

School hours
08.00 – 17.00 h

Maintenance
One facilities manager with one assistant

Local authority client
South Gloucestershire County Council

Architect
Concept: Boyes Rees Architects
Details: David Kent Architects

Structural engineer
Concept: Structures One
Details: Clarkebond

Environmental engineer
Mitie

Cost consultant
Bucknall Austin

Main contractor
Kier Western

M&E contractors
Mitie

Energy use breakdown
Gas: 83·2 kWh/m^2/y (estimates based on six months' data July 2005-January 2006, adjusted for local temperature)
Electricity: 32·6 kWh/m2/y
(estimates based on six months' data July 2005-January 2006)

CO_2 emissions
Predicted: (No energy modelling/target)
Actual: 28.6 kgCO_2/m^2/y
(255 tonnes/y total)

Costs
Cost: £1,456/m^2 (gross)
Total construction cost: £13 million

Funding
South Gloucestershire County Council

▼ Below
The main facade looks rather utilitarian, but achieved good airtightness the first time it was tested. *Photograph: Kier Western.*

◢ Below right
The administration offices are located at the front of the building, with classrooms arranged around internal courtyards. Despite the potential for natural ventilation, the school is mechanically ventilated.

Bradley Stoke Community School

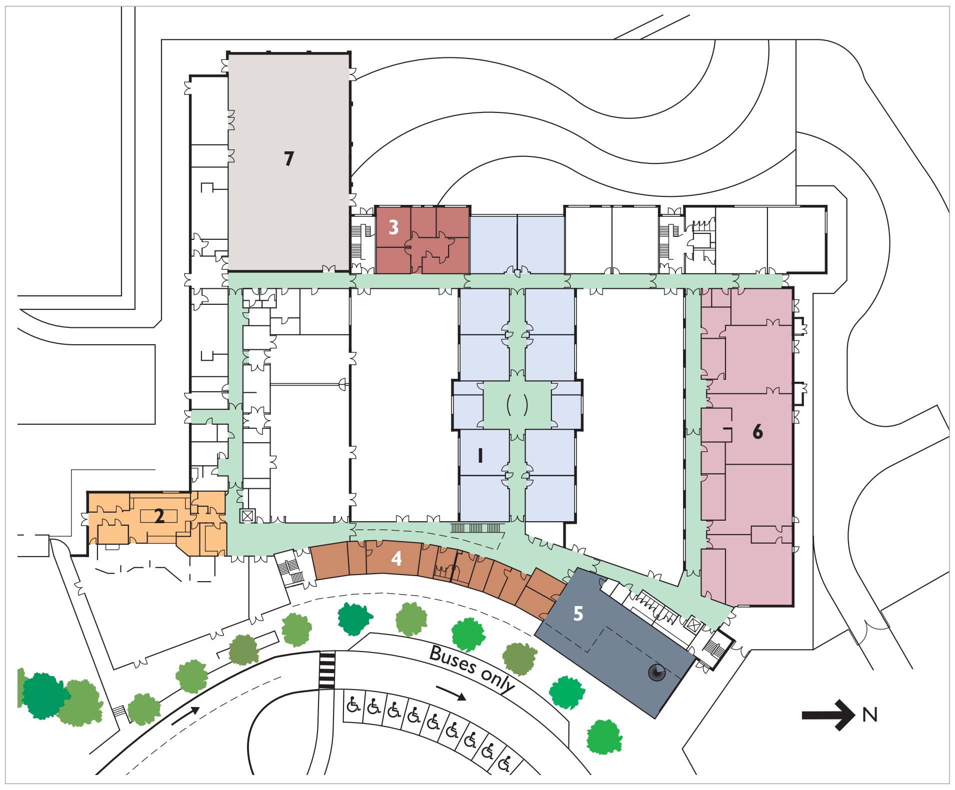
Bradley Stoke Community School is a mechanically ventilated school where low impact foundations were high on the builder's agenda.

Primary
Middle
Secondary
Academy

Summary

The major factor with Bradley Stoke Community School in north Bristol was the need to build it near a major road. Even though the school is mechanically ventilated to overcome traffic noise, the contractor adopted several strategies for reducing the damage to the environment caused by the school's construction.

All rooms in the school are mechanically ventilated, for a relatively modest construction cost. The school has a good travel plan (helped in part by most pupils living nearby) and a drainage system that follows principles of sustainable design.



🟦 **1** Classrooms
🟧 **2** Kitchens with plantroom above
🟥 **3** Student offices
🟫 **4** Offices
⬛ **5** Library with staffroom above
🟪 **6** Multimaterials and food technology with science labs above
⬜ **7** Sports hall

◀◀ Far left
Bradley Stoke Community School from the air.
The proximity to the M4 motorway lead the designers to mechanically ventilate most of the building.

◀ Left
A single air-handling unit on the roof supplies enough fresh air for the whole school.

◣ Below
The sports hall has some daylighting from high-level glazing, and acoustic material on the walls to cut the reverberation time.

Project details

Bradley Stoke is a new settlement of 25,000 people near the Second Severn Bridge. It was established in the mid-1980s, and had six primary schools but no secondary school. Pupils leaving the primary schools ended up travelling long distances to the closest secondary school.

The only available site was adjacent to the M4 motorway, background noise from which was measured at between 60 and 65 dBA, about the same volume as normal speech.

In July 2003, South Gloucestershire County Council held a competition to recruit a design and build contractor for a new school. It appointed Kier Western as main contractor the following October.

The client appointed specialist advisors, and drew up a written brief and performance specification. Although concept design was by Boyes Rees, the design and build contractor chose David Kent Architects (DKA) to carry out detailed design.

> “ The contractor used a recycled stone mixed with clay fill, applied and compacted in layers, to improve the ground conditions. This led to major savings in total embodied energy. ”

Sustainability on site

Kier Western took steps to reduce the environmental damage caused by the construction process. For example, it built a sealed wash-down pit for concrete vehicles and skips to prevent alkali from concrete contaminating the soil. Kier also used settlement tanks and filters when disposing of groundwater to avoid contaminating the site.

The main contractor made efforts to apply benign methods of disposal. For example, it arranged with the plasterboard manufacturer, Lafarge, to gather and recycle waste plasterboard.

Kier Western opted for pre-cast concrete pile foundations instead of the very large concrete pad foundations proposed in tender documents. This saved 3,000 m^3 of concrete and avoided the problem of having to dispose of a very large volume of soil.

Ultimately, the choice of foundations made a massive difference to both the school's embodied energy and the volume of waste generated during construction.

Ground improvements

The tender documents for Bradley Stoke laid out specific levels for the school building and different sports areas – in part for disabled access. However, the contractor found that constructing these levels would create significant amounts of poor quality subsoil.

A detailed re-modelling exercise avoided the excavation and disposal of 7,000 m^3 of soil. This led to other major economies, such as a huge number of construction vehicle movements to take away the subsoil.

A soil study found that soil quality was unsuitable for construction. Its moisture content and other ground conditions would have created problems for both construction traffic using the site and for the permanent car park paving. Initial design proposals assumed that lime and lime/cement (which both have high embodied energy) would be used to stabilise the soil.

However, the contractor used a recycled stone mixed with clay fill, applied and compacted in layers, to improve the ground conditions. This led to major savings in total embodied energy.

Part of the site had been filled with waste construction materials – mostly concrete – and significant quantities of this material were crushed on site and reused as hard core. Taken together, these ground improvement strategies eliminated much of the need for importing quarried stone to the site. It also reduced the number of traffic movements, and meant that embodied energy for the school was substantially lower.

◀◀ Far left
Wide overhanging eaves provide solar shading, and night-cooling purges the school of heat built-up during the day.

◀ Left
Corridor lights are linked to infrared movement sensors, and lights come on as pupils move around.

◣ Below
The learning resource centre has automatic comfort cooling (simple air conditioning), triggered when temperatures rise above 24°C.

Fabric and building services

Traffic noise from a busy road 250 m from the school caused the design team to pay particular attention to detailing the building's envelope. Air paths for noise and drafts tend to be the same, so it paid to achieve an airtightness of 7·5 $m^3/(h.m^2)$ at 50 Pascals (25 percent better than required by the *Building Regulations*).

The composite cladding material used on the main facade is impervious and proved straightforward to seal. However, there was no requirement or desire from the client to go beyond the minimum specifications for insulation laid down in the *Building Regulations*.

There were low-cost opportunities to raise levels of insulation, but a conscious decision was taken not to exceed statutory minimum requirements.

The original design brief specified a traditional mechanical supply and extract ventilation system. However, Mitie Engineering Services realised that because unoccupied classes would be ventilated, the school might suffer high running costs. It would also be no guarantee of good indoor air quality.

Mitie designed a high-quality mechanical ventilation system based on an acoustically attenuated air supply for each classroom. When classrooms are occupied, air enters through swirl diffusers on the ceiling and exits into the school's corridors via louvres in the partitions.

A single air-handling unit on the roof supplies air at 2·8 m^3/s throughout the school. The supply air is heated by passing over low temperature coils fed from three condensing boilers (the coils are over-sized to compensate for hot water supplied at 50°C). The fans are under the control of variable-speed drives to ensure that air volumes are matched to the level of occupancy – an energy saving feature.

▶ Right
The sports hall and canteen have supply air delivered through inflated fabric ducts.

Information technology

The school is one of the most technologically advanced in the country, with wireless and hard-wired information and communication technology (ICT) facilities in all areas. This includes interactive white-boards in all teaching rooms. Such facilities come at a price in terms of higher electricity consumption and higher internal gains (particularly in summer).

The designers adopted a night cooling strategy based on BSRIA guidance. Although the real test will come during a long, hot summer of occupation, early indications are that the strategy is a success.

Space heating is via an underfloor system, with the pipework embedded in the floor screed. The system operates on low temperature hot water (flow 50°C, return 40°C), which allows the condensing boilers to work in condensing mode all the time, thereby working more efficiently.

Every classroom has a sensor linked to the building management system (bms) which controls the heating and ventilation. If they wish, staff can track the temperature of their classroom through the day using a bms terminal in an office behind the school's reception.

There are suspended ceilings in all classrooms and corridors for acoustic reasons. The environmental engineers would have preferred to expose the concrete soffits to gain some convection and radiant cooling benefits, but the acoustic criteria were deemed more important.

In use performance

Regarding energy consumption, the school currently appears to be using less gas than good practice existing schools, but more electricity (see table overleaf). Of course, it is only one fifth occupied, and when the school is full both electricity and gas consumption are likely to rise – not least because of the increased winter ventilation when all the classrooms are used.

Overall, total carbon dioxide emissions for the school are currently better than the top 25 percent of secondary schools. The electricity consumption per m^2 is high but understandable (given that the school has electrically-powered ventilation, generous ICT provision and electronic whiteboards), and outweighed by low gas use. The school should monitor both electricity and gas use during the first two years of occupation, when fine-tuning may help to bring down energy consumption per pupil.

◀◀ Far left
To combat glare problems on laptop screens, blinds tend to be closed and electric lighting put on.

◀ Left
There is generous bicycle parking, and wide pathways mean that pavements leading to the school can be shared by pedestrians and cyclists.

▼ Below
Wireless and hard-wired information and communication technology abounds in all areas. Such facilities come at the price of higher electricity consumption.

	KWh/m^2/y		kgCO$_2$/m^2/y*		
	Electricity	Gas†	Electricity	Gas†	Combined
Bradley Stoke consumption 2005-2006**	33	83	14	16	30
Top 25 percent of secondary schools††	28	115	12	22	34

* Assuming 0·19 kgCO$_2$/kWh gas, 0·43 kgCO$_2$/kWh electricity.

** Estimates based on six months' data July 2005-January 2006.

† Gas use adjusted for local temperature.

†† Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003*.

It could be argued that the project team was quick to put the suppression of noise from the adjacent main road before the virtues of natural ventilation. The mechanical ventilation system is partly responsible for high energy use, and noise intrusion from the mechanical ventilation system is not far off what is generated by the road. Traffic noise may be higher on a wet day, but it is difficult to accept that natural ventilation couldn't have worked for areas of the school furthest away from the road.

Outside the school

The landscaping work in the school grounds included retaining and enhancing the existing hedgerows, and extending wildlife corridors. More than 160 ash, oak, maple and hawthorn trees were relocated within the project, and an existing pond was also moved to a more suitable site.

As all pupils live within two miles of the school, they are encouraged to walk or cycle to school. So far (with one year's intake) the school is close to meeting this objective. Safe routes to school and cycle storage for 192 bicycles helps to dissuade pupils from travelling in by car.

The school has run a Bike to School week to promote cycling, and also won a £20,000 grant from Sustrans under the latter's Bike It scheme, which helped meet the cost of extending cycle storage. The school has arranged cycle training for pupils, provided by South Gloucestershire's Road Safety Team.

What this means to you

- As the design progresses, retain features that could improve the school's long term environmental performance
- Recognise that the capital cost preoccupation of design and build contractors may militate against investment decisions, such as higher standards of insulation
- Be sceptical of road noise affecting one elevation as a justification for mechanically-ventilating an entire school
- Consider the embodied energy of all aspects of the construction process, including the ground-works
- Encourage pupils to think about the environmental effects of construction sites, using the school as an example
- Ensure that your opinions are solicited on the trade-offs between competing priorities, such as abating road noise versus openable windows. Designers' priorities may not be the same as teachers' priorities

▼ Below
The brief for Riverhead Infants School requested a building that was an exemplar of sustainable design. The finished product differed little from the architects' vision, shown opposite.

◢ Below right
The architect's response to the school's design brief. The brief was developed by the school's governing body which possessed construction expertise. The brief was clear and explicit, and led to this concept design which was almost exactly what was built.

Completed
September 2002

Floor area
1,340 m^2 (gross)

Pupil numbers
270

Architect
Architects Design Partnership

Services engineer
Slender Winter Partnership

Structural engineer
Anthony Ward Partnership

Quantity surveyor
Close Morton & Company

Landscape consultant
Robert Rummey Associates

Main contractor
The Buxton Group

Highways
Babtie Group

Travel plan
TPK Consulting

Significant cost elements
Structure: £609.19 m^2
Services: £251.81 m^2
Landscaping and drainage: £299.80 m^2
Total cost: £1,954,652

Energy consumption (2004-2005)
Electricity: 45·3 $kWh/m^2/y$
(adjusted for average local temperature)
Gas: 48·2 $kWh/m^2/y$

Carbon dioxide emissions
Predicted: 37·9 $kgCO_2/m^2/y$
(51 tonnes/y total)
Actual: 28·3 $kgCO_2/m^2/y$
(38 tonnes/y total)

Riverhead Infants School

Riverhead Infants School shows how green design can benefit from strong community involvement.

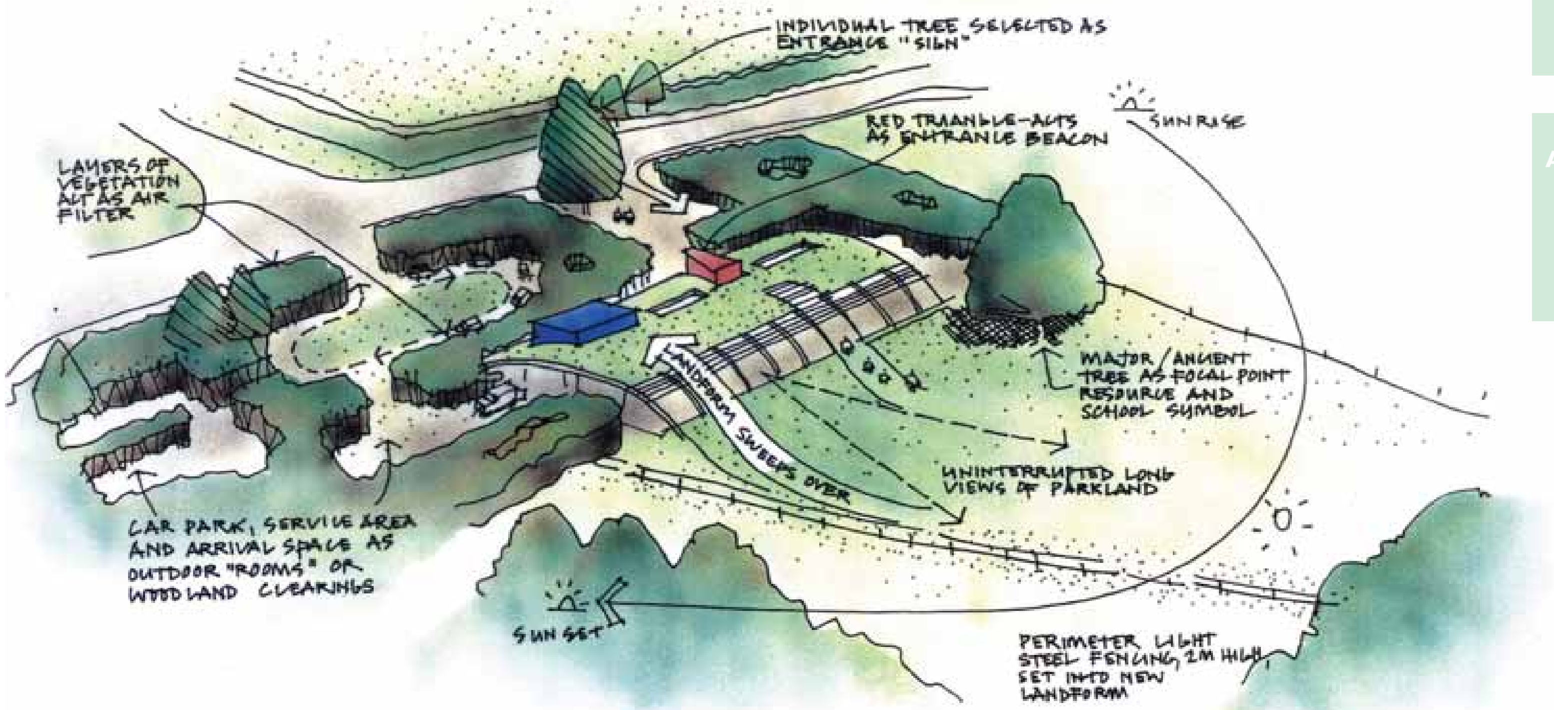
Summary

Riverhead Infants School in Sevenoaks opened in September 2002. It replaced an over-crowded Victorian building which had suffered a fire in the 1990s, and was believed to have the worst accommodation of any school in Kent (nine classrooms were in temporary huts).

Selling off the site realised around £1.5 million, and a further £1.06 million was available under the government's New Deal for Schools initiative.

In recognition that the new school was to be built on a green-field, green-belt site, the architects ADP designed the building to blend into its surroundings both visually and environmentally. This led to a low curved form, with the south-facing elevation blending into an earth bank in such a way that the land, even from a short distance, appears to sweep over the building. The steel-framed, single-storey structure itself is covered by a low, curved roof planted with sedum.

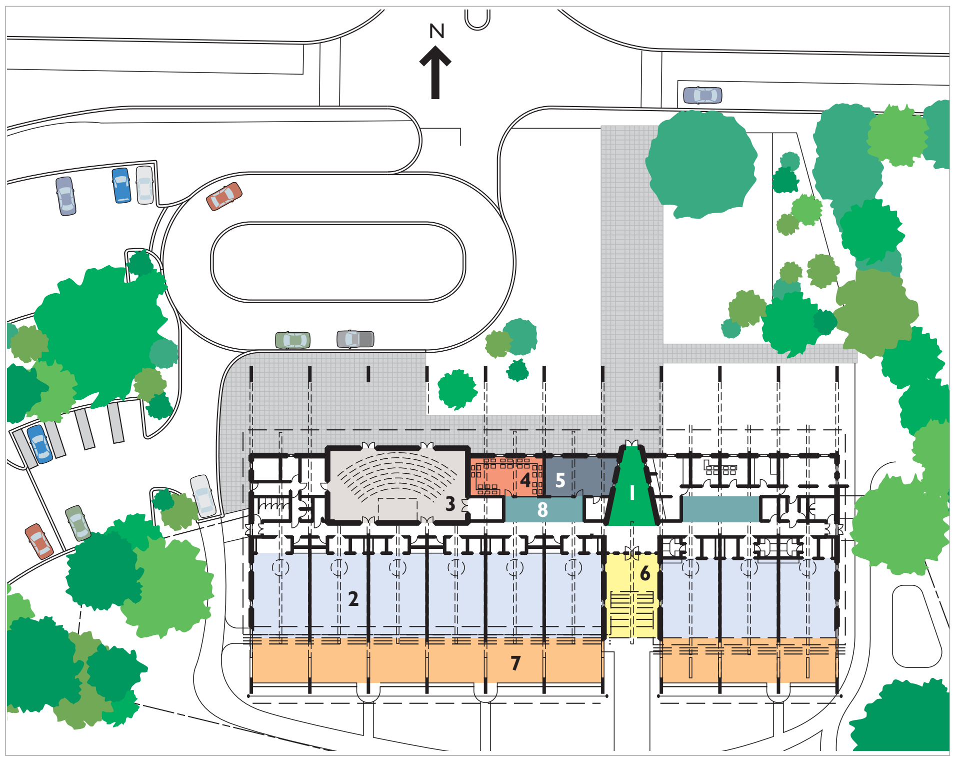
The single-storey height led to a deep-plan, 1,340 m^2 footprint arranged around two winter gardens. There are nine classrooms (varying in size between 60-65 m^2), a computer room, a library, offices and staff room, and a 140 m^2 multi-function hall. Opening rooflights were provided to give extra ventilation and daylight. All classrooms face south, away from the main road and towards a playing field and pastureland.



◀◀ Far left
External teaching areas face south, well away from the main road. Brise soleil protects the classrooms from excessive solar gain in summer.

◀ Left
Sevenoaks Infants School has introduced a walking bus scheme, where pupils are escorted between home and the school, along routes that enable children to join along the way.

◣ Below
All classrooms face south, protected by a sedum roof. Overhanging eaves protect external teaching spaces.



🟩 **1** Entrance
⬜ **2** Classrooms
⬜ **3** Assembly hall
🟧 **4** IT computer suite
⬛ **5** Library
🟨 **6** Brise soleil shaded play area
🟧 **7** External teaching spaces
🟦 **8** Winter garden

Design process

The school's small team of very active governors (among whom were a land agent, a chartered surveyor, and a chartered engineer) wrote the brief for the design competition. This was in-line with the area standards of *Building Bulletin 82*. Once outline planning permission had been granted, the governors ran the project.

The governors decided to use a traditional form of procurement. The school was fully designed by an architect (chosen through a competition) and constructed by a building contractor. In their view this option gave the governors more control over the design and, they hoped, would deliver a better quality building.

The governors also believed that a clear brief for the competition would result in a robust design. Roger Olsen, one of the governors, recalled how important it was for the brief to make clear what a client really wanted from a building: "I wanted to give strong clues as to what we wanted, without being prescriptive," he said. "There were also things the governors specifically wanted, such as a library to signal the importance we wanted to attach to literacy."

▶ Right
Electronic whiteboards and desktop computers are common even in infants' schools.

▶▶ Far right
The school was designed on a child-oriented scale, with low window sills and low vision panels in doors.

◢ Below
Riverhead school was designed with flexibility of IT in mind, and based on the view that every desk may require a PC.

It was also important to ensure that all the careful thinking was done at the beginning. "We did not want a superficial brief that [only] became the real thing later in the design process," said Olsen. "To do that would have been irresponsible, demoralising for the professional team, and could cause huge cost overruns."

The winning design matched the brief in all respects. The governors ranked the desired qualities of the school according to their importance. Issues of high importance were:
- A school that was child-oriented
- Classrooms that were enclosed
- Flexible for changes in the national curriculum
- Flexible for changes in IT
- Good comfort conditions
- Secure
- Easy to maintain
- Within the budget.

Issues of relatively low importance included a landmark style of architecture.

Sustainable design was regarded as being of medium importance. That said, the governors and the local authority were keen to reduce dependence on the private car for getting the children to school – important in Sevenoaks where there are more cars per household than anywhere else in the UK.

This led to the development of walking buses – a group of volunteer adults who walk a specified route and collect children from chosen stops en route, to an organised schedule. Footpaths and crossings were upgraded, and everyone wears a yellow reflective jacket so they can be seen easily.

The walking bus gives children exercise, builds friendships and improves safety. Moreover, it reduces the congestion, pollution and CO_2 emissions associated with the school.

	KWh/m^2/y		kgCO_2/m^2/y*		
	Electricity	Gas†	Electricity	Gas†	Combined
Riverhead 2003-2004	45	48	19	9	28
Riverhead 2004-2005	46	49	20	9	29
Top 25 percent of primary schools††	25	113	11	22	33

* Assuming 0·19 kgCO_2/kWh gas, 0·43 kgCO_2/kWh electricity.

† Gas use adjusted for local temperature.

†† Twenty-fifth percentile for energy consumption recorded in DfES (2004) *Energy and Water Benchmarks for Maintained Schools in England 2002-2003.*

Sustainable design

The brief resulted in a very flexible building, one that can be reconfigured to allow changes in layout in the future. The use of underfloor heating, for example, enables non load-bearing walls to be moved without the need to disrupt the services, the roof, or the floor.

The designers chose local and recycled materials where possible, such as crushed, recycled glass for bedding paving instead of sand.

The school is almost entirely naturally ventilated. Air is drawn in on the south side of the building to avoid noise and pollution from the busy road to the north, and expelled through electrically-controlled rooflights. Each classroom has an openable transfer vent above the door, so that air can find its way out on cold or windy days when it is impracticable to open the glazed double-doors.

The underfloor heating is powered by weather-compensated condensing boilers and controlled by local controls in each classroom. The heating system also has variable-speed pumps to reduce pumping energy when demand for heating falls.

Performance in use

Electricity consumption is more than double the design estimates – perhaps because of extensive computer use and/or very high lighting demand, especially external lighting. Even with the high electricity consumption, the school comes out better than the top 25 percent of existing primary schools for total CO_2.

The school achieves very good performance for gas consumption, with meter readings from 2003-2005 showing that the school used much less energy than anticipated for space and water heating, and less than half of the benchmark figure (see table).

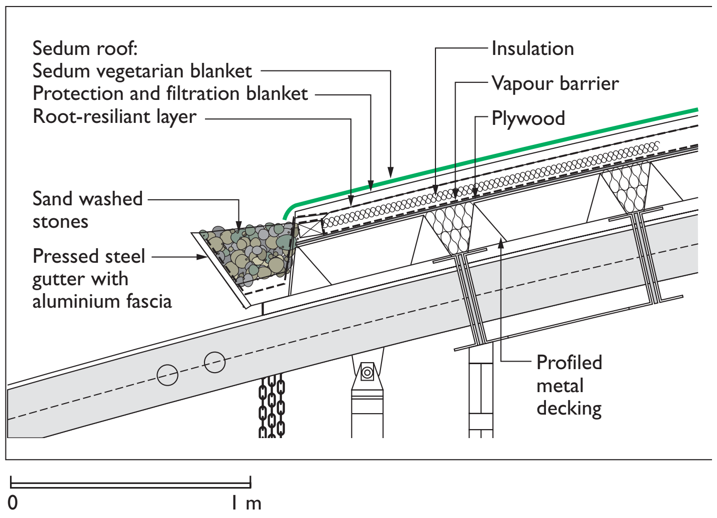
Headteacher Christine Dyer is extremely happy with the school: "It's wonderful," she said. "It's so much easier to run than the old school which had lots of mobile huts which weren't really fit for purpose, and the children are safer."

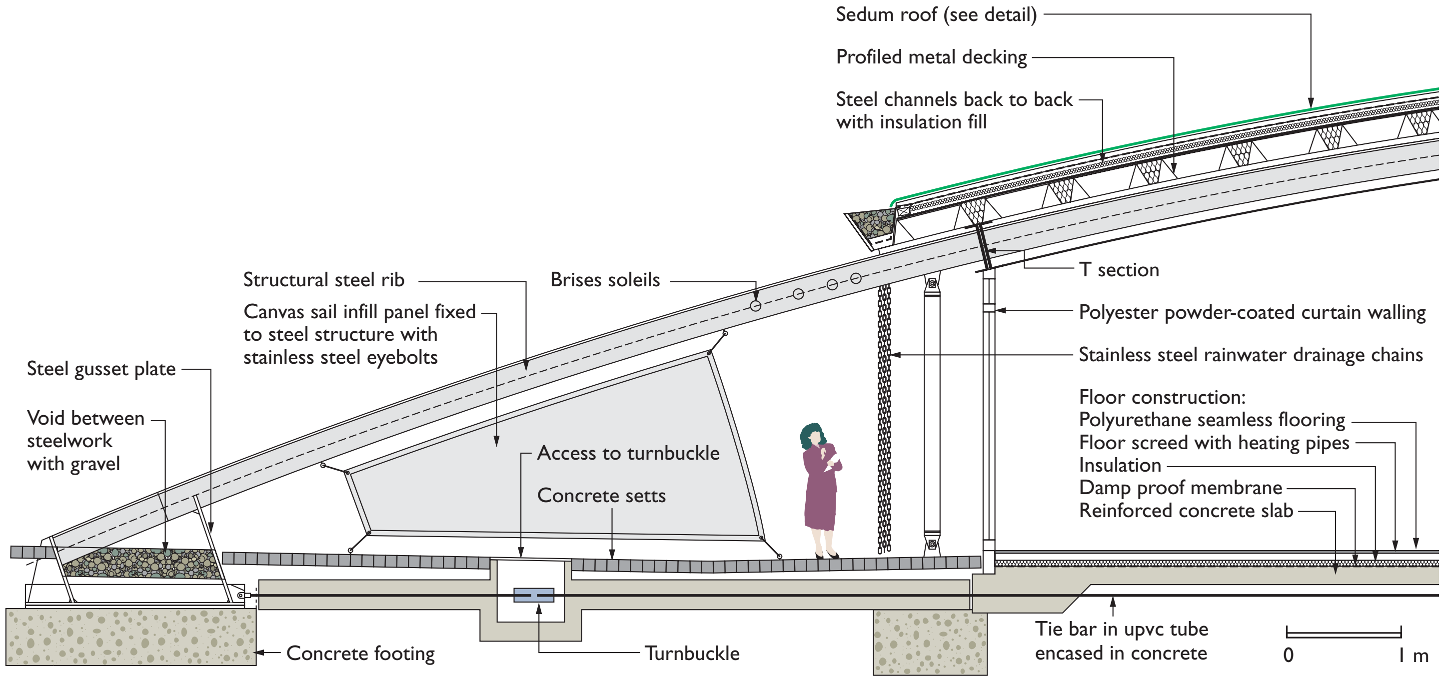
The design team clearly benefited from an expert client team composed of parents and design professionals. E-mail proved to be a more effective form of communication than meetings.

The building was built to within one percent of budget and took just two years and 10 months to construct, from outline planning permission to occupation.

◀ Left
Rooflights enable natural daylight to illuminate the school's two winter gardens.

◢ Right and below
A cross-section of the construction. The highly insulated sedum roof acts as a thermal sink, while external brise soleil reduces solar gain. Note the use of steel chains that act as rainwater drainage channels for the roof.





What this means to you

- Compose a brief carefully, and consider sustainability and flexibility of design
- Remember that the quality of the project is proportional to the quality of the brief
- Be ready for occupation, with security, maintenance and insurance in place
- Ensure there is a suitable contingency on cost and programme
- Ensure that the design detail remains in sharp focus, and recognise that late changes can be difficult and expensive
- Ensure your wants and needs are reflected in the brief
- Ensure the design provides flexibility in teaching the curriculum, and is able to accommodate changes in the national curriculum
- Feedback on the building's performance is useful to everybody in the process

Feedback method	Education		Details	Public domain	Links
	Higher education	Schools			
Design Quality Indicators for Schools		Yes	A version of the DQI system developed by the Construction Industry Council specifically for schools	Yes	www.dqi.org.uk
DesignMySchool	Yes	Yes	A practical tool that enables pupils to become involved in an assessment of their learning environment	Yes	www.designmyschool.com
Joinedupdesignforschools		Yes	An approach that links designers with students to address common problems within school buildings	Yes	www.thesorrellfoundation.com/initiative.html
School Works		Yes	An assessment tool to help improve the design of schools and to aid the briefing process	Yes	www.school-works.org
BREEAM Schools		Yes	A schools version of the established BREEAM environmental rating scheme	Yes (by licensed BREEAM assessors)	www.breeam.org
Building Use Studies (BUS) Occupant Survey and Reporting Method	Yes	Yes	The BUS analysis method generates feedback data, primarily from the occupants, on building performance	Yes	www.usablebuildings.co.uk
Design Quality Method		Yes	A walk-through survey and scorecard approach	No	No direct links but further information is available from NAO and BRE
CIBSE TM22 Energy Analysis Reporting Method	Yes	Yes	A systematic way of undertaking an energy survey	Yes	www.cibse.org CIBSE members have free internet access to TM22. Others will need to buy it
Learning From Experience (LFE)	Yes	Yes	A handbook on how teams can learn from experience	Yes	www.cbpp.org.uk – in the Tools section of the Resource Centre
PROBE – Post-occupancy Review Of Buildings and their Engineering	Yes	Yes	PROBE incorporates public-domain feedback techniques	Yes	www.usablebuildings.co.uk Follow the PROBE menu for examples of buildings which have been studied with the BUS occupant method
School Building Assessment Manual		Yes	A guide for new school buildings consisting of a survey and discussion tools to help understand how school buildings work	Yes	www.usablebuildings.co.uk/fp/OutputFiles/PdfFiles/FR23p1SchoolAssesmentMethods.pdf
Soft Landings	Yes		An arrangement between the client and the design and building team to smooth the handover process	No	No direct links, but more information on www.usablebuildings.co.uk

Tools promoting sustainable design

Design facilitation and feedback techniques are increasingly recognised as vital tools in the design, construction and operation of schools.

There are a growing number of tools which can be used to support the design of schools by engaging the school stakeholders. Some of these, eg BREEAM Schools, promote sustainability, see www.teachernet.gov.uk/sustainableschools. Others, such as the Design Quality Indicators for Schools (DQI for Schools), help designers and clients to understand what is required of a new school. Some, such as s3, encourage the sustainable operation of school buildings.

We have used Post Occupancy Evaluation (POE) as a means of assessing the performance of five of the case study schools. We would have liked to conduct this exercise on more of the schools but were constrained by several factors; for example, some schools were partially occupied or had not been in operation long enough for the exercise to be meaningful.

Kingsmead achieved an unusually high POE score using the Building Use Studies Occupant Survey and Reporting Method and has proved to be a very popular sustainable school. The lessons from Kingsmead and the other case study schools point to how sustainability can be integrated into the design process.

Design facilitation and feedback techniques are increasingly recognised as vital tools in the design, construction and long-term operation of schools. These tools can be used to inform briefing and procurement processes, as well as being a mechanism for reality-checking a school's systems and controls. Feedback techniques are a powerful means to ensure that designers respond to teachers' needs; to validate design decisions to understand what is happening in your school; and to identify where a school needs fine-tuning.

While some methods have been developed specifically for schools, this does not mean that more generic learning and feedback tools can't also be used. See www.usablebuildings.co.uk/fp/index.html for a review of some of the tools available at the time of writing. The following list of tools is not definitive, and other methods are in development.

Tools for design facilitation

The Design Quality Indicator for Schools

The Design Quality Indicator for Schools (DQI for Schools) provides a framework for the assessment of school design. It is used to assist teachers, parents, school governors, pupils, people from the community, local authority clients and building professionals achieve design excellence in new or refurbished school buildings and grounds.

In the initial stage, it is used to help a group of key stakeholders to form a consensus about priorities and ambitions for the design brief. During the design phase, DQI for Schools can be used by the same stakeholder group to assess how well the plans for building work meet the objectives.

Once the building work is completed and the school is in use, the DQI for Schools tool can be used to assess how well it functions in relation to the ambitions of the stakeholder group.

The main DQI tool is a questionnaire designed to be completed at a facilitated workshop. The workshop should be attended by a wide variety of stakeholders who should include teaching and non-teaching staff, pupils, parents, governors and other building users. It contains questions on the type and purpose of the building, grouped into three sections:

- Functionality (with facets of use, access and space)
- Build quality (including performance, engineering and construction)
- Impact (form and materials, internal environment, urban and social integration, character and innovation).

The Building Schools for the Future programme uses the DQI for Schools, together with involvement from the Commission for Architecture and the Built Environment (CABE), to promote design quality throughout the briefing and design processes.

The DQI for Schools also provides feedback for benchmarking and to aid the briefing process of new projects. The process requires a facilitator. The CIC can identify one on behalf of an organisation, or an individual can be sent on a two-hour training course. Go to www.dqi.org.uk/schools

The DQI for Schools was applied to help establish the design brief for an extension to the existing school at Parliament Hill School. Go to www.dqi.org.uk/DQI/common/CaseStudy2.htm

DesignMySchool

DesignMySchool is a practical tool devised as a set of simple interactive questions to involve pupils in an assessment of their learning environment. It allows them to rate various aspects of the design of their school, feed back information to their teacher and make constructive suggestions to support the quality of learning in the school.

Depending on the school's objectives, DesignMySchool can be used by an entire school, individual classes or smaller groups.

While DesignMySchool is intended for secondary pupils, other age groups could also use it with support and explanation from teachers.

Students can work through the on-screen questions in pairs or small groups as this promotes discussion and engagement. Message boards covering a range of subjects have been set up to promote communication between schools.

www.designmyschool.com hosts practical tools, ideas and resources to enable pupils, teachers and parents to participate "in the innovation of their school".

The website allows the visitor to test DesignMySchool on a demonstration account. For more information go to ww3.ultralab.net/projects/designmyschool/projectdescription and click on the first link.

Joinedupdesignforschools

In joinedupdesignforschools (a programme created by the Sorrell Foundation), designers work with teams of students to find a design solution for common problems within the school.
Each project has four phases:

- **The challenge**: the client team, comprising 10 to 15 students selected by the headteacher, identifies the issues to be addressed
- **The brief**: The team creates a brief to demonstrate the problem to the designer
- **The conversation**: Over a three-month period, the client team meets with the designer, completes visits and discusses the designer's original ideas
- **The concept**: A final design concept is accepted by students, and the solution is presented to the school community. Between 2001 and 2004, around 100 students from 65 schools worked with 50 designers using joinedupdesignforschools.

Projects completed revealed a number of common problems involving toilets, social areas, sixth form and dining spaces, student storage, school uniform design, and school identity. See www.thesorrellfoundation.com/initiative.html

School Works

School Works involves architect- and design-led assessments, but is also relevant to clients such as school governors, parents and the wider community.

Linked to the process is the School Works' online game, a computer game for pupils with curriculum materials, lesson plans, worksheets and teaching guides that can be used to encourage class discussion on school design.

School Works' publications and case studies promote a consultative approach to design. The design process used at Kingsdale Secondary School is outlined in the School Works' Toolkit.

The participatory approach involves school users in the widest sense: pupils, staff (teaching and non-teaching) and the community working together with an interdisciplinary design team. For more details and case studies go to www.school-works.org/dSite_kingsdale.asp

Tools for monitoring and feedback

BREEAM Schools

The environmental assessment method, BREEAM, was introduced in the mid-1990s to assess the environmental designs of new and significantly refurbished buildings.

A version of BREEAM tailored for schools was introduced in 2004.

BREEAM Schools addresses a range of environmental considerations in a simple, easy to understand and flexible way. It also helps design teams identify and address environmental issues during the design and construction phases.

The methodology identifies design decisions that may harm or enhance the environment under eight broad headings: management, energy use, water, health and well-being, pollution, transport, land use and ecology, and materials and waste.

By adopting measures in response to the above issues, designs are awarded credits. The number of credits achieved is used to calculate an overall score for the building, which is translated into a BREEAM Schools rating of Pass, Good, Very Good or Excellent.

More details about BREEAM Schools are given on the sustainable design website www.teachernet.gov.uk/sustainableschools and at www.breeam.org/schools.html

BUS Occupant Survey and Reporting Method

The Building Use Studies (BUS) Occupant Survey and Reporting Method is a questionnaire-based survey and benchmarking tool for the rapid and comprehensive study of user needs. Adaptable for a range of building types, it comprises a self-completion occupant questionnaire, the results from which can be compared to a national benchmark database.

The BUS will carry out a survey on a consultancy basis, or will make it available to designers, architects and university research teams under licence.

The survey method can be used as the basis for occupant surveys of schools, either alone or in conjunction with other techniques as part of post-occupancy evaluation or diagnostic performance studies.

Five of the case studies in this guide were analysed using the BUS method.

The survey itself covers a variety of occupant satisfaction indices, such as winter and summer temperature, air quality, noise, lighting, health and overall comfort.

The Design Quality Method

The Design Quality Method (DQM) was developed by the Building Research Establishment (BRE) specifically for the schools and healthcare sectors. The tool has been used on PFI schools for the National Audit Office and in a number of national audits of recent schools.

The DQM consists of a walk-through survey and scorecard conducted by a team of experts. At the time of writing the methodology is not in the public domain, but conducted by the BRE. The results of the PFI studies can be obtained via National Audit Office publications and www.bre.co.uk

Energy Analysis Reporting Method

The Energy Analysis Reporting Method (EARM) is published by the Chartered Institution of Building Services Engineers as CIBSE TM22: Energy Analysis Reporting Method. The method is a systematic way of undertaking an energy survey, reporting the results and calculating likely savings from changes in use, technology or management.

The Energy Analysis Reporting Method uses a three-stage method for collecting and reporting annual energy consumption, cost and CO_2 emissions data:

- Simple fossil fuel and electricity consumption indices per square metre of floor area
- Allowances for special building and energy uses
- Detailed assessment of building and system performance.

The Energy Analysis Reporting Method is useful at any time in the inception, design development and running of a school. The technique can be used to summarise design information and predictions, and act as a cradle-to-grave benchmarking tool. The method is quoted in Approved Document L2 of the 2006 Building Regulations, and is an element of the *Part L Compliance Toolkit* published by the CIBSE.

TM22 can be used with CIBSE TM39 Building Energy Metering, which provides guidance for owners and operators of existing buildings, facilities managers and designers on cost-effective energy metering and sub-metering. For more information search the CIBSE website at www.cibse.org

Learning From Experience

Learning From Experience (LFE) is a handbook on how teams can learn lessons from their work. David Bartholomew Associates developed the procedure in 2003.

Learning From Experience involves a method of facilitating interviews and discussions in which a team learns from experience in a positive and non-confrontational manner.

The Learning From Experience Manual describes techniques for resourcing, setting-up, running, leading and reporting on one or more feedback workshops and/or interviews to extract the experiences of a project team.

The process is useful at any time, but in particular:

- Before starting on a project (foresight reviews)
- While undertaking a project (insight reviews)
- When a project is over (hindsight reviews).

Typically there are five phases to an exercise: planning, gathering information, creating knowledge, sharing knowledge and applying that knowledge.

The Learning From Experience Manual can be downloaded free of charge from www.usablebuildings.co.uk/fp/index.html by clicking on the Learning From Experience link.

The PROBE system

PROBE (Post-occupancy Review Of Buildings and their Engineering) is a collective term for the assessment methods used in the post-occupancy evaluation of 18 notable UK buildings, the results of which were published in Building Services Journal between 1995-2001.

The PROBE project developed a suite of robust and empirical assessment procedures, including:

- A preliminary questionnaire for the building or facilities manager
- The Building Use Studies occupant survey, including a journey to work module
- The CIBSE TM22 Energy Assessment and Reporting Methodology
- A building envelope pressure test to CIBSE TM23 conducted by the BRE or BSRIA.

The package of survey techniques can be used on any building, but principally public, commercial and educational buildings.

All the methods can be used independently, but used together they have proved to be a very effective and pragmatic way of unravelling the technical and environmental performance of a building, alongside the perceptions and experiences of building occupants.

The PROBE section of www.usablebuildings.co.uk has most of the surveys available for download.

School Building Assessment Manual

The School Building Assessment Manual is a US-developed guide for new school buildings. It consists of a collection of survey and discussion tools to help people understand how schools work. It was designed to apply to primary and secondary school buildings (known as K-12, for Kindergarden through to year 12, in the USA).

The assessment manual includes a walking tour, photography-based questionnaires, a wish poem, and discussions in small groups.

The survey methodology is geared to architecture and design assessment although it has wider relevance to school governors and local authority decision-makers.

The School Building Assessment Manual was developed at the School of Architecture, North Carolina State University, and supported by the National Clearinghouse for Educational Facilities.
www.edfacilities.org/pubs/sanoffassess.pdf.
For more information go to
www.usablebuildings.co.uk/fp/index.htm

Soft Landings

Soft Landings is an innovative arrangement between a client and a design and building team to smooth the often fraught transition leading up to the handover of a building. Soft Landing methods include contract clauses to smooth the transition of a building through completion to beneficial occupancy.

The formal contractual approach was developed by a team of consultants and researchers, facilitated by the Estate Management and Building Services department at the University of Cambridge, and latterly taken forward by Mark Way at consulting firm RMJM.

For more information read *Making feedback and post-occupancy evaluation routine: Soft Landings – involving design and building teams in improving performance* by Mark Way and Bill Bordass, published in Building Research and Information, Volume 33 Number 4. It can be viewed at www.tandf.co.uk/journals/pr.asp

For a review of Soft Landings see www.tandf.co.uk/journals/press/rbri.pdf

Additional sources of information

Two publications are available from the **Commission for Architecture and the Built Environment (CABE)**: *Being Involved in School Design: a Guide for School Communities, Local Authorities, Funders and Design and Construction Teams*, and *Picturing School Design*. For more details go to www.cabe.org.uk

The **INTEGER (Intelligent and Green) Education Project** provides a framework to stimulate pupil's interest and understanding of real-world activities. It does this by integrating these into both theoretical and practical parts of their National Curriculum activities. For more details go to www.integerproject.co.uk/educate.html and www.integerproject.co.uk/images/photos/education_pack.pdf

Workout is a secondary school grounds toolkit. For more details go to www.ltl.org.uk

The **Handover of Office Building Operations (HOBO)** protocol has been produced by the BRE. It is a pro-forma checklist of items critical to a successful handover. While designed for office buildings, the HOBO principles are broadly applicable to schools as it encourages information exchange, training, demonstration and fine-tuning. It is available as BRE Digest 474 from www.brebookshop.com. See also projects.bre.co.uk/earlypoe/POEinDLP.pdf

ConstructionSkills, the sector skills council for construction, aims to provide resources to help promote teaching and learning through construction, as well as keeping young people informed about their construction career options.

For more details go to www.citb-constructionskills.co.uk/curriculumcareers/

Further reading

Being Involved in School Design: a Guide for School Communities, Local Authorities, Funders and Design and Construction Teams, Commission for Architecture and the Built Environment, CABE 2004.

Designing School Grounds, Schools for the Future publication, to be published 2006 by the DfES.

Grounds for Sharing, a guide to developing special school sites, Jane Stoneham, 1996, Learning through Landscapes, ISBN 1 872 865 232.

Lessons from School Buildings In Norway And Germany Design & Construction of Sustainable Schools Volume 1, The Lighthouse on Sustainability, 2005, ISBN 1 905061 07 2, www.sust.org

Picturing School Design a visual guide to secondary school buildings and their surroundings using the Design Quality Indicator for Schools, CABE 2005.

Primary Ideas: Projects to Enhance Primary School Environments, The Stationery Office, www.tso.co.uk 2006, ISBN 0 11 271183 9.

Further information

British Trust for Conservation Volunteers – School Advisory Service
www.btcv.org/commgrp/school.html

BSRIA
www.bsria.co.uk

Building Research Establishment
www.bre.co.uk

Cheshire County Council guidance on sustainability in schools is available via
www2.cheshire.gov.uk/ecoschools/

Chartered Institution of Building Services Engineers
www.cibse.org

Conservation Works
www.conservationworks.com

Crispin School in Street in Somerset has included sustainability within the whole ethos of the school. Go to www.nc.uk.net/esd/school_management/ws_case_studies/sec_crispin_01.htm and www.crispin.somerset.sch.uk/welcome.htm

DfES energy and water benchmarks can be accessed at
www.dfes.gov.uk/rsgateway/DB/SBU/b000477/index.shtml
www.dfes.gov.uk/rsgateway/DB/SFR/s000449/SFREandW2602-web.pdf
www.databases.dft.gov.uk/schools/

Eco-schools
www.eco-schools.org.uk

English Nature
Information on the Nature for Schools initiative can be found at
www.englishnature.org.uk/science/nature_for_schools/

Extended Schools
For support for extended schools, go to
www.teachernet.gov.uk/extendedschools

Food
www.teachernet.gov.uk/wholeschool/healthyliving/foodanddrink
www.foodinschools.org

Global Action Plan
www.globalactionplan.org.uk

Globe Programme
www.globe.gov/

Groundwork
www.groundwork.org.uk

Growing Schools Programme
The Growing Schools Programme aims to encourage schools to use their grounds to deliver the curriculum.
www.teachernet.gov.uk/growingschools

Healthy Schools
www.wiredforhealth.gov.uk

Learning through Landscapes provides training and support for the design use and management of school grounds.
www.ltl.org.uk

Local Authority Sustainable Construction Network
www.wellbuilt.org.uk/lascn/

National Playing Fields Association
The National Playing Fields Association is the national organisation responsible for acquiring, protecting and improving playing fields and playgrounds, tel: 020 7833 5360.
www.nfpa.org

Parliament Hill School
For information on sustainability measures at Parliament Hill School, go to
www.dqi.org.uk/DQI/common/CaseStudy2.htm

Royal Institute of British Architects (RIBA)
www.riba.org

School Councils
www.schoolcouncils.org

Teachernet
www.teachernet.gov.uk/sustainableschools is a web-based service, which brings together sources of advice and practical support for teachers and school heads and governors.

Travel planning
www.teachernet.gov.uk/sustainableschools/framework/framework_detail.cfm?id=41

Water in schools
www.waterintheschool.co.uk

Wildlife Trusts
www.wildlifetrusts.org/index.php?section=localtrusts

WWF Learning for Sustainability
Largue Primary School in rural Aberdeenshire rose to the challenge of delivering Education for Sustainable Development in a small school. Go to www.wwflearning.co.uk/data/files/largue-primary-school-making-a-start-energy-saving-school-pdf-131.pdf