A special report for the 2007 BSRIA Briefing

PRIMARY SCHOOL CARBON FOOTPRINTING

adjusted carbon factors, January 2008

A Victorian school, a 1970s school, and a post-millennium sustainable school

Which one has the lowest carbon footprint?

CARBON FOOTPRINTING
PRIMARY SCHOOLS

BSRIA has carried out a carbon footprinting study of three primary schools – a school built over 100 years ago, a school built in the 1970s, and a new school designed to the latest building standards – to find out which has the most sustainable low energy performance

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Kingsmead Primary School, Northwich, Cheshire.

INTRODUCTION

Schools begin to be obsolete almost as soon as they're occupied. For a start they're subject to the ultimate agents of erosion: children. Second, the school curriculum is changing so fast and so radically that any school over 10 years old is arguably out of date. Third, new teaching technology in the form of computers and electronic whiteboards is putting pressure on power supplies and comfort conditions.

All schools are becoming staturated with technology, but most are not designed to handle it. Energy use is soaring at the one time that carbon dioxide emissions need to be cut dramatically.

Gordon Brown pledged £45 billion to rebuild and transform the schools estate. This massive capital investment is being used to create more sustainable schools designed to use less gas, electricity and water, and emit less carbon dioxide.

But are the new schools truly more energy efficient than the ones they're replacing? Does new automatically mean better – and more sustainable? Are new schools easier to manage and maintain? Moreover, is it true that new schools deliver better-educated children?

To find out, BSRIA has carried out a detailed study to identify the carbon footprint of three primary schools from three eras of school building – the Victorian period, the early 1970s and an award-winning school built in 2004.

The carbon footprinting exercise used two main methods of assessment: an energy analysis of each school's gas and electricity consumption (and resulting carbon dioxide emissions), and an occupant satisfaction study to determine whether the energy being used was delivering comfortable and productive schools.

All data were compared against prevailing national benchmarks. Primary schools were chosen for ease of comparison, as they are relatively simple and are subject to fewer variables than middle or secondary schools.

The three schools in the study are Leigh Primary School in rural Kent, built in the late 1890s, Michael Faraday Primary School in Southwark, built in the early 1970s, and Kingsmead Primary School in Cheshire, built in 2004.

Leigh Primary School, Leigh, Kent.

Photograph©Roderic Bunn/BSRIA


Michael Faraday Primary School, Walworth, Southwark.

Leigh Primary School

Leigh Primary School serves a small village of the same name, 10 miles south of Sevenoaks in Kent. It was built in the late 19th Century to classic proportions and layout: two-storey cottage-style architecture with high ceilings and generous glazing. Over the years the accommodation has been expanded, and the ground floor of the old school house altered to provide more classrooms.

The site is constrained, and the only major additions in over 100 years have been a single classroom extension and a sports hall, constructed in 2004. Otherwise the school is more or less original. It is owned by Kent County Council.

The school is home to 21 teaching and administrative staff and 121 children, with the normal occupancy level around 135. It has five open-plan classrooms, most of which double-up as linking corridors. One classroom has become an ICT room with 10 desktop computers. All classrooms have electronic whiteboards and projectors. The catering kitchen is the smallest of the three schools studied.

Most children and staff live locally, although a few travel from Tunbridge Wells and Tonbridge. Infrequent local bus services mean that some children travel by car.

In energy terms the school's original Victorian classrooms are heated by direct gas-fired heaters. These are 10 kW (max) Rinnax Energy Saver units of varying ages, with the newest around 12 years old. Classrooms created from converting the ground floor of the school house are heated by radiators served by a Potterton Netaheat gas-fired boiler. Small electric heaters serve a classroom constructed in 1999.

A new unvented gas-fired boiler serves a new sports hall. Hot water is supplied to two large fan-convectors along one wall. Two roof-mounted fans can be operated in supply or extract mode, depending on need, to supplement ventilation from windows. The latter are openable by wall-mounted winders.

Ventilation in the main school is by openable windows. Most windows are original, and all are single-glazed. The headteacher, Wendy Wallace-Holman, is keen to improve the glazing for acoustic as well as thermal reasons, but lacks the budget to do so. There has been little or no recent investment in improving the school's thermal insulation, so the school tends to be cold in winter. Freestanding electric convector heaters are pressed into use on very cold mornings.

Despite a lack of investment, the school takes its environmental responsibilities seriously. It signed up to the Eco-School initiative in 2001 and achieved a Silver Certificate in 2005. It is now working towards Green Flag status. Improvements have included cistern timers on urinals, spray taps for washbasins, and a switch-off policy for all electrical systems such as whiteboards and lights. Children are employed as light monitors to ensure lights are switched off.

Energy management is primarily conducted by the caretaker, who also switches off and defrosts the school's fridges and freezers during school holidays. All paper is recycled, and the school has invested in composting bins and a water butt – simple things, but they all contribute to reducing the school's carbon footprint.

An OFSTED visit in late June 2007 rated the school as 'good' in all respects.

Michael Faraday Primary School

Michael Faraday School serves the local community of Walworth in south-east London. It is located within the Aylesbury Estate, said to be the largest social housing complex in Europe. The school serves around 350 pupils between the ages of 3-11 years.

Almost all the pupils attending the school live in the Aylesbury Estate, and over 60 percent of them are eligible for free school meals – high compared to the national average. The school therefore has a fully equipped catering kitchen.

The single-storey school buildings were constructed in the early 1970s to a style and standard typical of the era: a highly-glazed, lightweight timber and brick construction.

The school was built on the site of an earlier Victorian school, of which only the original dining block remains. This ornate building was used to house a small swimming pool, but this was taken out of use some years ago when the building fell into disrepair. The separate nursery and administration blocks have separate heating systems.

Photograph©Roderic Bunn/BSRIA

Cramped and in disrepair – but still rated 'outstanding' by OFSTED for its teaching – a typical classroom at Michael Faraday Primary School. The reality of the lived-in primary school classroom is a world away from elegant concepts shown in architects' design submissions.

Photograph©Roderic Bunn/BSRIA

The abandoned swimming pool in Michael Faraday Primary School, located in the former Victorian dining block.

The school's 16 classrooms are mostly open-plan, but 35 years on the school is cramped and no longer supports the needs of the curriculum.

The school was up for replacement at least eight years ago, but plans were put in abeyance when the decision was taken to redevelop the Aylesbury Estate. "The carrot's been dangling forever," says a rueful headteacher, Karen Fowler.

As a consequence very little money has been spent on repair and maintenance. Structurally, the school is in very poor condition, with aged boilers running flat out in winter desperately trying to heat a building where the rooflight frames have rotted away. The school buildings have deteriorated so far that the caretaker can only do what he calls "crisis management".

Some original roof-mounted extract fans (designed to purge heat from classrooms in summer) no longer work, which leads to overheating in summer. In the hall, the high level windows no longer open, and some lead flashings on the roof have corroded away.

The two Kayanson gas-fired boilers are run without summer and winter settings. There are no radiator controls or thermostatic radiator valves.

Heating for the classrooms is from air-blowers served by hot water from the main boilers. These recycle and warm the room air. In summer, around twenty 3 kW desk fans keep the occupants cool; in winter these are replaced by a similar number of convector heaters.

Staff at the school do not try to manage the use of energy, although they have a keen desire to improve its carbon footprint. "We deserve a new school because we've been living in shabby conditions for years, freezing in winter and boiling in summer" says Karen Fowler.

The school will be replaced in 2008. Energy efficiency is high on the list of requirements. The architect SMC Alsop was appointed in July 2007 to lead the design.

Kingmead Primary School

Kingsmead Primary School was opened in September 2004. It serves a new housing development in Northwich, Cheshire. As the school was an attempt to create an exemplar of sustainable design and construction, it is brimming with sustainable design features and sources of renewable energy.

The school has a curved corridor, running more-or-less east-west, which acts as the main circulation route. 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.

Rooflights fitted with motorised solar blinds allow solar gain when it is needed in winter, but help keep it out in summer. A fully-equipped catering kitchen serves the school's 210 pupils. 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 concrete block internal walls are not load-bearing. This provides flexibility for changing room layouts.

The school makes extensive use of green technology, such as a 60 kW wood-chip boiler (supplemented by a gas-fired condensing boiler), solar panels to top-up the domestic hot water system, and photovoltaics for electricity generation. The photovoltaics deliver 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.

The rainwater recovery system features a perspex drainpipe and an electronic panel to show how much rainwater is being collected. This provides entertainment for pupils when it is raining hard, and education material for maths and geography lessons. The schoolchildren have formed an eco-council which meets once a fortnight to discuss sustainability activities. The school achieved Green Flag status in January 2007.

Photograph©Trevor Smith/DFES

Careful space planning and cost control enabled the architects at Kingsmead Primary School to provide winter gardens between each classroom and the playground. These act as thermal buffers and places to store muddy shoes.

CARBON FOOTPRINTING

The carbon footprint of all three schools was assessed using the same methodology (see box: "carbon footprint methodology"). All contextual variables were reduced by correcting for local weather conditions, the number of pupils, and by reporting energy consumption and carbon dioxide emissions per square metre of treated floor area.

The primary assessment covered the major sources of carbon dioxide: fossil fuels, electricity, and water supply for similar 12 month periods, between March 2006 and April 2007. Journey to school and food miles were not measured, although some information was obtained by interview.

All three schools have been compared with the best available energy benchmarks. These are given in *Good Practice Guide 343 Saving Energy – A Whole School Approach* (*GPG 343*). However, the benchmarks (based on 2001 data) do not reflect the greater use of computers and the recent introduction of electronic whiteboards, all of which contribute to higher electrical loads. (It is no surprise that even new schools are struggling to meet good practice or even typical levels for electricity consumption.)

At first glance it appears that Kingsmead School is an exemplar of sustainability. It has the icons of green design, such as the biomass boiler and solar water heating, and these features have been successfully linked to the curriculum. Also, the occupants think the building is wonderful. What, then, about the school's energy consumption?

Post-occupancy assessments reveal that all new buildings require about two years to settle down into a pattern of performance: one year for problems with systems to be identified, and another year for the remedial actions to prove successful. Kingsmead Primary School was studied in early 2006 when some of the problems with the energy systems had not been resolved.

Photograph©Trevor Smith/DFES

Above: The classrooms at Kingsmead Primary School have been orientated to face north, with rooflights to improve the amount of daylight into the space. Compare this with one of the classrooms at Michael Faraday School, *below*, where blinds are down and lights are on even on bright days. This is often the case in schools that face south – even new ones.

Photograph©Roderic Bunn/BSRIA

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Kingsmead's biomass boiler

Carbon footprint methodology

Energy consumption
Energy consumption was calculated from metered readings of electricity and fossil fuel (natural gas) for the most recent available year. In most cases a mix of actual or customer readings were used, but in a few cases the use of estimated readings could not be avoided. Estimated utility readings are notoriously unreliable, as are certain types of meter.

Both Michael Faraday and Leigh schools received credit notes for over-estimated readings during 2006. For example, Michael Faraday School received a credit note (not a rebate) for £5146 in 2006, which underlines the importance of keeping customer records and never paying a bill based on estimated consumption.

The resulting kilowatts per square metre and carbon dioxide figures were obtained by inputting the energy data into the spreadsheet program in *CIBSE TM 22 Energy Assessment and Reporting Method*. All the historic heating data were corrected using regional degree-day (weather) data for the measured period.

Electricity is more polluting than natural gas. A carbon factor of 0·43 kgCO_2 has been used for compatibility with the 2002 benchmarks (*Good Practice Guide 343 Saving Energy – A Whole School Approach*). However, the UK's energy mix is relying less on nuclear and more on coal, so a more contemporary carbon factor of 0·52 kgCO_2 has also been applied to the electricity data.

Where possible, adjustments have been made for the percentage of heating provided by electricity. No allowance in the Kingsmead calculations were made for the calorific contribution of the woodchip boiler, therefore the total heating energy demand may be higher than the figures quoted for utility-supplied power. Readers can make their own analysis based on the 17 m^3 of woodchip delivered over the winter of 2006-2007. (Wood chip energy density is between 2-4 kWh/kg at a bulk density of 175-350 kg/m^3.)

Catering power was not measured separately. For the record, the DFES energy surveys estimate that four per cent of energy in a primary school is accounted for by the catering equipment.

Travel data was obtained for Southwark, but the carbon consequences of the various modes of travel used by staff are subject to many variables. The three school contexts are also very different (rural, suburban and urban, with varying access to public transport). So for this comparative study, an analysis of travel miles and food miles was not included.

Water consumption
Water consumption data was obtained from metered readings for a representative year and compared to the benchmark figures in *GPG 343*.

Kingsmead and Leigh primary schools had very accurate water consumption data from actual readings. Michael Faraday Primary school had a new water meter fitted in June 2006. Although the data for the summer (unoccupied) period is missing, extrapolation from actual data enabled an accurate assessment to be made for the year. Sensitivity analysis had little effect on the reported figure.

The wood-chip boiler has proved the most difficult item to get working properly and contributed to much higher consumption of gas than was assumed by the design team. After months of investigation it was found that a temperature sensor was installed in the wrong place. The sensor should have been installed in the mixed-flow pipework between the back-up gas-fired condensing boiler and the woodchip boiler, but unfortunately it was in a location that favoured the back-up boiler.

When heating was needed, the woodchip boiler reacted more slowly than the automated controls system desired. The school's controls system then called for the gas boiler to provide instantaneous heat. The woodchip boiler tried to settle back into tick-over mode, but snuffed out too easily.

The control problem with the wood-chip boiler has contributed to much higher consumption of gas than was assumed by the design team. Kingsmead school is very well insulated, so with a minimal heating load in autumn and winter, the woodchip boiler is struggling to run at low loads. Not surprisingly the gas boiler is taking the lead.

Electricity use at Kingsmead includes three cctv cameras and external security lighting. Mindful of the high electrical burden of this equipment, the school has recently reprogrammed the security lighting to come on later and go off earlier. The energy data reveals that Kingsmead School is using 59 kWh/m^2/y for electricity and 119 kWh/m^2/y for gas. This compares with 25 kWh/m^2/y and 110 kWh/m^2/y respectively for good practice quoted in *GPG 343*.

Despite efforts to control electrical consumption, Kingsmead Primary School is still consuming double the best practice figure (and 28 kWh/m^2/y more than the typical benchmark). As the end-uses in Kingsmead are not metered separately (internal lighting, security lighting, pumps, controls, and small power loads), it is not possible to know definitively where the power is being used.

Gas consumption is surprisingly high for an exemplar school. Even with the biomass boiler and high levels of thermal insulation, the school is no better than the top 25 per cent of schools on the Department for Children, Schools and Families (DCSF) database when it might have been expected to beat it.

In the winter of 2006-07, 17 m^3 of woodchip was used in the biomass boiler. This has not been included in the footprinting exercise (see box: Carbon footprint methodology).

In 2005-06, water consumption at Kingsmead was very low, at 2·22 m^3/pupil/y, below the DCSF 'good practice' benchmark of 2·7 m^3/pupil/y. However, in 2006-07, the figure jumped to 5·14 m^3/pupil/y, way above the DCSF 'typical' benchmark of 3·8 m^3/pupil/y. This was partially due to problems with the school's Stormsaver rainwater recovery system, used for toilet flushing and grounds irrigation. Owing to a filter problem the system was out of action at the end of 2006 and the tanks were empty for a time. The winter was also uncharacteristically dry.

This is evidence that sustainable technologies offer no automatic guarantees of good performance.

Unlike mains supplies, even basic energy-saving technology like rainwater recovery has to be managed and maintained by school staff in order to sustain a low-carbon footprint.

Overall, Kingsmead's carbon dioxide emissions for 2006-2007 were 48 $kgCO_2/m^2/y$ using the CO_2 conversion factor in *GPG 343* (see box 'Carbon footprint methodology'). As a comparison, the DCSF would expect to see the top 25 per cent of primary schools achieve 33 $kgCO_2/m^2/y$ or better.

So what about the 1970s primary school? Unlike Kingsmead, Michael Faraday school has no pretensions to low energy. Everything – the aged boilers, the fluorescent lighting, and the original blower heaters – effectively run flat out. There is no energy management and no water saving devices like spray taps or urinal flush controls. It's not that the school staff don't care – they just have few options in a school with rotting windows and poor insulation. Despite this, the staff and children are very environmentally aware.

The carbon footprint for Michael Faraday Primary School proved difficult to determine as the school does not monitor its energy meters. It also tends to pay bills based on the utilities' estimated readings, which are notoriously inaccurate. As an example, between June and September 2006 the school received a credit of £5146.

With so few actual readings, it was only possible to estimate Michael Faraday's electricity consumption to be around 85 $kWh/m^2/y$. This is about double the DCSF 'poor' benchmark for primary schools of 47 $kWh/m^2/y$, and is high enough to suggest significant out-of-hours consumption or meter reading inaccuracies. The nursery wing has some electric storage heaters, and these might be a contributing factor.

The estimated gas consumption for 2006/07 was, at 177 $kWh/m^2/y$, above the 'typical' value of 157 $kWh/m^2/y$. Overall, the carbon footprint of Michael Faraday Primary School lies around 66-71 $kgCO_2/m^2/y$.

At 7·36 m^3/pupil/y, water consumption at Michael Faraday Primary School is the highest of the schools in this study, and is high enough to suggest that water leakage might be a factor.

Although Leigh Primary School is a small school (597 m^2) and has modest catering facilities, it's poorly insulated and not very airtight. The data shows that Leigh Primary School accounts for 46 $kWh/m^2/y$ for electricity and 168 $kWh/m^2/y$ for gas. At 0.43 carbon factor, this equates to a carbon footprint of 51 $kgCO_2/m^2/y$, about four percent worse than Kingsmead.

The water consumption at Leigh Primary School is commendable – even more so compared to the performance of Kingsmead in 2006-07 when the rainwater recovery system failed. Leigh Primary may be a smaller school, but clearly the investment in water-saving devices is paying off.

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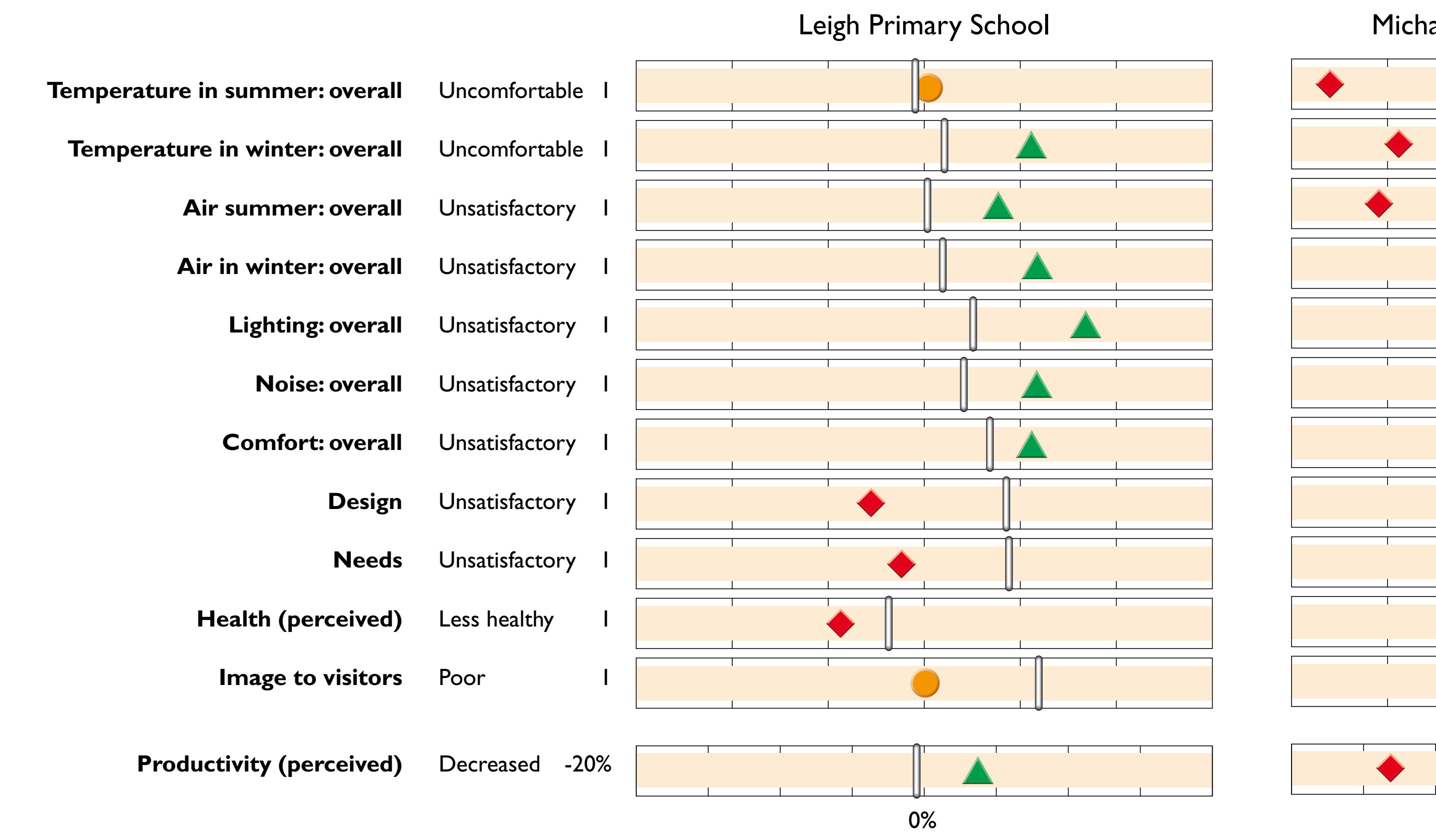
Photograph©Roderic Bunn/BSRIA

The rooflights at Michael Faraday Primary School no longer open and the shading is in poor repair. Makeshift solar control is achieved with black plastic in the far corner. The ceiling tiles regularly break up due to water damage.

Photograph©Roderic Bunn/BSRIA

The reality of older schools where little money is available for improvements: *ad hoc* and largely ineffective solar shading at Leigh Primary School, which also creates conflicts with window opening.



Green triangles represent mean values significantly better or higher than both the benchmark and scale midpoint.
Amber circles are mean values no different from benchmark.
Red diamonds are mean values worse or lower than benchmark and scale midpoint.

Kingsmead Primary School

An occupancy survey was carried out by Building Use Studies in March 2006, a year after occupation. The survey was funded by the Department for Education and Skills.

The results were startling: Kingsmead Primary School falls in the top 10 percent of buildings in the current BUS dataset, making it one of the best school buildings BUS has surveyed. Occupants also seem to tolerate the school's faults. For example, although it is perceived as too hot and still in summer, overall comfort scores are very high.

The approach to lighting at Kingsmead refutes the conventional wisdom that classrooms should face south. The controllable top-lights in the deepest part of the classroom spaces seem to work well. The quality of daylighting is good enough to encourage users to keep the lights off and the blinds up.

Staff say that the conditions in the building significantly contribute to their perceived productivity at work. This is no surprise given the extremely good thermal comfort scores, attention to detail in the design, and high level of awareness that users have of how the building is supposed to work and be used.

A further vital factor is the attitude of the school governors and teachers 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.

All in all, the survey reveals Kingsmead School to be 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.

Michael Faraday Primary School

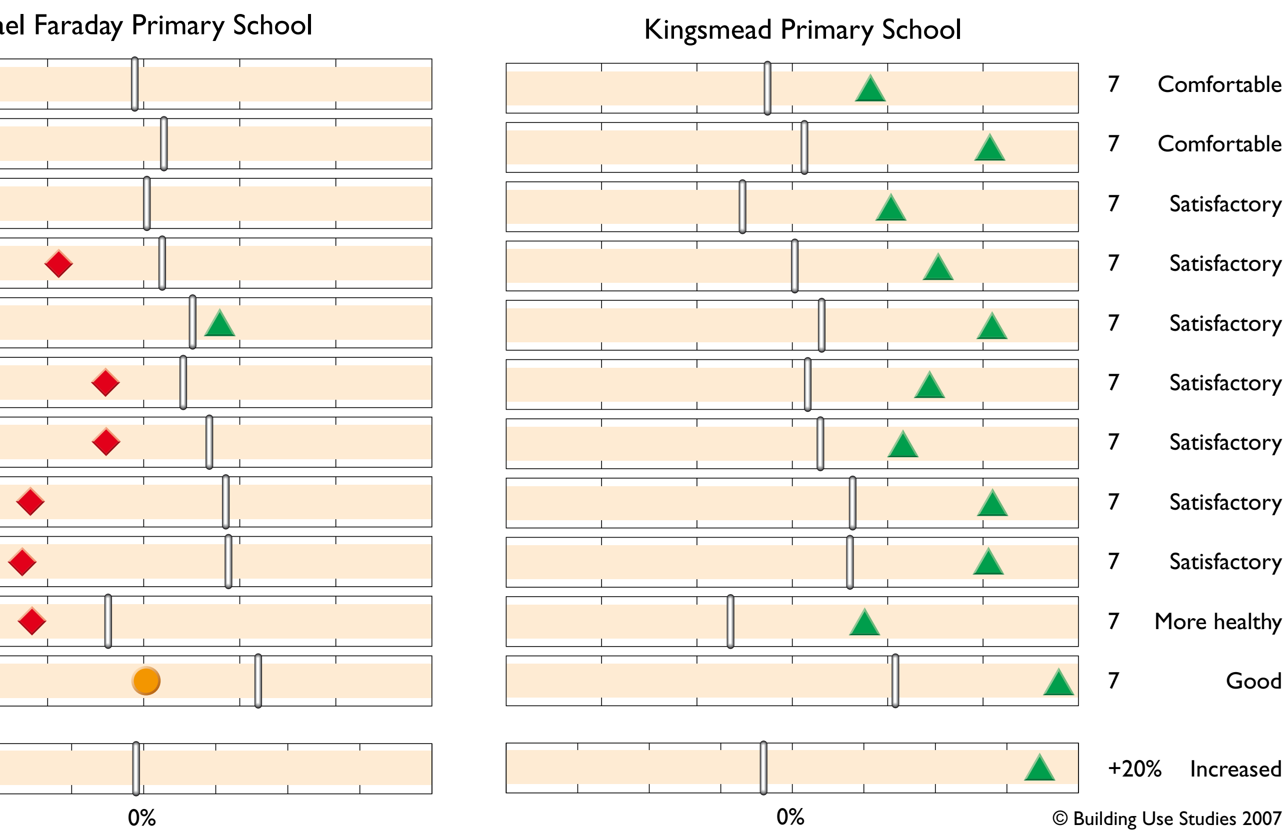
The author carried out a BUS occupancy survey in June 2007. The survey results are among the worst on the BUS database and reflect the fact that the school buildings are in a bad state of repair. The school's limited insulation, poor airtightness and rudimentary solar control means that it bakes in summer and freezes in winter.

The school caretaker, Phil Childs, freely admits that the heating is used at full power just to keep people warm – there is no attempt at energy efficiency. "We don't run the heating system to a budget," he said. "We run it to a need."

All the heating and lighting systems are the original 1970s fittings, and staff universally complain about glare from sunlight and electric lighting, stuffiness in winter, and poor productivity due to the bad comfort conditions.

On the plus side, the open-plan nature of the school is liked by many staff, although this causes noise problems. The poor sound insulation means that noise from children in corridors and playgrounds can be distracting.

In common with many school surveys, the staff at Michael Faraday School say that there is not enough space in classrooms or shared areas. The



Be careful to read the directions of the scales and the scale labels. Benchmarks are represented by the white line through each variable. Note that the benchmarks for Kingsmead Primary School are for 2006 and therefore slightly different to the other two schools studied in 2007.

staff room doubles as a meeting room and eating area, which means staff have nowhere to escape.

Despite the building's innumerable shortcomings, a recent OFSTED inspection ranked the school as 'Outstanding' – as it did in 2001. Clearly, the school's appalling physical condition does not determine the quality of education. That is determined more by the quality of the teaching, the motivation of staff and the leadership of its headteacher than by the quality of the architecture.

Leigh Primary School

The author carried out a BUS occupancy survey in June 2007. The results show that the Victorian school scores significantly better than the UK typical benchmarks for temperature, air quality, lighting, noise and overall comfort.

The school's design is marked down by staff and it also struggles to meet the needs of today's curriculum, which has a stronger emphasis on project-based teaching and one-to-one tuition, and relies on computers and electronic whiteboards. With its solid internal walls and circulation routes via classrooms, a Victorian school like Leigh Primary is not easy to adapt to meet today's curriculum. Although classrooms have been added by adapting the ground floor of the original schoolhouse and by a recent extension, the basic layout is far from ideal.

Despite some grumbles about glare from sun and sky on computer screens, Leigh School's lighting scores compare well to those of new schools, which suggests that the basic Victorian design principles have proved remarkably robust for over 100 years.

Leigh Primary School is not perceived to be a healthy building by the staff. As with most old buildings, Leigh Primary School can be dusty because it is difficult to clean.

Overall, Leigh Primary School scores well on comfort, poor on the soft variables, but is reasonable overall – remarkable for an old, inflexible, outmoded building.

The occupancy survey methodology

Occupant satisfaction was measured using the established Building Use Studies (BUS) methodology. The BUS method is a questionnaire-based survey and benchmarking tool used to poll the teaching and administration staff for their views on thermal comfort, control over conditions, storage and space, noise, and perceived productivity.

Adaptable for a range of building types, the survey comprises a self-completion occupant questionnaire, the results of which can be compared against a national benchmark database. The method was used in the 2006 DFES book *Design of Sustainable Schools – Case Studies*. For more information go to www.usablebuildings.co.uk.

All samples were statistically significant, but response rates for the three schools varied between 60-100 percent.

Photograph©Roderic Bunn/BSRIA

A classroom in the newer extension to Leigh Primary School. This has some electric wall heaters. All classrooms have a whiteboard projector.

Photographs©Roderic Bunn/BSRIA

Whiteboard projectors use power even in standby mode. It doesn't help when the switch is on the ceiling and has this kind of label on the power socket.

Photographs©Roderic Bunn/BSRIA

To counter glare on LCD screens, Leigh Primary School has daylight-diffusing film on the inside of the IT room windows. Simple solutions like this can be very effective, but architects seem to avoid such solutions for new schools, prefering instead to opt for more expensive and complex solar shading (either that, or nothing at all).

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Sub-metering shows that the school's energy consumption rose when the sports hall was opened in 2004. Although little is known of the quality of construction, the hall uses warm air blowers for heating rather than a more energy efficient underfloor heating system. The staff have noticed that the ceiling tiles become dislodged on windy days, which raises questions about the hall's level of airtightness.

Discussion

Carbon footprinting is not an exact science. For various reasons it is not possible to identify where all the energy in a school is going – and why. Energy meters are notoriously inaccurate, especially gas meters.

Equipment such as gas hobs and dishwashers in kitchens, electronic whiteboards in classrooms, and external security lighting can be responsible for significant energy consumption, but these systems are rarely metered separately.

These factors need to be borne in mind when coming to any conclusions about the comparative performance of the three schools in this study.

Unsurprisingly, Michael Faraday Primary School easily comes out as the most polluting of the three schools. There is a massive default to on for all the main gas and electrical systems in winter just to maintain comfort conditions.
It is easy to see why. Even when it was new the school had poor thermal insulation. The fabric is lightweight and the windows are single glazed. The heating and ventilation systems – those that still work – were not energy efficient in 1974 and certainly aren't in 2007.

In spatial terms the school still works quite well. The recent OFSTED rating of 'outstanding' also refutes conventional wisdom that academic attainment is closely linked to the quality of a school's design. It is teachers that make the difference, not the architecture.

Leigh Primary School is the most revealing of the three. Its carbon footprint per square metre is almost identical to that of Kingsmead Primary School, widely publicised – with strong justification – as being one of the most sustainable new primary schools in the UK.

Although Leigh School is less than half the size of Kingsmead, the two schools are almost identical in their carbon footprint. Leigh may have half the number of pupils and no catering kitchen (hot meals are brought in), but Kingsmead has a bio-fuel boiler, solar water heating, photovoltaics and a rainwater recovery system. These should at least offset some of the energy used for catering.

Although these technologies are not metered separately, the quoted carbon emissions assume a contribution. This means that Leigh's performance looks better, because if Kingsmead did not have these technologies, its reliance on main gas and electricity might be even higher. As it is, the schools are very similar in performance on a per square metre basis: Kingsmead at 48 $kgCO_2/m^2/y$ and Leigh Primary School at 51 $kgCO_2/m^2/y$. Of course, the high electricity consumption of all three schools may be less to do with poor performance, and more a reflection of out-of-date benchmarks. Nevertheless, the fact that the consumption of mains electricity in schools is climbing should be a cause for concern.

Although Leigh Primary School has made a conscious effort to reduce energy consumption, there is no doubt that an even greater improvement in its carbon footprint would come from a refurbishment of the school's heating and lighting systems, and investment in thermal insulation and double glazing. With that, Leigh could become a low energy school.

Furthermore, Leigh Primary School has long since paid back its initial investment and the energy used to construct it. It was probably built with local labour, using mostly local supplies. Its longevity is as testament to a high build quality. Is it any surprise that Victorian school buildings like Leigh Primary are in great demand for conversion to houses when a local authority decides it is no longer serving a need?

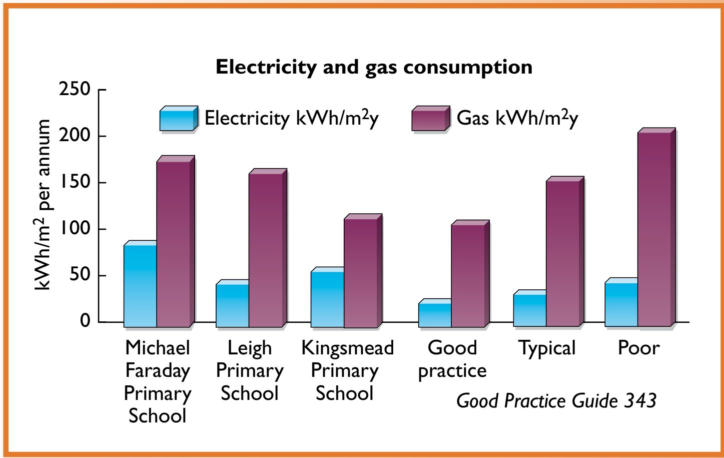
Although housing conversion may be a sustainable act in itself, the comparative performance of Leigh Primary School shows that its replacement by a school built to modern building standards like Kingsmead may not automatically improve a carbon footprint. If the government is serious about sustainability, then Victorian primary schools deserve greater understanding – and continuing investment – by local authorities.

Despite being an awkward building to use, Leigh Primary School is a time-capsule of Victorian robustness and simplicity. Its energy performance is steady. By contrast, Kingsmead Primary School is more flexible, adaptable and thereby more suited to the modern curriculum, but sustaining this good energy performance clearly requires diligent management and maintenance by the school staff and the local authority.

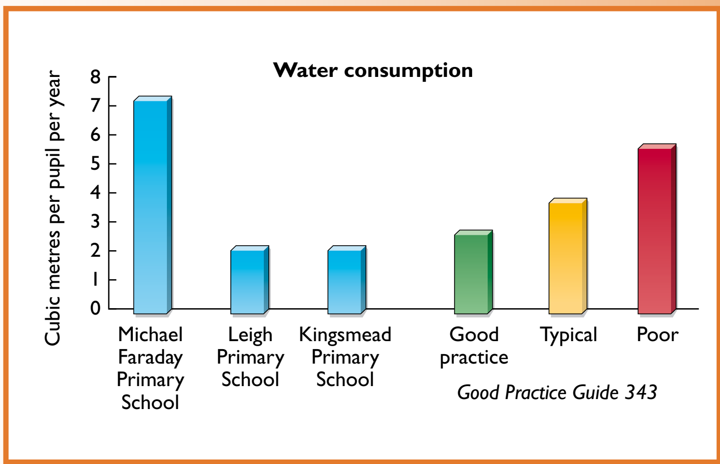
Ostensibly low energy technologies like bio-fuel boilers and solar water heating are, by definition, more complex and more demanding to run. The application of such sustainable technology is no guarantee of permanent good performance, it all needs managing – it is not fit-and-forget. If the equipment falls into disrepair for any reason, a school can easily default to a higher-energy condition just to maintain comfort or safety levels. Toilets need to be flushed, no matter where the water comes from.

Energy-saving technology can also put school administrators on a management and maintenance treadmill that they are not expecting nor trained to handle. It also diverts attention from teaching children. As Kingsmead's headteacher, Catriona Stewart, put it: "Our new school requires about three times more effort to manage than a Victorian school or a 1960s pile."

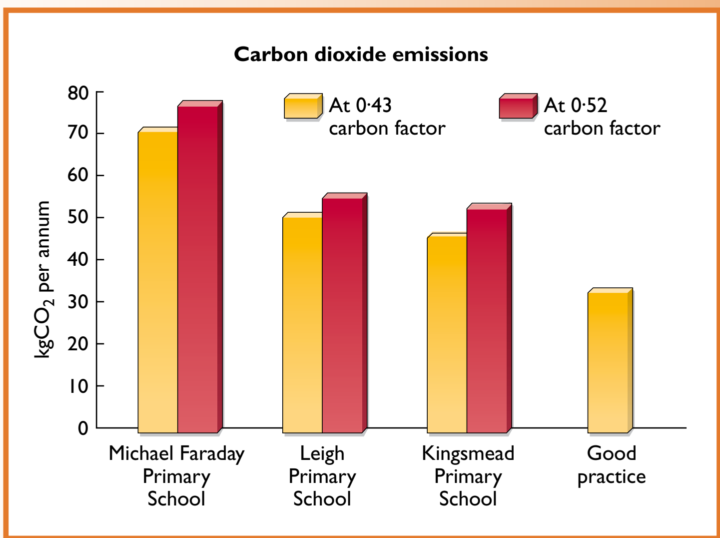
It is the government's intention that every child will be educated in a 21st Century school by 2020. But what do we



Electricity and gas consumption (adjusted actuals) for the three primary schools compared with the 2002 benchmarks in *Good Practice Guide 343 Saving Energy – A Whole School Approach*. The electricity consumption for Michael Faraday Primary School is a best estimate.



Water consumption for the three primary schools compared with the 2002 benchmarks in *Good Practice Guide 343 Saving Energy – A Whole School Approach.*



Carbon dioxide emissions from the three primary schools compared with the top 25% of schools on the Department for Children, Schools and Families' database. (This graph was adjusted in January 2008 to include the more contemporary 0·52 carbon-dioxide conversion factor. The 0·43 factor is more relevant to *GPG 343*.)

mean by a 21st Century school? One built in the 21st Century, or one that meets the needs of the 21st Century?

The distinction is subtle but important. The rush to replace all our old schools is predicated on a fundamental belief that anything not built in the 21st Century is substandard. In a headlong rush to build new, we may be in danger of losing the virtues of our existing schools – whether it be demolition through disrepair, or closure to amalgamate several schools onto a new site.

The government is understandably keen to promote its Building Schools for the Future strategy. But in contrast with the £45 billion earmarked for the BSF and academies programmes, only £375 million was earmarked for refurbishment in 2007. Why so low when the returns could be so high?

Clearly, there are eras of building that have delivered poor quality construction, and it is best that these buildings are replaced. But all schools should be subject to a more detailed examination of their intrinsic virtues – including longevity, adaptability, and value to the community – before decisions are taken to replace them with something doubtless more up to date and adaptable, but more expensive to run and maintain (and not necessarily long-lived).

About the author

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Credits

Adrian Leaman of Building Use Studies for permission to use the BUS occupancy survey method; Colin Farrelly for the energy consumption data of Kingsmead Primary School; Ellen Salazar of Elementa Consulting for assistance with the energy profiling of Michael Faraday School; Nigel Anderson of BSRIA for quality assurance; and the headteachers and staff of the three schools studied for their enthusastic co-operation.

Further reading

Design of Sustainable Schools – Case Studies was published by TSO in 2006. Copies can be obtained from www.tsoshop.co.uk. ISBN-13 978 0 11 271190 2.

Leigh Primary School, Kent

www.leigh.kent.sch.uk/

Completed
Circa late 1800s

Floor area
597 m^2 (gross internal)

Pupil numbers
121

2006/07 carbon footprint
Electricity: 26 500 kWh/y (46 kWh/m^2/y)
Fossil fuel (gas): 72 927 kWh/y (168 kWh/m^2/y)
Other: None

Carbon dioxide emissions*
At 0·43 kgCO_2 electricity: 51 kgCO_2/m^2
At 0·52 kgCO_2 electricity: 55 kgCO_2/m^2
Water: 262 m^3 (2·17 m^3/pupil/y)

Michael Faraday School

www.michaelfaradayschool.co.uk/

Completed
1974

Floor area
2308 m^2 (Treated floor area)

Pupil numbers
340

2006 carbon footprint
Electricity: *circa* 195 000 kWh/y (*approx* 85 kWh/m^2/y)
Fossil fuel (gas): 265 00 kWh/y (*approx* 177 kWh/m^2/y)
Other fuel: None

Carbon dioxide emissions*
At 0·43 kgCO_2 electricity: *circa* 71 kgCO_2/m^2
At 0·52 kgCO_2 electricity: *circa* 78 kgCO_2/m^2
Water: 2575 m^3 (7·36 m^3/pupil/y)

Kingsmead Primary School, Cheshire

www.kingsmead.cheshire.sch.uk/

Completed
August 2004

Floor area
1296 m^2 (gross internal)

Pupil numbers
210

2005/06 carbon footprint
Electricity: 76 000 kWh/y (59 kWh/m^2/y)
Fossil fuel (gas): 131 566 kWh/y (119 kWh/m^2/y)
Other: 17 m^3 woodchip consumed between November 2006 – February 2007

Carbon dioxide emissions*
At 0·43 kgCO_2 electricity: 48 kgCO_2/m^2
At 0·52 kgCO_2 electricity: 53 kgCO_2/m^2
Water: 466 m^3 (2·22 m^3/pupil/y)

*
Lower value: 2002 primary generation mix
Higher value: 2007 primary generation mix

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