schools for the future

Cost of BREEAM compliance in Schools

education and skills
creating opportunity, releasing potential, achieving excellence
Acknowledgments

The Faithful+Gould team responsible for preparing this report are:

Sean Lockie
Ian Butterss
Douglas Adams

The DfES team consisted of:

Richard Daniels
Andrew Thorne
Executive Summary

Background to this Report

In 2004 a revised BREEAM standard for schools was launched by the DfES with Very Good as the mandatory requirement. In 2006, Part L of the Building Regulations were also tightened. The DfES wanted to understand the cost implications of both these changes so we commissioned Faithful+Gould to undertake this research. There was also pressure on the DfES to raise the standard to Excellent.

The chart below presents the main findings of this study.

The cumulative cost of BREEAM credits, as an additional project cost, are shown on the Y axis for an increasing BREEAM score shown on the X axis.
The costs for achieving BREEAM credits have been analysed and ranked in increasing order of magnitude. Beginning with BREEAM credits that can be achieved at zero cost and moving to crossing the line at a score of 40 achieves a BREEAM Good rating at little extra cost. Very Good, at a score of 55 is achievable in this example at an extra £18/m².

The attempt to reach BREEAM Excellent at a score of 70 sees the add on cost climb very steeply, and the rating is difficult to achieve without the addition of renewables, which become a more cost effective means of reaching this target. The use of renewable energy generation scores energy credits which can be among the most expensive to achieve.

This graph represents a ‘Standard’ school of around 3,000m². The cost of achieving BREEAM ratings of Good and Very Good is higher than this for smaller schools, for which the curve rises more steeply with increased costs for any score. BREEAM Excellent is very onerous for small projects because of the fixed costs involved in achieving many of the BREEAM credits.

A single point is shown on the graph for Heat Pump (GSHP) or Biomass heat generation as they are assumed to be used for all the heat requirements. Each type of renewable generation was assessed assuming a single renewable energy source. The line for wind generation is difficult to see on the graph because it follows the solar thermal line very closely.

The graph could look different for a school for which renewables are mandatory, such as are required by some planning authorities. The renewables part of the graph would be prioritised and placed at the start of the rankings. This makes the starting point greater than zero cost for zero BREEAM Score.

Site specific restrictions on the available BREEAM credits, such as represented by the cases of very rural or very urban schools, result in the upward sweep of the curve at the right to be even more pronounced and make BREEAM Excellent harder to achieve. On the other hand a BSF school is likely to start from a higher position and the sweep upwards is less pronounced due to the procurement method.

The angle at which the line meets the target performance is a measure of the risk associated with the predicted cost. Estimates of the cost of Good and Very Good are less risky than estimates for achieving Excellent, because at around Excellent the marginal cost of BREEAM credits is very high, adding around £5-10/m² to the cost of the school for every credit achieved.

While BREEAM Excellent is achievable at about £60/m² in the Standard school, particular circumstances in some projects may make it so expensive as to be unaffordable.

Compliance with the new Building Regulations Part L2A and acoustic requirements detailed in BB93 may be treated as an additional starting cost. These costs have been estimated at £47/m² for this Standard school. If this is added at the origin of the line then all costs in the graph will be increased by this amount. These mandatory requirements have pushed up costs of schools by about 5%.
1  PROJECT BACKGROUND
1.1 BREEAM
1.2 DfES COST GUIDELINES FOR SCHOOLS

2  COST OF BREEAM
2.1 METHOD
2.2 EFFECT OF SIZE OF SCHOOL
2.3 EFFECT OF TYPE OF SCHOOL
   2.3.1 BSF SCHOOLS ASSUMPTIONS
   2.3.2 URBAN SCHOOLS ASSUMPTIONS
   2.3.3 RURAL SCHOOLS ASSUMPTIONS

3  BEYOND BREEAM & LZC
3.1 ENERGY CREDITS USING LONDON RENEWABLES TOOLKIT
3.2 CALCULATING THE ENERGY CREDITS USING SBEM
   3.2.1 ACHIEVING THE CREDITS FROM LZC TECHNOLOGY
   3.2.2 PHOTOVOLTAIC SYSTEMS
   3.2.3 SOLAR ENERGY SYSTEMS
   3.2.4 WIND GENERATORS
   3.2.5 BIOMASS
   3.2.6 HEAT PUMPS
   3.2.7 SUMMARY OF SBEM RENEWABLES RESULTS

4  COST OF REGULATORY REQUIREMENTS
4.1 BB93 ACOUSTICS
4.2 BUILDING REGULATIONS PART L2A
4.3 SUMMARY OF MANDATORY COSTS

5  SUMMARY
1.1 BREEAM

BREEAM [Building Research Establishment Environmental Assessment Method] Schools is a system for assessing the environmental performance of new and refurbished buildings. The environmental performance is expressed on a scale from 'Pass' to 'Excellent'.

Figure 1: BREEAM Schools 2006.
BREEAM Schools considers nine classes of environmental impact which are weighted in accordance with a consultation process carried out by BRE. The adoption of such a weighting system to allow the trade-off between unlike impacts has been a major step forward in enabling sustainability to be costed and introduced to building designs.

- **Management**: Commissioning, site management and procedural issues
- **Health and well being**: Factors affecting health and well being of the occupants
- **Energy**: Operational energy and CO₂ emissions
- **Transport**: Transport related CO₂ emissions and location related factors
- **Water**: Consumption of mains water
- **Land use**: Greenfield and brownfield sites
- **Ecology**: Ecological value of the site and the impacts of siting
- **Materials**: Environmental implications of building material choices
- **Pollution**: Minimising air and water pollution.

The DfES issue cost guidelines for building schools. These guidelines form the basis of Local Authority capital building budget allocations and are used to set funding levels for capital programmes including the Building Schools for the Future programme (BSF). The guideline costs contain an elemental build-up, plus design fees, prelims, abnormals etc. Further information on the guidelines can be found at: [http://www.teachernet.gov.uk/costinformation](http://www.teachernet.gov.uk/costinformation)

In 2004 the DfES launched the BREEAM Schools programme. Separately the OGC issued Common Minimum Standards for the built environment in the Public Sector with a suggested requirement to achieve an Excellent BREEAM rating for new public sector buildings. Partnership for Schools (PfS) also called for a minimum of BREEAM ‘Very Good’ on all new build schemes. The present DfES guideline costs make no allowance for the on-costs associated with this BREEAM compliance.
A logical way of approaching the minimum cost solution is to secure the zero cost items first, then the low cost, then select medium followed by high cost items in order of cost. As these are selected we monitor the BREEAM score and graph it, showing the diminishing return that BREEAM investment has.

The schools scenarios discussed later in 2.3 (standard, urban, rural, BSF) determine for each type a set of BREEAM credits which are cost free and another set of credits which are unachievable at any cost.

A simplifying and important observation in carrying out this analysis is that the energy credits are likely to be among the most costly. This means we can first analyse the costs excluding energy credits, and then add these as a group of high cost credits.
It is assumed that the Part L requirements and BB93 compliance are both part of the base requirement and add no cost because they have to be achieved anyway. Other zero cost BREEAM scores are added, then the low cost, medium cost and so on, so that the graph displays diminishing returns in the capture of BREEAM scores. Ultimately an Excellent score is set to cost more than an extra £60/m².

The marginal cost of the last scores at around Excellent (70) is very high, and a contribution from renewables may be cost effective to displace these.

The reason energy credits are so costly is that they are only merited once compliance with Part L2A (2006) is achieved. This is already a demanding standard which will require the designers to use all the low cost measures at their disposal, such as low U values in the building envelope and high efficiency plant. To go further than Part L will generally require the use of renewables.

The following graph illustrates the increasing cost for the standard building.

Good BREEAM performance is a score of 40, Very Good 55 and Excellent is 70.
2.2 Effect of size of school

This analysis is based on a school of 3,000m². Running the model again for larger and smaller schools yields different results. These have been combined in a single graph showing an envelope within which this Standard type of school of various sizes will lie. This is graphed in Figure 3. It can be seen that the cost begins to climb rapidly for small schools as BREEAM targets go up. This is because a proportion of the cost of BREEAM is a fixed cost with respect to school area.

One of the most significant findings is that the size of a school is an important determinant of the add-on cost. In assigning costs to each of the BREEAM credits it was found that certain costs were associated with the size of the school while others were ‘fixed’, inasmuch as they would be the same no matter the size of the school.

An example of a variable cost is the cost of cyclist facilities which must be provided for 10% of the school population, and these go up in direct proportion with the size of the school.

An example of a fixed cost is that of seasonal commissioning which is costed at £1,200 being three days of a control engineer’s time to visit at three monthly intervals, a day each. This would be about the same no matter the size of the school. Other costs such as metering or consultancy will be incurred whatever the size. Many of the Management credits are of this type.
This results in a significant extra burden on small schools or schools which are only being partially rebuilt or refurbished. The Targeted Capital Fund (TCF) has a requirement for a BREEAM Schools rating of Very Good, and applies to all major new-build and refurbishment projects valued at over £500,000 for primary schools and £2m for secondary schools, and involving rebuilding or complete refurbishment of more than 10% of the floor area of a school. The £500,000 lower limit will capture numerous schools of just over 500m$^2$, (though in the case of large schools this may be less than 10% floor area and would therefore not apply).

Figure 3 Standard School Cost of BREEAM for different sizes (excluding most energy credits)
2.3 Effect of type of school

There are numerous assumptions behind our analysis of what constitutes a Standard School which will not hold for real projects. The starting point for a construction project could include whether it is a BSF school, whether it is in a rural or urban location plus a range of site specific issues which could have an effect on the cost of targeting a particular BREEAM score.

2.3.1 BSF schools assumptions

Schools being procured under the BSF programme are generally being procured in a group and in a way that requires a continuing relationship with the delivery partner over 25 or 30 years. This means the consortium delivering the schools is going to be made of large companies with financial strength whose interest is bolstered by their ongoing commitment which does not finish at construction completion.

The size and risk represented by these projects means that specification and contract issues are more rigorously dealt with, and the concern of the contractor for durability and keeping down maintenance cost and unitary (annual) charges means they would normally be more concerned with quality and energy running cost issues. There is a closer relationship between the constructor, designer, FM team and the considerable size of the project and associated managerial overheads will lead to a greater willingness to consult with stakeholders and employ specialist consultants.

This may not always be the case in practice but the tendency will exist.

Therefore a range of credits have been assumed as ‘givens’ which, although they may add cost, are not optional. This method of procurement and design enhancement should mean the average BSF school will cost more than other schools but the budgeting for this is outside the scope of this study of the add-on costs of BREEAM.
Examples of credits which are ‘given’ or which could be accommodated by the BSF process at little extra cost are:

i) Seasonal Commissioning i.e. 3, 6, and 9 months after occupation

ii) Considerate Constructors Scheme participation with a good score

iii) Monitoring of Construction Site Impacts including waste segregation so as to score 3 out of the 4 credits

iv) Consultation with local community and building occupiers and other stakeholders, which is a normal part of BSF procurement, including methods such as DQI, consultation with Crime Reduction Advisor, and consultation with students and staff

v) Whole Life Costing carried out which is a normal part of PFI procurement in order to quantify life cycle risk over the concession period

vi) As a result of (v), and maintenance commitments, design of materials for robustness is presumed

vii) Review of furnishings and fitting for VOCs (Volatile Organic Compounds)

viii) Building thermal simulation at design stage to ensure thermal comfort

ix) Provision of cyclist facilities is more likely to be accommodated

x) The second credit for water conservation, assuming only the first will be achieved as a matter of course

xi) Dedicated storage of segregated recyclable materials which, while likely to be overlooked in the Standard development, would be an integral part of BSF because the provider has probably signed up to local recycling targets

xii) Enhancing site ecology as a BSF project will probably employ an ecologist and act on their recommendations
This gives a BSF school or group of schools a running start of 15 credits against non BSF procured schools. This is illustrated graphically for the 3,000m² school in figure 4. This shows that the on-cost of compliance with a target for a BSF school is much less, and that Very Good is achievable at little if any extra cost. However there are also hidden up-front costs of this type of procurement, so the starting point may be considered to be more than zero. Moreover the marginal cost for the last couple of credits before excellent is still very high.

---

Figure 4 Standard & BSF Schools Cost of BREEAM (excluding most energy credits)
2.3.2 Urban schools assumptions

There are numerous credits in BREEAM associated with site characteristics which are outside the control of the designer. Some of these may be grouped and considered together as ‘Rural’ or ‘Urban’. The standard school lies between these two. Real urban or rural schools may often not share the characteristics we apply to them here. We use the terms as a shorthand way of describing whether they achieve or don’t achieve a particular set of BREEAM credits. The set of credits which differentiate our Urban school from the Standard are:

i) The first credit associated with Considerate Constructor scheme is more likely to be secured as a result of the likelihood of a more constricted site making necessary better site management and neighbour accommodation

ii) Detailed site investigation is more likely to occur on a constricted urban site due to the possibility of buried services among other things

iii) The footprint is presumed to be on previously developed land

iv) The change in ecological value is presumed to be zero, as would normally be the case when developing brownfield sites

v) The credit for segregating construction waste is unlikely to be achieved because of site restrictions

vi) The credit for very high daylight factor is considered unachievable because of a deep plan and multi storey construction to maximise use of building footprint

vii) The second credit for cyclist facilities is presumed to be unavailable due to space restrictions

viii) The credit for either not having upper floors, or specifying upper floors of Green Guide A materials, is presumed unavailable because a multi story building is presumed necessary and in-situ concrete the preferred material

ix) Credits for impact on biodiversity are presumed to be unavailable including the setting up of Local Wildlife Partnerships
These presumptions are not always valid for an urban site, but together they serve to illustrate a construction project of a different character to the Standard. Many urban sites will suffer a set of preconditions somewhere between this and the Standard.

Figure 5 shows the cost of approaching BREEAM Excellent are much higher for the urban school even though some extra credits are achieved at low or zero cost. This is because of credits which are assumed to be unachievable (v to ix above), so more expensive credits must be targeted to achieve Excellent. In fact without consideration of energy credits, and therefore renewables, Excellent is unachievable.

There is a general caution that can be made here with regard to using the Standard school data to predict the on-cost on a real project. This is that certain credits will be achieved at lower cost and others made unachievable by circumstances. This is unlikely to effect budgets by very much unless Excellent is being targeted. Here the geometry of the curve is such that every extra credit counts and has a significant cost impact. Furthermore there is less certainty about the cost in this region of the curve. Hence targeting Excellent brings with it much more cost risk than the targeting of lower scores.
2.3.3 Rural schools assumptions

Site considerations of typical rural sites also include and preclude a different set of BREEAM credits which we use to characterise a rural school. They are:

i) Detailed site investigation is presumed to be carried out as with the urban site, but in this case it will be prompted by issues surrounding greenfield site use, such as soil properties and presence of groundwater

ii) The two credits available for ready access to frequent public transport services are assumed to be unattainable

iii) The use of an ecological consultant is presumed to be given

iv) The school is presumed to be committed to protecting protected features and habitats and will likely appoint a Biodiversity Champion, and minimise, monitor and report on the impact of site works

v) Site treatment and other measures are presumed to be carried out to minimise water pollution

Figure 6 shows a comparison of the rural school with the Standard. The two curves are similar. This is true over most of the range with some of the low cost rural credits making it lower cost to achieve Good or Very Good. The curves cross before Excellent as the rural location means certain transport credits are unachievable. By the time of reaching Excellent both curves are on a steep rise.

Figure 6 Standard & Rural Schools Cost of BREEAM (excluding most energy credits)
Earlier it was observed that the energy credits were mostly more expensive than the most expensive of other credits with only a few exceptions. In some of the graphs in the previous section energy credits become important as the plot approaches a score of 70.

The issues surrounding energy credits are very topical because the new building regulations (Part L 2006) have stepped up energy performance, and BREEAM awards energy credits only when Part L performance is exceeded. Part L compliance is at the limit of affordable fabric and plant efficiency measures, so achievement of a significant number of BREEAM energy credits implies the use of renewables or LZC technology (Low or Zero Carbon). This is why these energy credits can be expensive to achieve.
The percentage improvement in the CO₂ emission rate over the base rate (notional building) is used to allocate the number of credits, on the basis of the table shown below.

<table>
<thead>
<tr>
<th>Credits</th>
<th>New Buildings</th>
<th>Refurbishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+1%</td>
<td>-50%</td>
</tr>
<tr>
<td>2</td>
<td>+2%</td>
<td>-25%</td>
</tr>
<tr>
<td>3</td>
<td>+4%</td>
<td>+0%</td>
</tr>
<tr>
<td>4</td>
<td>+6%</td>
<td>+4%</td>
</tr>
<tr>
<td>5</td>
<td>+8%</td>
<td>+7%</td>
</tr>
<tr>
<td>6</td>
<td>+10%</td>
<td>+10%</td>
</tr>
<tr>
<td>7</td>
<td>+12%</td>
<td>+12%</td>
</tr>
<tr>
<td>8</td>
<td>+14%</td>
<td>+14%</td>
</tr>
<tr>
<td>9</td>
<td>+18%</td>
<td>+18%</td>
</tr>
<tr>
<td>10</td>
<td>+22%</td>
<td>+22%</td>
</tr>
<tr>
<td>11</td>
<td>+30%</td>
<td>+30%</td>
</tr>
<tr>
<td>12</td>
<td>+40%</td>
<td>+40%</td>
</tr>
<tr>
<td>13</td>
<td>+50%</td>
<td>+50%</td>
</tr>
<tr>
<td>14</td>
<td>+60%</td>
<td>+60%</td>
</tr>
<tr>
<td>15</td>
<td>≥70%</td>
<td>≥70%</td>
</tr>
</tbody>
</table>
3.1 Calculating Energy Credits Using London Renewables Toolkit

It is a useful theoretical framework to examine the cost/benefit of renewables based on the maximum potential benefit as if all the generated energy is used. In reality surplus output will either be wasted (solar thermal) or exported to the grid (wind and PV -photovoltaics) or utilisation will drop as the heat pump or biomass boiler is switched off when not needed. As the size of the installation increases more and more surplus energy will be generated. However assuming all output is able to be put to good use, the different renewables can be compared based on outputs and costs referenced to the London Renewables Toolkit.
Figure 7 shows add-on BREEAM costs for energy credits up to 10 using renewables, based on the Carbon savings and cost assumptions in the London Renewables Toolkit (download from: [www.london.gov.uk/mayor/environment/energy/london_renew.jsp](http://www.london.gov.uk/mayor/environment/energy/london_renew.jsp)) with the exception of wind generation. It assumes that there is a demand for all generation and each renewable option is the only one selected. The PV data line is not continued beyond 4 credits to provide a comparative chart with the other options, but the extrapolated cost per m² for PV to achieve 10 credits is £130/m². This illustrates how expensive PV is in relation to the others. In practice the size of the PV array is likely to be limited by cost or suitable roof area. GSHP and biomass options would be typically sized to fit all or a majority of the heat requirements there are many examples of biomass with gas backup so a fixed score of about 8 credits would be achieved for them; and the size of solar thermal panels would be limited by the hot water demand of the school.

The London Renewables Toolkit rate for wind turbine costs is £1,000/kW which suggests that they are relatively large. Smaller wind turbines are more expensive per kW.

A school-sized wind turbine is likely to cost much more per kW, so in the case of wind an estimated cost based on enquiries with manufacturers and suppliers has been used.

It can be seen from the graph that the addition of renewables has an increasing cost per credit as we have seen with the economically ordered addition of other BREEAM measures. For the Standard school of 3,000m² with a TER (Target Emission Rate) of 27 kg CO₂/m²/annum, these costs are mostly rising faster than the cost line for the other BREEAM credits.

The lines are curved because the credit allocation is not directly proportional to reduced emissions, and they become harder to achieve as their contribution increases.

The best fit of renewable depends on local resources and conditions. The Toolkit prices and yields only provide sufficient detail for preliminary feasibility studies of options, and actual data should be used after the first assessment.

The carbon saving data in the London Renewables Toolkit generally results in higher energy yields and therefore lower costs than if SBEM is used to calculate them.
### 3.2 Calculating the Energy Credits using SBEM

Emissions rates are calculated using the Simplified Building Energy Model (SBEM), part of the National Calculation Methodology (NCM) for energy performance of buildings, which includes the emissions offset by the use of renewables.

Compliance with Part L2A of the building regulations requires demonstration of a predicted Building Emissions Rate (BER) for CO$_2$ that meets the Target Emissions Rate (TER) for the School. The CO$_2$ emission rate is measured as kg CO$_2$ per m$^2$ per annum.

SBEM calculates the BER for a building based on input data. The TER for a building is derived from similar calculations for a “notional building”.

The notional building has the same situation and weather conditions as the building under evaluation and standard operating patterns and assumptions for fabric etc. The TER (for the current Building Regulations) requires an improvement factor (IF) to be applied to the notional building performance along with a factor to encourage the application of low and zero carbon technologies (LZC benchmark).

The formulation is:

\[
\text{TER} = \text{Cnotional} \times (1 - \text{IF}) \times (1 - \text{LZC benchmark})
\]

IF and LZC are set, as in the table below:

<table>
<thead>
<tr>
<th>Building services strategy</th>
<th>Improvement factor (IF)</th>
<th>LZC benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heated and naturally ventilated (and spaces with no heating or ventilation)</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>Heated and mechanically ventilated</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>Air conditioned</td>
<td>0.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>

This means that for a heated and naturally ventilated building the total improvement is 0.85 x 0.9 or an improvement of 23.5%.
Low and zero carbon technologies may be omitted from the building, in which case the improvement must be achieved by good design and practice alone. It is in the nature of the calculation that the lower the TER is, the harder it is to gain energy credits.

3.2.1 Achieving the Credits from LZC Technology

Data from a modern energy efficient school was loaded into SBEM to create a base model. Very good standards for insulation, controls and efficiency of plant were included, and the building was found to be on the borderline with respect to Part L compliance. Any improvements from this point, i.e. to score any BREEAM credits, requires the use of LZC technology as all other parameters are at the limit of their economic improvement.

A standard Building Services set up was adopted. In this scenario the following was applied:

Main Heating System.............Central heating using water: radiators
Heating system Heat source..............................LTHW Boiler
Heating system Fuel type................................Natural Gas
Domestic Hot Water (DHW) Generator type......Same as HVAC:
Main Heating system
DHW Generator Fuel type..........Natural Gas (default from above)
Various individual configurations of LZC technology were then added to the model to see what effect this had on the BER and thus the energy credits available. From this the additional costs per m² were calculated.

### 3.2.2 Photovoltaic Systems (PVS Generators in SBEM)

A “good” location for the PVS i.e. Orientation South and Inclination 30° was assumed. Various areas for monocrystalline silicon PVS were input into SBEM to record what BER resulted and the associated credit that would be achieved. Areas were recorded when they produced a tipping point into an extra credit.

The following output resulted:

<table>
<thead>
<tr>
<th>BREEAM Credits</th>
<th>Cost of PVS £</th>
<th>£ / m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>22,525</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>48,110</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>99,374</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>150,365</td>
<td>48</td>
</tr>
<tr>
<td>6</td>
<td>200,915</td>
<td>65</td>
</tr>
<tr>
<td>7</td>
<td>251,881</td>
<td>81</td>
</tr>
<tr>
<td>8</td>
<td>303,450</td>
<td>97</td>
</tr>
<tr>
<td>9</td>
<td>354,195</td>
<td>114</td>
</tr>
</tbody>
</table>

**Figure 8 Increasing Cost of PVS credits**

Costs are based on £850 / m² for the PVS and a school size of 3,000 m².

An extra credit is available for the first addition for renewables because of the feasibility study which is presumed to be carried out, merits a credit.
A further extra credit is gained once 10% of the TER is generated from renewables. Adding PVS to the project continues to reduce the value of BER but gaining extra credits rapidly becomes unaffordable from this simple analysis. (It is possible to achieve all 15 credits if enough space were to be available for the array, and if the budget were unlimited).

### BREEAM Credits
<table>
<thead>
<tr>
<th>BREEAM Credits</th>
<th>Cost of SES £</th>
<th>£ / m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>13,330</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>22,400</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>40,400</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>67,600</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>166,000</td>
<td>55</td>
</tr>
</tbody>
</table>

Figure 9 Increasing Cost of SES credits

It was not possible to improve the performance to 7 credits from 6. The output BER from SBEM reached a minimum with about 415 m² of SES (i.e. demand for hot water was fully supplied) but the system had already become uneconomic long before this size was reached. Costs are based on £400 / m² for the SES and a floor area of 3,000 m².

### 3.2.3 Solar Energy Systems (SES in SBEM)

A “good” location for the SES i.e. Orientation South and Inclination 30° was assumed. Various areas for a Solar Energy System (there are no further options) were input into SBEM to record what BER resulted and the associated credit that would be achieved. Areas were recorded when they produced a tipping point into an extra credit.

The following output resulted:
3.2.4 Wind Generators

Inputs for wind generation allow for selection of terrain type, rotor diameter (for swept area), hub height and power rating. The terrain was set at suburbs in line with the location of the school used for the model. The analysis here was based on the actual specifications and costs of a selection of small scale wind generator types found through the British Wind Energy Association (BWEA) website.

The findings in the table below resulted from this analysis:

<table>
<thead>
<tr>
<th>Turbine Type</th>
<th>diameter m</th>
<th>hub height m</th>
<th>power kW</th>
<th>cost £</th>
<th>cost £/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven WT600</td>
<td>2.55</td>
<td>5.5</td>
<td>0.6</td>
<td>7,800</td>
<td>2.50</td>
</tr>
<tr>
<td>Proven WT600</td>
<td>2.55</td>
<td>12</td>
<td>0.6</td>
<td>8,100</td>
<td>2.60</td>
</tr>
<tr>
<td>Proven WT2500</td>
<td>5.5</td>
<td>6.5</td>
<td>2.5</td>
<td>11,000</td>
<td>3.50</td>
</tr>
<tr>
<td>Swift Rooftop WE system</td>
<td>2.1</td>
<td>10</td>
<td>1.5</td>
<td>3,000</td>
<td>1.00</td>
</tr>
<tr>
<td>Swift Rooftop WE system</td>
<td>2.1</td>
<td>20</td>
<td>1.5</td>
<td>3,000</td>
<td>1.00</td>
</tr>
<tr>
<td>Windsave 1000</td>
<td>1.75</td>
<td>10</td>
<td>1</td>
<td>1,500</td>
<td>0.50</td>
</tr>
<tr>
<td>Windsave 1000</td>
<td>1.75</td>
<td>20</td>
<td>1</td>
<td>1,500</td>
<td>0.50</td>
</tr>
<tr>
<td>XC02 Quiet Revolution</td>
<td>4.2</td>
<td>11.5</td>
<td>6</td>
<td>30,000</td>
<td>9.60</td>
</tr>
<tr>
<td>Proven WT2500</td>
<td>5.5</td>
<td>11</td>
<td>2.5</td>
<td>12,400</td>
<td>4.00</td>
</tr>
<tr>
<td>Proven WT6000</td>
<td>5.5</td>
<td>9</td>
<td>6</td>
<td>18,300</td>
<td>5.90</td>
</tr>
<tr>
<td>Proven WT6000</td>
<td>5.5</td>
<td>15</td>
<td>6</td>
<td>19,100</td>
<td>6.10</td>
</tr>
<tr>
<td>Proven WT15000</td>
<td>9</td>
<td>15</td>
<td>15</td>
<td>40,000</td>
<td>12.80</td>
</tr>
<tr>
<td>Proven WT15000</td>
<td>9</td>
<td>25</td>
<td>15</td>
<td>44,300</td>
<td>14.20</td>
</tr>
</tbody>
</table>

The popular smaller scale wind generators are not very useful for producing BREEAM credits, being too small.

The price per kW drops significantly as the size increases. In fact it drops so much that Wind Power breaks the trend observed in the previous section of increasing cost and diminishing returns, a trend which is reinforced by the way BREEAM credits are allocated.

In practice there are diminishing returns because exported or surplus power would not be valued the same as power generated and used on site. Even considering this, the cost advantages of size in wind generation are unlikely to be counteracted.
3.2.5 Biomass

Biomass boilers are considered to be carbon neutral because the fuel has absorbed CO$_2$ during growth. There is a large potential for gaining BREEAM credits. They require a viable source of fuel and there is a requirement for ash disposal and periodic cleaning.

There is also an additional requirement for an additional fuel storage and feed system. Cost of the fuel is comparable with other solid fuels.

Difficulties have been encountered in using biomass boilers in well-insulated buildings with low and intermittent heating loads. For larger installations they may form part of a modular system with conventional boilers.

<table>
<thead>
<tr>
<th>Main Heating System</th>
<th>Credits</th>
<th>Extra cost (£)</th>
<th>Extra cost (£/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Central Heating using water: radiators</td>
<td>15</td>
<td>93,016</td>
<td>29.88</td>
</tr>
</tbody>
</table>
Costs are based on: installed capacity = 0.166 (2x 0.083) kW / m² TFA (2241 m²) and £200/kW. Cost / m² GIFA (3,113 m²).

The cost, from the London Renewables Toolkit, is over and above a standard Natural Gas fuelled system.

SBEM does not allow a 50/50 solution of biomass/other heat source for combined space heating and hot water but does allow biomass options for either heating or hot water. This analysis assumes all heating is from Biomass.

Biomass is the most cost effective of the renewables options and competitive with many other measures in terms of cost of BREEAM credits. However this analysis does not consider other disadvantages of biomass, such as those arising from management and lifecycle costs.
3.2.6 Heat Pumps

For a heat pump system to work efficiently the operating conditions need to be carefully chosen. The set up was assumed to be providing heat for lower temperature systems than a conventional wet radiator system (this is often the case in schools).

The heat pump cannot supply domestic hot water to the required temperature to minimise the risk of legionella, so a dedicated DHW boiler fuelled by Natural Gas was selected for this analysis.

<table>
<thead>
<tr>
<th>Main Heating System (DHW supplied by dedicated boiler and Natural Gas)</th>
<th>Credits</th>
<th>Extra cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump Central Heating using water: floor heating</td>
<td>11</td>
<td>123,275 £</td>
</tr>
</tbody>
</table>
3.2.7 Summary of SBEM Renewables Results

Revisiting the theoretical graph of Cost of Renewables based on the London Renewables Toolkit, we make the following modifications:

- plot biomass and heat pumps each as a single point because the system would be sized to supply all the heat (or majority of the heat)
- limit the maximum number of credits available for solar (solar thermal and PV)
- reflect the higher cost of smaller wind power

For the Standard school we used to generate these results in SBEM we had a TER and BER of about the same value, which was 27 kg CO$_2$/m$^2$. Using this we find the marginal cost of renewables to range from £1.73/m$^2$/credit for biomass to £12.2/m$^2$/credit for PV. PV is more affordable where fewer credits are targeted and may be readily adopted alongside other renewables options.
The different schools modelled were assumed to comply with all regulatory requirements. However since the £1,080 budget has been set some years ago before BB93 requirements and Part L (2006), a sum could also needed to be added to the budget in respect of these.
4.1 BB93 Acoustics

The optimum energy/ventilation/acoustics solution is still evolving in school design which means risk is associated with cost estimates of these and ideally they should not be considered in isolation.

Faithful+Gould/Atkins conducted a study in December 2003 for DfES to assess the uplift cost of compliance with BB93, the acoustics requirements.

Excluding locations where external noise, usually from traffic, is of such intensity that mechanical ventilation would be required in place of natural ventilation by opening windows, the study concluded that the uplift cost on average would be in a range around 1.69% which is about £21.50/m$^2$.

The caveats are that this is based on a limited study of seven schools and it is expected that the range of costs will be wide, dependent as they are on the vast range of site conditions that could be encountered.

Fees have gone down as consultants become more accustomed to the requirements of BB93 and more used to carrying out the calculations. On the other hand the knock-on effect of ventilation acoustic dampening required with cross flow and ventilation stacks have served to push costs up.

We estimate fees are £3.80/m$^2$ with a minimum allowance of £2,500. Atypically noisy sites or designs with unusually shaped rooms could cost much more.
4.2 Building Regulations Part L2A

This analysis is based on the cost of Building Regulations compliance on a school with the typical dimensions of a 3,000m$^2$ school with the on-cost of improving a basket of measures required to improve the building from a 2002 building regulations standard to 2006 standard, verified in SBEM. The on-cost estimate was trialled with dimensional changes, e.g. from three storey to single storey and from 3,000 m$^2$ to 500 m$^2$ to see if the costs are likely to be different between different styles of school.

Our base model school has generous ceiling heights (4m.), window areas and ventilation ducts to ensure good daylight levels and fresh air. This is a good starting point and should be possible within the base budget. If the starting point is from a school with smaller window areas, the extra costs of compliance will be lower.

Compliance with ADL2A requires improving U values and plant efficiencies and possibly adding some renewable energy until the required improvement factor of 23.5% [100%- 90% x 85%] is achieved. The most cost effective approach is to improve as many different fabric and plant elements as possible, as concentrating on only one or two will lead to diminishing returns and higher cost. SBEM showed that it was possible to comply using a range of conventional measures rather than introduce renewables, however some improvements are on the limit of current good practice.

Below is a list showing the range of measures adopted to comply and the estimated cost per square metre based on the dimensions of the model school. Some of the measures are costed and some are assumed to be included in the base cost. If the cost of a measure in £/kgCO$_2$ is less than the cheapest of the renewables then it should be considered. In general renewables are costly but under certain local conditions wind power or biomass may well be cheaper than some of these.

**Wall insulation improvement of U value from 0.35 to 0.25 W/m$^2$K**

Increasing the thickness of mineral wool insulation by 35mm is estimated to cost an extra £1.75/m$^2$ of total wall area.
**Roof insulation**  
(Improvement of U value from 0.2 to 0.13 W/m²K)

Increasing the thickness of glass wool insulation by 95mm is estimated to cost an extra £4.75/m² of total roof area.

**Floor insulation**  
(Improvement of U value from 0.25 to 0.22 W/m²K)

Increasing the thickness of polyurethane insulation by 15mm is estimated to cost an extra £2.25/m² of total floor area.

**Window**  
(Improvement of U value from 2.2 to 1.9 W/m²K)

A metal frame with thermal break and insulated warm edge spacers, a 4-16-4 configuration [4mm glass – 16mm argon – 4mm glass] and low e coating have been assumed. The extra cost is hard to establish as window costs have a strong dependence on whether the sizes being ordered are standard. It can also be assumed that prices for quality windows will be falling as low U value becomes a standard requirement. We have allowed £25/m² which is for the low e coating alone. This could reduce the U value by about 0.2 W/m²K.

**Boiler efficiency**  
(from 75% to 89%)

This is regarded as low cost. Cost of condensing boilers has been dropping because they are now required under the Building Regulations, so volumes have been increasing and market barriers reducing. Moreover, alongside the other efficiency measures being taken the boiler can be downsized.

**Lighting Efficacy**  
(better than 50 lumens per Watt)

Selecting a T8 or T5 tube lighting with HF ballast is a common design choice for schools in any case. Therefore we have assumed no on-cost. We assume triphosphor fluorescent lamps will be used. Incidentally this does not take into account the efficacy or utilisation factor presented by the luminaire which can vary a lot, or the size of the lamp. As a rule, the longer the tube is, the better the efficacy.
**Lighting Controls**

Auto off controls are accorded good credit in the version of SBEM used, and we have assumed these are installed. They can be controlled by presence sensors, time clocks or both. These would require a controller and a presence sensor for each classroom, and some minimal extra costs in wiring. We have allocated £275 per classroom.

**Out of Range warning from metering systems**

Meters with digital outputs are assumed to cost no more. Assuming lighting and power is separately metered along with fuel and water, a simple M&T system is proposed which raises automatic alarms using four meters. This will reduce the BER (Building Energy Rating) by 3-4% at relatively low cost and should be considered except in small buildings. We have allowed £1,200 fixed price for this but this assumes a water meter local to the others. Otherwise this may entail installation of an extra water meter or extra communications equipment.

**Pressure testing and improvement of air permeability (from 10 m³/ m²/hr to 7 m³/m²/hr):**

The better detailing, use of air barriers, sealants, and the closer monitoring of construction will all cost extra. It is very difficult to estimate as it will be different for each project so Faithful+Gould has made a provisional allowance of £5/m². The testing will also cost more even if performance is not being targeted. This was costed at £1,000 plus £3/m². The fixed part of the cost was meant to reflect the extra overhead cost of testing a small school.

**Extra Design work in using SBEM or Building Simulation**

It has until now not been common to model schools energy use to the extent required by SBEM. Some building simulation packages (TAS and IES Virtual Environment) now have an SBEM ‘corner’ which does the calculation automatically when a building is simulated. As it probably takes almost the same time to fully simulate a building as enter its dimensional data into SBEM, we expect it will be common for simulation to be carried out in future for all substantial buildings. We estimate 2 man-days, say £1,000 per 1,000 m² for this.
Results

The following table shows the likely increased cost for a range of school types. The result for a medium/large school is £22/m².

The results are not very sensitive to changes in room height, or number of floors, though the number of floors makes a difference particularly in going from one to two, as floor and roof insulation halves. Nor are they very sensitive to % window area.

The results are sensitive to the floor area, particularly of smaller schools. This is because the level of fixed costs has a proportionately larger impact on small schools. The fixed costs are associated with pressure testing and monitoring and targeting. Pressure testing has to be carried out anyway, but a smaller school may opt for other measures than M&T.

Separating out fixed and variable costs of the primary and secondary schools in the table we have:

<table>
<thead>
<tr>
<th></th>
<th>Primary School</th>
<th>Secondary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Cost</td>
<td>£2,200</td>
<td>£2,200</td>
</tr>
<tr>
<td>Variable Cost</td>
<td>£25.72</td>
<td>£20.84</td>
</tr>
</tbody>
</table>

The difference is mainly due to the secondary school being built over three floors, while the primary is single level, which reduces floor and roof insulation uplift to a third.
### Area GIFA m² per unit

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>3000</td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

### Outside wall area inc windows

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>478</td>
<td>2102</td>
<td>404</td>
<td></td>
</tr>
</tbody>
</table>

### Percentage of floor area for outside openings (doors and windows)

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

### No floors

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

### Pressure test target m²/m²/mhr

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

### Pressure Testing per m²

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£1000</td>
<td>£3/m²</td>
<td>£5.00/m²</td>
<td>£5.00/m²</td>
</tr>
</tbody>
</table>

### Better detailing 10 m³/m²/hr to target m³/m²/hr

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£5.00/m²</td>
<td>£5.00</td>
<td>£5.00</td>
<td></td>
</tr>
</tbody>
</table>

### Wall Insulation improvement U value

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>.35</td>
<td>.25</td>
<td>£1.75/m² wall</td>
<td></td>
</tr>
<tr>
<td>£0.50</td>
<td>£0.88</td>
<td>£1.09</td>
<td></td>
</tr>
</tbody>
</table>

### Window U value 2.2 -> 1.9

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£28.00/m²</td>
<td>£5.60</td>
<td>£5.60</td>
<td></td>
</tr>
</tbody>
</table>

### Roof (£/m²/W/m2-K) U value .2 -> .13

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£4.75/m²</td>
<td>£1.58</td>
<td>£4.75</td>
<td></td>
</tr>
</tbody>
</table>

### Floor (£/m²/W/m2-K) U value .25 -> .22

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£2.25/m²</td>
<td>£0.75</td>
<td>£2.25</td>
<td></td>
</tr>
</tbody>
</table>

### Boilers efficiency from 78 -> 89% £/m²

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£0.00</td>
<td>£0.00</td>
<td>£0.00</td>
<td></td>
</tr>
</tbody>
</table>

### Lighting Efficacy (HF 1200mm tubes) better than 50 lumens/W

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£0.00</td>
<td>£0.00</td>
<td>£0.00</td>
<td></td>
</tr>
</tbody>
</table>

### Lighting controls, auto off, cost per classroom aM&T with auto alarms for out-of-range

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£275/ class</td>
<td>£3.03</td>
<td>£3.03</td>
<td></td>
</tr>
</tbody>
</table>

### Warnings for heating, water and lighting

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£1,200</td>
<td>£0.40</td>
<td>£2.40</td>
<td></td>
</tr>
</tbody>
</table>

### Building Simulation

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
<tbody>
<tr>
<td>£1.00/m²</td>
<td>£1.00</td>
<td>£1.00</td>
<td></td>
</tr>
</tbody>
</table>

### Cost per m²

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Medium Secondary School</th>
<th>Small Primary School</th>
</tr>
</thead>
</table>
4.3 Summary of Mandatory Cost

Mandatory cost uplifts are summarised as follows. Numbers are rounded.

<table>
<thead>
<tr>
<th>Regulatory Measure</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustics Minimum Cost</td>
<td>£2500</td>
</tr>
<tr>
<td>Acoustics Variable Cost</td>
<td>£25.3/m²</td>
</tr>
<tr>
<td>Part L Fixed Cos</td>
<td>£2200</td>
</tr>
<tr>
<td>Part L Variable Cost</td>
<td>£20.84/m²</td>
</tr>
</tbody>
</table>

The cost uplift for regulatory measures is therefore £47/m² for a 3,000m² school, or about 3.7%.
Combining the charts of the BREEAM score and renewable credits (assuming these are targeted last) gives the graph in Figure 11. In general, and in most types and sizes of school, renewables are the most expensive means of gathering BREEAM credits.

A local requirement or aspiration for renewables may mean that renewables are not the last addition but occur as an upfront cost in the same way as the regulatory requirements.
If the cost of regulatory requirements were included in Figure 11 as a cost to be met before the BREEAM score is added, it would shift the lines up by £47/m².

This graph changes for non standard schools in three main ways:

i) More up-front costs, for BSF schools or schools subject to planning or LA requirements of 10% renewables, included earlier in the score.

ii) Costs rise steeply and Excellent becomes unachievable, where because of site conditions a certain range of credits are unachievable, which means more expensive credits must be targeted if Excellent is to be achieved. This occurs in both urban and rural schools, but in each case a different set of credits become unattainable.

iii) Whole curve shifts up, making all scores more expensive. This occurs at smaller schools.
Recommendations for further work:

1. Re-examine the costs of renewables resulting from bulk purchasing, new technologies and effect the growth in the ESCO market could have on capital costs.

2. Assessment of the whole life and operations costs associated with the various BREEAM standards.
For further information about sustainable schools please contact:

Andrew Thorne  
Department for Education and Skills Schools Capital Design Team

Schools Capital Design Team  
Department for Education and Skills  
7A, Caxton House,  
6-12 Tothill Street  
Westminster  
London  
SW1H 9NF

Tel: +44 (0)207 273 6693  
Fax: +44 (0)207 273 5703

E-mail: andrew.thorne@dfes.gsi.gov.uk  
E-mail: sustainable.schools@dfes.gsi.gov.uk

For further technical information please contact:

Sean Lockie  
Regional Director Faithful+Gould

Faithful+Gould  
Euston Tower  
286 Euston Road  
London  
NW1 3AT

Tel: +44 (0)20 7121 2121  
Fax: +44(0)20 7121 3002

E-mail: sean.lockie@fgould.com