SCHOOL DESIGN:
OPTIMISING THE INTERNAL ENVIRONMENT

BUILDING OUR FUTURE: SCOTLAND'S SCHOOL ESTATE

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SCOTTISH EXECUTIVE

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Scottish Executive 2007

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PREFACE

Since the launch of the joint Scottish Executive and Convention of Local Authorities (COSLA) school estate strategy *Building Our Future: Scotland's School Estate*, the Scottish Executive has, in partnership with others, been promoting the sharing of good practice in school design with stakeholders through national conferences, workshops, guidance publications and other projects.

The purpose of this publication is to encourage continuing improvement in school design and to build on lessons learned. It follows on from previous guidance on *School Design (2003), Research on Acoustic Design in Scottish Primary Schools (2005), Design and Construction of Sustainable Schools Vol 1 and 2 (2005)* and *Post Occupancy Evaluation (2005)*. These publications are available to download from the Scottish Executive website.[1]

The Scottish Executive commissioned a Project Team comprising Drivers Jonas Mott Macdonald and members of Sarah Wigglesworth Architects and Hawksmoor Engineering Ltd (Acoustics), to research and prepare a guidance document that would assist internal environmental design. This guidance covers internal air quality (IAQ), heating, ventilation and acoustics in school buildings, in response to points that have been raised recently by stakeholders through conference and seminar discussions, school visits and post occupancy evaluations. The document suggests ways in which local authorities might consider improving internal environmental comfort to create better learning and teaching environments.

Research has indicated that the Building Bulletins, produced by Department for Education and Skills (DfES), and guides published by the Chartered Institution of Building Services Engineers (CIBSE) are often used when preparing briefs for internal environmental conditions in many Scottish school projects. This document is not intended to replace those publications but, rather, aims to provide advice and guidance to help with school design in the Scottish context and to deal with some of the conflicts that arise between the various environmental factors.

This guidance is not intended to be prescriptive. Rather, it seeks to highlight potential solutions that local authorities might consider using to help them deal with and resolve these conflicts. The conclusions reached and the design solutions offered are the work of the Project Team and are, in large part, generic solutions. It is for local authorities and their advisers to assess their needs and consider

[1] www.scotland.gov.uk/schoolestate

whether these would help determine an appropriate solution for their specific projects.

During the research the Project Team conducted interviews with a number of people involved in school design, including local authority and school staff as well as private practice architects and engineers. A workshop, involving industry professionals and local authority representatives, was held to consider and discuss a draft version of the guidance. We would like to thank all those who contributed towards the development of this guidance.

SEED (Scottish Executive Education Department)
March 2007

SECTION 1 EXECUTIVE SUMMARY

This guidance is principally aimed at local authorities and school design teams. A range of other stakeholders with an interest in school building design, including pupils, staff, communities, architects, and construction and financial professionals may also find the guide useful. Achieving high quality standards in school buildings requires a strong partnership between all those involved in the process of designing, procuring and managing the school estate. The aim of this guidance is to improve internal environments in Scottish schools through clearer briefing and a more integrated approach towards thermal, visual and aural comfort criteria. Research has indicated that a significant number of briefs for new and refurbished schools are potentially conflicting, and resolution of these contradictions usually occurs too late in the design period for an informed decision to be made (for example, the derogation of acoustic criteria due to the use of opening windows for natural ventilation purposes). It is not the intention of this guidance to create a move away from performance based specification, but to assist the client to develop integrated and non-contradictory performance criteria for internal learning and teaching environments.

GOOD LEARNING AND TEACHING ENVIRONMENTS ARE ESSENTIAL FOR SUCCESSFUL SCHOOLS. THIS GUIDANCE WILL HELP THOSE INVOLVED IN NEW AND REFURBISHMENT SCHOOL PROJECTS MAKE INFORMED DECISIONS WHEN WORKING WITH DESIGNERS TO DEVELOP A BRIEF THAT HAS THE BEST CHANCE OF BRINGING ABOUT A SUCCESSFUL LEARNING AND TEACHING ENVIRONMENT.

EXECUTIVE SUMMARY

This guidance recommends carrying out a pre-engineering exercise[2] that will lead to the preparation of a clearer brief. It is not appropriate to simply refer to established guidance such as the existing DfES (Department for Education and Skills) Building Bulletins and CIBSE (Chartered Institution of Building Services Engineers) guides. Established guidance should be used to assist in creating a briefing document on a project specific basis. In many cases the pre-engineering exercise will be in addition to the current activities carried out during early design development; however it is considered that an overall programme reduction will be achieved due to clearer briefing to designers.

The key conclusions of this work are:

- **The need for a pre-engineering exercise to be carried out**
- **The importance of early consultation and communication with users leading to agreed internal environmental standards and an informed client**
- **The need for a holistic approach to the interrelationships between the environmental criteria, and an acceptance that compromises may be needed**

[2] Pre-engineering is an analysis of the site and building's ability to deliver internal environmental standards with defined constraints

SECTION 2 INTRODUCTION

The School Premises (General Requirements and Standards) (Scotland) Regulations 1967 and the 1973 and 1979 amendments to those regulations give statutory requirements for school environmental conditions. Over the last 30 years, expectations of the environmental standards in our schools have evolved beyond that set out in the Regulations and more exacting requirements are often desired by clients. This guide will identify the briefing and design approach that is needed to deliver these enhanced standards. This publication develops in more detail the guidance that is given in the Scottish Executive's publications. *Building our Future Scotland's School Estate: School Design* (2003), *Sustainability* (2004), *Output Specification* (2004) and in the Scottish Executive sponsored publications *Design and Construction of Sustainable Schools volumes 1 and 2* (2005). Key environmental design issues are explored in the existing publications, but are examined here in more detail, together with suggested approaches to manage the delivery of these design aspects through common school procurement methods. The full range of Scottish Executive school estate guidance is available on the website[3] and should be used in conjunction with this guide. The use of the DfES Building Bulletins for environmental and other briefing purposes is widespread in Scotland. The Bulletins include guidance on some of the more recent environmental developments including acoustic conditions. They are acknowledged as providing a good basis for specifications for UK school designs.

IT HAS BEEN FOUND THAT ASKING DESIGNERS TO SIMPLY COMPLY WITH THESE BULLETINS HAS BEEN A COMMON APPROACH TO ENVIRONMENTAL BRIEFING FOR SCOTTISH SCHOOLS, LEADING TO CONFLICTS IN SPECIFICATIONS AND SUBSEQUENT DEROGATIONS.

[3] www.scotland.gov.uk/schoolestate

INTRODUCTION

This guidance document aims to assist local authorities in the development of more specific design briefing documents for internal environmental conditions in schools, namely thermal comfort, acoustics, indoor air quality (IAQ) and lighting.

A lack of clear briefing to design teams can result in a situation where late decisions are taken on environmental standards without the necessary time for informed client discussions about the implications of the proposals.

The primary aim of this guidance is to assist in the development of a specification for environmental standards that will reflect any compromises required between the various environmental standards.

The benefits of developing more specific design briefs for schools are related to the contradictory aspects of some of the existing design guidance. For example, good daylight standards are beneficial for learning and teaching spaces due to the quality of light and the reduction of energy use for artificial lighting. However, buildings designed to achieve good levels of daylight can also contribute to high summer temperatures, glare and associated discomfort for pupils and teachers.

This guidance aims to inform briefing teams of the need to carry out earlier consultation to allow clients to prioritise and allocate appropriate resources to these issues in order to produce a clearer brief for design teams.

The guidance contains general information on concept design and more detailed sections on the primary environmental design factors for schools. Whilst we acknowledge that there is a link between the factors, it was considered useful to discuss each of the primary factors in isolation before examining the interrelationships that exist between them. The guide then covers the briefing and design process and concludes with potential design solutions and specification examples.

All new building work in Scotland, including alterations, extensions, conversions and demolitions, must have a building warrant prior to any work commencing on site, except where it is specifically exempted by the Building (Scotland) Regulations 2004.[4] There are 64 mandatory functional standards and the verifier

[4] Copies of the *Building Regulations* and *Technical Handbooks* are available on the SBSA website – www.sbsa.gov.uk

will decide whether any specific design complies with these standards. Guidance to help designers and verifiers comply is set out in six sections, contained in two *Technical Handbooks* produced by the Scottish Building Standards Agency (SBSA), that cover Structure, Fire, Environment, Safety, Noise and Energy. One Handbook covers domestic buildings while the other, covering non-domestic buildings, would be relevant to school buildings. Section 5, Noise, applies only to domestic buildings and any residential school building therefore, would need to comply with section 5. **A revised edition of the *Technical Handbooks* comes into force on 1 May 2007.**[4]

The issue of sustainable school design is not explicitly mentioned in this guide. It is considered that the achievement of acceptable environmental standards for learning and teaching is one of the considerations that is at the heart of sustainable school design. There is a strong link between internal environmental design and energy use in schools and the achievement of these standards should be met with a low carbon solution. The forthcoming carbon performance requirements in the building regulations will set minimum standards that must be met for carbon emissions.

Although fully automated building control systems for internal environmental conditions can be applied to schools, it is believed that individual control of the learning and teaching environment is important in allowing users to choose conditions that are appropriate for the range of learning and teaching activities that can be undertaken in the space. Good design should allow use of manual and automatic control where appropriate.

[4] Copies of the *Building Regulations* and *Technical Handbooks* are available on the SBSA website – www.sbsa.gov.uk

SECTION 3 CONCEPT DESIGN

This section considers the factors that are important in determining the design concept for the school. The choice of site will establish certain characteristics of the school's design. The various aspects of the site are discussed in relation to their influence on the environmental strategy for the school. Potential energy sources and climate change are also considered in this section.

DESIGN OPTIONS FOR THE SCHOOL NEED TO ASSESS FULL LIFECYCLE COSTS, INCLUDING MAINTENANCE COSTS, WHEN CONSIDERING AFFORDABILITY.

CONCEPT DESIGN

3.1 OVERVIEW

In order to initiate a successful school building project, a brief must be developed in conjunction with the Project Team which recognises the needs and vision of the end users, the condition of the school site, the programme of design and construction, and the project budget.

If these factors can be established at an early stage then a school can be designed that meets economic, visionary and design expectations in an agreed time frame. While an initial appraisal can be undertaken quite quickly to gain a basic understanding of the conditions of the site, it is essential to obtain professional advice even at the briefing stage to ensure that the client team is well informed before progressing with the concept design. It is equally important to discuss initial ideas with the building users to determine what their needs, desires and capabilities are and to address alternative solutions in light of user capability issues, difficult site conditions, planning restrictions and financial and time constraints.

Compliance with the Building Regulations can have a significant effect on design solutions and designers need to be aware of the relevant standards. The Disability Discrimination Act (DDA) 1995 and the Education (Additional Support For Learning) (Scotland) Act 2004[5] will also have a strong influence on any design solution.

From 1 May 2007 the Building Regulations require every building to be designed and constructed in such a way that the energy performance in carbon dioxide emissions is calculated in accordance with a methodology which is asset based, conforms to the European Directive on the Energy Performance of Buildings 2002/91/EC, and uses UK climate data. The Simplified Building Energy Model (SBEM) is a calculation tool which may be used with the methodology which conforms to the Directive and is recommended to calculate the carbon dioxide emissions. A version for use with this guidance is freely available at www.ncm.bre.co.uk. It may be appropriate to use other tools with the methodology (such as using detailed simulation models), particularly where the building is considered to be a complex design and consultation with the local authority building standards department is advisable.

5 Under the Education (Additional Support For Learning) (Scotland) Act 2004 (Section 5 – General functions of education authority in relation to additional support needs) states that “Every education authority must, in exercising any of their functions in connection with the provision of school education, take account of the additional support needs of children and young people having such needs.”

Bringing the ethos of the school building into the curriculum through passive, everyday classroom life is an ideal way of educating pupils and staff about the environment. Connections to nature can be achieved through views toward the natural landscape, onto living walls and landscaped grounds. Direct connections to the outside can be integrated through individual classroom gardens, green balconies or terraces. Utilising natural, tactile materials inside of the classroom, exposing sustainable systems, and demonstrating techniques through iconic forms such as rainwater catchments and wind turbines can serve not only to educate staff and pupils but also to add to the identity of the school and the community. Being able to take pride in a building will encourage its users to take ownership of it, to care for it and to actively participate in its success.

3.2 SITE ANALYSIS

Before a school building is designed it is essential to ensure that the site selected for the new school can serve the community for which it is intended, while providing features which help the design team to develop a sustainable and comfortable learning and teaching environment.

While it is frequently the case that site selection is determined by planning restrictions, site ownership or economic viability, it is still essential to undertake a thorough analysis of the site conditions in order to help determine where decisions about the environmental strategy that is developed may best be focused. The following list of questions should form the basis of a value management analysis when considering site selection for school buildings:

Q: What are the climatic conditions of the site?
(Latitude, Solar altitude)

Key concerns: Temperature, Sunlight, Wind, Precipitation

The location and microclimate of a site has a real impact on the environmental design of the building. Average external temperatures will affect the heating and cooling requirements within the school to maintain a suitable learning and teaching environment. In addition, the latitude of the site will have an influence on the sun's altitude in winter and summer which, in turn, will have an impact on the building's capacity to capture sunlight.

At higher latitudes, for example in Orkney, solar altitude will decrease and overshadowing between buildings is more likely to occur. This will mean that buildings will have to be further apart to avoid overshadowing. An increase in latitude is also likely to mean lower external temperatures and therefore greater heating loads and insulation requirements on the school.

Collect data on the general climatic conditions to determine:

- Temperature – winter and summer extremes, take into consideration global warming
- Sunlight – hours of sunlight per year, sun altitudes (seasonal), solar heat gain
- Wind – wind speeds, wind directions
- Air quality – levels of air pollution, carbon dioxide levels
- Precipitation – amount of rainfall per year, intensity and type of rain (e.g. wind-driven rain), and humidity

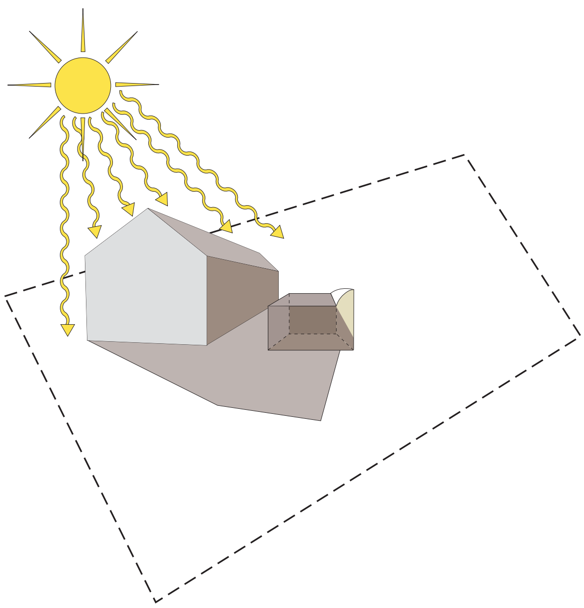
Q: What is the topography of the site in terms of its impact on environmental control strategies?
(Flat, Terraced, Sloped)

Key concerns: Effect on microclimate

A slope on a site is likely to produce overshadowing and increase the solar gain received by the building(s). Hillside and coastal sites can be windy and therefore buildings may be more prone to infiltration and draughts and hence heat loss. Care should be taken to protect buildings from the prevailing wind. Landscape features such as a large hill, forests or tree breaks can provide opportunity for rain shadow, light shadow, or windbreaks.

Assess the site to determine:

- Overshadowing of natural landscape features affecting solar heat gain/loss, light, rain shadow, and windbreaks

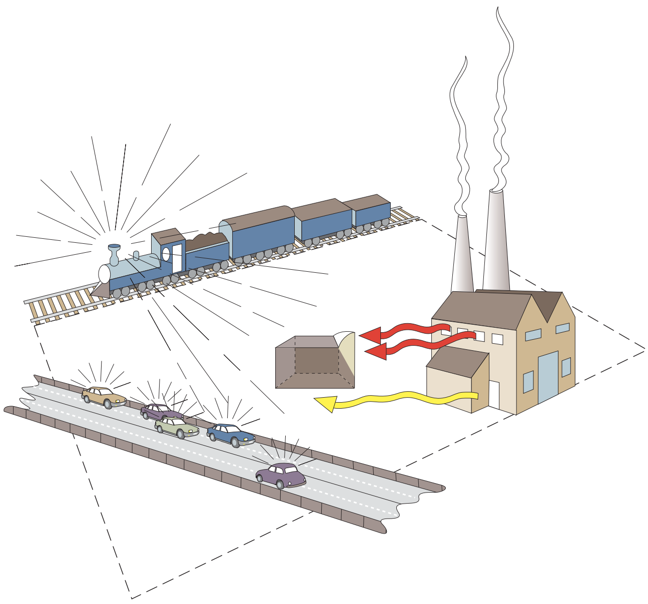


Q: Is the site sheltered?

Key concerns: Safety, Noise, Access, Constructability, Air quality, Planning constraints

The setting of the school site is likely to affect whether operable windows could potentially provide fresh air, whether height of building or location of windows might pose a security issue, whether or not a building needs to be raised, or land needs to be regenerated.

If the school site is located close to a main road or near another loud noise source (e.g. a train track or a busy public park or building), this could have a direct effect on the siting of the school building within the grounds, as well as its orientation and form. External noise sources, as well as the effects of odours and air quality from local industry, should all be considered when planning classroom location and ventilation.



Look for:

- Air pollution from local industry, roads and highways (contamination, odour, etc.)
- Noise pollution from neighbouring buildings, roads, and public parks
- Proximity to utilities (mains cold water, natural gas, electricity)

Q: Are there neighbouring buildings?

Key concerns: Proximity, Function

When assessing the relationship of a neighbouring building to the site, it is important to consider the proximity and orientation of the building. Issues such as noise, lack of air movement, wind corridors, overlooking and overshadowing can arise when dealing with buildings in close proximity. On the other hand, a neighbouring structure could provide a rain shadow or windbreak.

Assess buildings for:

- Shadowing – rain, light, wind
- Function – air pollution, noise pollution

Conclusion
Understanding the site is probably the single most important task of the design team next to identifying the needs and aspirations of the client and users. In order to utilise a site to its full potential, it is important to recognise and understand the limitations of the site and use any difficult or unusual features to maximise the possibility of a unique design. As such, it is possible to begin developing building options that are not only imaginative but also viable at an early stage. Furthermore, it will make the whole design process more efficient resulting in a higher standard of feasible strategies for the site.

3.3 BUILDING FORM AND LOCATION

Once the site conditions have been analysed and a brief has been developed during the feasibility stage of the process, key decisions can begin to be made about the building's relationship to these priorities. Such decisions will enable the clients and users to establish key criteria for design, such as the siting of a new school building and its formal characteristics. If the project is to be undertaken as a refurbishment then the building form and location will be predetermined. This does not mean that the factors described below, (which should be taken into consideration when determining the environmental performance of the building) should be overlooked, but that the existing form should be evaluated for its suitability and an environmental strategy developed which can be managed within this form.

Careful siting can promote the sustainability of the buildings and the overall development. At the earliest stage of design, topography, micro-climate, and orientation should be evaluated with regard to the following sustainability issues and the site planned accordingly. The layout of highways, buildings, landscaping, and planting should:

- facilitate access to buildings by everybody, including people of limited physical mobility;
- allow rainwater to drain to sustainable urban drainage systems (SUDS);

- maximise the advantages of passive solar gain in order to limit energy demand;
- create a benign micro-climate, particularly by limiting wind speeds which can increase energy demand;
- allow for the installation of one or more low or zero carbon technologies (LZCT), which might include micro-renewables, combined heat and power, and communal/district energy systems; and
- provide supportive habitats for wildlife.

It is important to understand that sustainable buildings do not have to incorporate bolt-on technologies such as wind turbines and photovoltaic cells. A thorough analysis of the site on a strategic level will guide a design to take optimal advantage of existing conditions to integrate natural systems of heating, cooling, lighting, and ventilation. These passive options, if considered early on as key principles of the design, will render solutions that are not only economically and environmentally sustainable, but provide a high-quality learning and teaching environment.

3.4 FACTORS AFFECTING BUILDING FORM AND LOCATION

Q: Can the building be located and orientated for natural lighting, ventilation and passive heating?

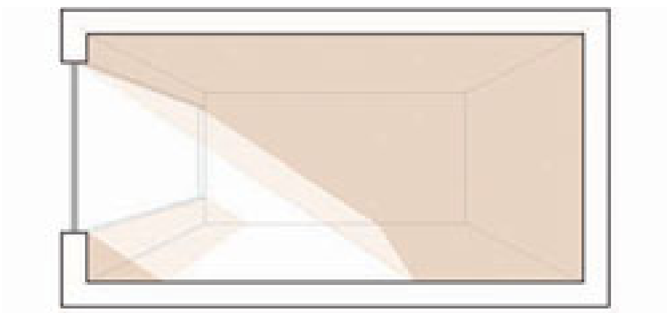
Key concerns: (Thermal mass, orientation, wind chimneys, fenestration)

Daylight is not only crucial to the learning and teaching environment, it is also a key factor in the reduction of energy bills.

If the proximity of noise sources leads to proposals to mechanically ventilate the school rather than acoustically treat the natural ventilation solution, then the full life cycle costs of the ventilation systems should be considered (as part of the decision-making process within the cost benefit analysis).

The location, form, and orientation of a building will have a major effect on the ability to light, ventilate and heat the space naturally and passively. Where possible, it must respond to the need to provide solar access to all rooms.

It is important to both maximise daylight and allow beneficial use of sunshine for winter heating.



Q: Can the form of the building encourage day lighting, natural ventilation, and passive heating?

Key concerns: (Heights, depths, areas)

The amount of glazing and its location should be optimised to encourage daylight penetration. Simple measures such as selecting high window head levels will encourage maximum light penetration deep into the classroom. It is important to consider this in conjunction with the depth and height of the classroom. If the classroom is deep, clerestory glazing, or the implementation of skylights on the far side of the room can help bring natural light into the shaded areas. These openings can also be used to aid ventilation.

Though encouraging natural lighting by way of roof lights is not an option for the lower floors of a multi-storey scheme, bringing in light through the use of a shared atrium space can be. In addition, a multi-storey option can be designed to increase the efficiency of stack-effect when dealing with natural ventilation, and internal atria can provide an opportunity for cross ventilation.

Large amounts of glazing can cause summer overheating and glare. It is important to consider these issues together with potential noise transfer through natural ventilation openings when examining building form options.

Q: How is the building to be massed?

Key concerns: (Volume to Surface Area ratio)

Consider the exposed external area in relation to getting maximum daylight to all teaching areas: the more exposed external area of a building, the greater the opportunity for natural lighting. However, this must be balanced against a greater risk for heat loss.

Q: Can external noise sources be avoided through masking or location?

Key concerns: (Location of noise source and mediation of noise travel)

In the event of a disruptive noise source near the site, a building could make use of location to diminish its effects. For example, situating the classrooms on the far side of the building away from the source of noise, on the lee of a hillside within trees, or in a courtyard, can serve to prevent noise from carrying. Other noise prevention measures such as noise barriers, fences, and screens can become an integral part of the building form.

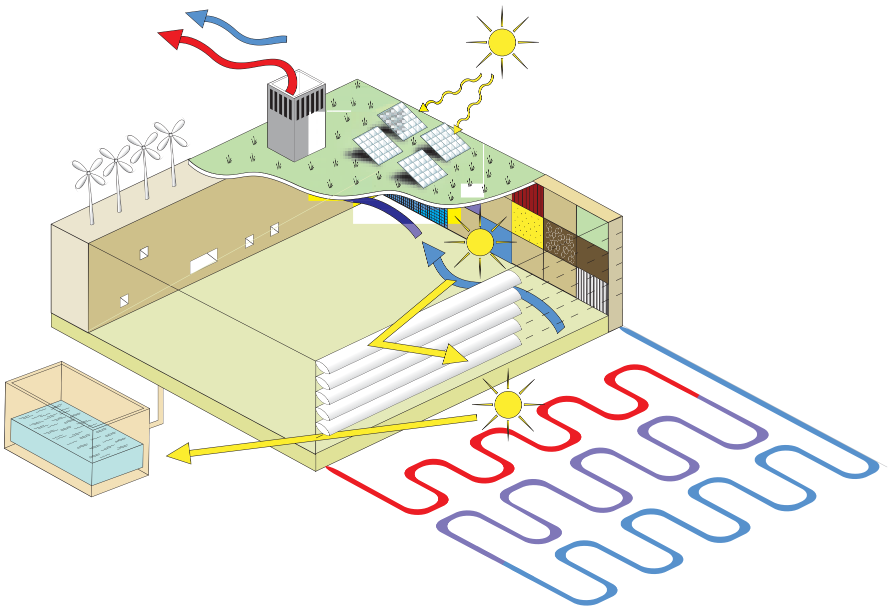
An increase in the insulation of exterior walls, triple-glazing, or massive external walls can also help diminish the effects of an external noise source. These items would have to be considered as part of any cost benefit analysis.

Q: Are there any rooms in the school which have specific or enhanced environmental performance requirements?

Key concerns: (Music Rooms, Art Spaces, ICT rooms)

Although the former suggestions apply to a typical classroom environment, it is important to consider whether there are any specific rooms that deviate in their environmental requirements. For example, a music room will require a higher level of soundproofing than a typical classroom, and it might be worth considering not only where the room is located on the site, but where it is located in relation to other, noisier spaces, such as a cafeteria or gymnasium. Simple organisational moves in terms of adjacency and contiguity of space and function can help to decrease the burden on environmental systems in increasing/decreasing heat gain, day lighting, and sound penetration. An art room, for instance, might require cross ventilation or operable glazing to diminish odours from paints, glues and other such materials. ICT rooms have significant amounts of internal heat gain and avoiding orientations that add high amounts of solar heat gain to the room is recommended.

3.5 ENERGY SOURCES



Before beginning to consider the generation of energy from renewable sources, one should aim to minimise, where economically possible, the total energy demand of the building. The strategic intent should be to maintain an incentive for continuous further improvement in energy efficiency performance over time on the understanding that current targets and regulations are not end goals but are intermediate stages towards an ultra-low energy building.

Heat energy within buildings comes from a variety of sources including solar gains, light fixtures, computer equipment and the human body, and all of these factors should be taken into consideration. In order for a space to be comfortable for its occupants, there must be the correct balance of humidity, temperature and air movement. While this is often achieved by supplementing natural heat gains with heating devices such as radiators, other devices may be used to manage this balance and reduce the financial costs of running a space. Up to a point, reducing energy demand rather than meeting demand from renewable sources can be the most cost effective means of reducing carbon emissions.

The revised edition of the *Technical Handbook* will require a minimum standard for carbon performance. Low or zero carbon technologies are clearly the best way to provide energy for schools. The use of these technologies in schools will often offer a useful teaching resource and this benefit should be considered when options are discussed.

Although natural ventilation of classrooms in the summer is an energy efficient means of cooling, natural ventilation of classrooms in the winter for indoor air quality (IAQ) standards is more complex. Winter natural ventilation is often achieved by the use of opening windows. The energy performance of these rooms should be understood, as the issues relating to good IAQ, elimination of draughts, and low energy performance are often ignored.

Energy demand reduction

- Appliances, equipment, and artificial light sources (*heat*)

The most energy-efficient lamp types are metal halide, linear fluorescent, and compact fluorescent. It is recommended that appliances with A grade energy efficient ratings be selected. All ICT equipment should be carefully selected to minimise energy use and wastage (i.e. provision of flat screen LCD monitors and lap-top computers).

- Form, Orientation, and Fenestration (*all systems*)

As discussed in section 3.2, the location, form, and orientation of the building can all serve to reduce the energy demand. Glazing should be maximised to allow beneficial use of winter sunshine heating to offset base heating loads. The consequential possibility of summertime overheating may be mitigated by inclusion of external adaptive window shading measures, simple moveable shutters or louvres and by use of deep window reveals.

- Thermal Mass (*heat*)

This is the capacity for buildings to store heating and cooling energy and slow down the cyclical fluctuations in temperature. Walls, floors or ceilings can help achieve this if exposed to ambient indoor temperatures. Serious consideration should be given to where best to provide this for the specific requirements of the school.

- Air tightness and Insulation (*heat*)

Air tightness of the building is essential when conserving energy and care must be taken to ensure that the quality of construction can deliver this. It is therefore worthwhile considering running an air tightness test.

- Natural Ventilation (*ventilation*)

Natural ventilation schemes should be adopted where possible, particularly for classrooms. An automated control system may be used in association with air quality sensors, for example, to manage the system effectively. The extent and nature of user control and manual override should also be considered.

- Heat recovery on mechanical ventilation systems (*heat*)

It is advisable to provide heat recovery to all air supply and extraction systems in order to provide pre-heating of the incoming air supply to those spaces that require mechanical supply of fresh air.

- Building automatic controls (*all systems*)

A building automatic control system can help efficient operation of lighting, heating and ventilation and monitor CO_2 levels.

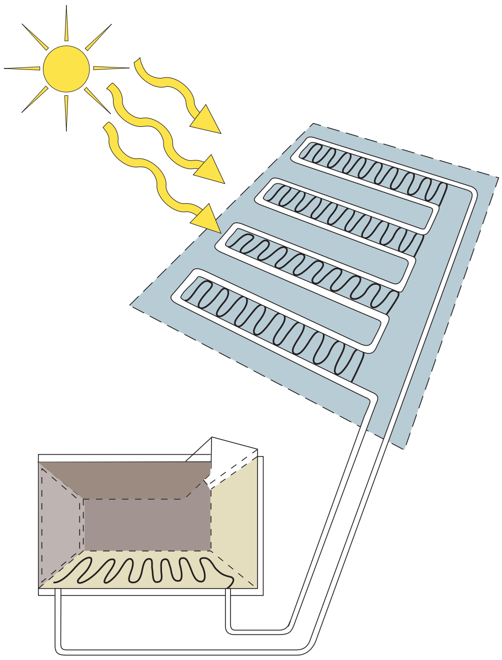
Alternative Technologies and Renewable energy sources

The use of alternative energy technologies in school buildings is increasing although in some instances these are small scale installations whose primary aim has been demonstration, rather than energy supply. This is particularly the case with wind turbines and photovoltaic solar panels. The revised edition of the *Technical Handbook* (2007) will set minimum standards for carbon dioxide emissions from buildings and so the provision of a significant amount of the schools' energy requirements from renewable sources will become an increasingly viable method of meeting this new standard. The UK Government's 'Green Guide'[6] details whole life costing and other economic assessments for alternative energy sources. The following list of technologies can be applied to schools and the feasibility of using these solutions should be examined during concept design.

[6] Available at www.sustainable-development.gov.uk/government/estates/green-guide/index.htm#best3

- Solar thermal water heating (*heating*)

This system of heating water is highly efficient as it uses the sun's energy directly to heat water. It is cost effective and is becoming commonplace in many commercial buildings.



- Ground Source heat pumps (*heating/cooling*)

These use the heat stored in the ground to raise the temperature of water sufficiently to make an appreciable difference in energy costs. In summer they provide cool water naturally.

- Boreholes (*ventilation, heating and cooling*)

A source of fresh site-supplied water that can provide summer cooling and a heat source in the winter.

- Earth tubes (*heating/cooling*)

Pipes buried in the ground provide cooled or pre-heated air for intake into the building.

- Photovoltaic panels (*power*)

Glass-faced panels, tiles or cladding use solar energy to produce electricity. Photovoltaic panels can be incorporated into the building fabric and allow good integration of energy production with the building architecture. The decision on whether to use photovoltaic panels will require a full lifecycle costing exercise.

- Biomass (*heat, power*)

A way of generating on-site heat from a renewable source (wood chips, wood pellets). Areas for storage and delivery routes are needed. Automatic feeding of boilers is the only viable option.

- Wind energy (*power*)

Can offer a viable source of energy on windy or exposed sites. Planning restrictions may be an issue.

3.6 WEATHER DATA AND CLIMATE CHANGE

There is growing evidence to suggest that the UK climate is changing and, in this context, it is important that new or refurbished building projects take future climate change scenarios into account.[7] The main climate change scenario for the UK is that winters will be warmer and wetter, while summers will be hotter and drier. The Building (Scotland) Regulations (2004) acknowledge climate change and designers are alerted to the fact that it would be appropriate for more severe weather conditions to be taken into account.

The implications for building design are as follows:

- Wet buildings are harder to heat as damp reduces the insulating effect of building fabric. Standard 3.10 in Schedule 5 to Regulation 9 of the Building (Scotland) Regulations (2004) covers the need to have a building envelope that is able to withstand the effects of precipitation so that it does not endanger the building.
- Increased rainfall may also increase the risk of condensation, with possible implications for mould growth and consequent health problems.
- Passive cooling techniques need to be sympathetic to normal user behaviour. For example, the tendency to open windows in hot weather is only helpful if this has the effect of cooling the building; if the weather outside is very hot this may increase the user's discomfort due to overheating. This can be addressed by educating the building users about the environmental systems.
- Over reliance on the provision of mechanical systems to alleviate the more extreme conditions can add to the problem of climate change through the excessive use of fossil fuel energy (unless renewable or low energy alternatives can be developed). Conventional energy sources may not always be reliable in the future, especially during periods of extreme weather (which put strain on energy utilities).

[7] Roaf, S., Crichton, D., Nicol, F. (2005). *Adapting Buildings and Cities for Climate Change: A 21st Century Survival Guide*

Design briefs need to address the issues associated with climate change by setting clear criteria for performance to which the design team must respond. Designers need to demonstrate that the building is able to adapt and remain functional over its projected life expectancy.

For buildings to provide a safe and comfortable environment in the future they should:

- **Provide the means for occupants to regulate the indoor climate.**
- **Avoid the use of mechanical cooling where possible.**
- **Avoid the need for large amounts of energy to provide comfortable interiors.**

In addition there is a need to:

- **Educate building professionals on how to design buildings that meet these needs.**
- **Educate building users on the ways to avoid heat stress and cold stress in ways that require little energy use.**
- **Instigate mechanisms for warning building users and the authorities when dangerous weather episodes are expected.**
- **Educate clients, stakeholders and users.**

SECTION 4 ENVIRONMENTAL DESIGN FOR SCHOOLS

This section gives an overview of the key environmental factors that need to be considered during the concept design stage to help determine an appropriate environmental control strategy for the school. The relationship between the environmental factors is important and in some instances it is necessary to compromise between achieving the ideal standard for each factor and the optimal balance between them all. This is not unusual and is a function of many design processes.

THE EARLY RECOGNITION OF THE ENVIRONMENTAL INTERRELATIONSHIPS SHOULD CREATE A MORE INFORMED CLIENT AND FACILITATE A DETAILED DIALOGUE BETWEEN DESIGNERS AND SCHOOL USERS THAT SHOULD RESULT IN A CLEARER BRIEF.

ENVIRONMENTAL DESIGN FOR SCHOOLS

4.1 OVERVIEW

The statutory environmental requirements for Scottish schools are contained in The School Premises (General Requirements and Standards) (Scotland) Regulations 1967 and the 1973 and 1979 amendments to those regulations. The environmental design requirements in the regulations are as follows:

- **Heating**

Required temperatures are given in the School Premises Regulations for a range of spaces, from 10°C for games halls up to 18.5°C for shower and changing rooms. These temperatures are to be maintained when the outside air temperature is 0°C and with a defined outside air change rate in the space. For example, the air change rate for classrooms is given as two air changes per hour. Although user air temperature expectations are now higher than those given in these Regulations the air change rates are generally consistent with current industry design standards.

- **Acoustics**

The School Premises Regulations state:

> “Every part of the school building shall have the acoustic conditions and insulation against disturbance of noise appropriate to the use for which the part of the building is designed.”

The definition of what is considered appropriate is not given. *DfES Building Bulletin 93 (Acoustic Design of Schools)* has defined good acoustic standards for schools.

- **Lighting**

A minimum lighting level of 108 lux is required by the School Premises Regulations. Current design standards are in excess of this minimum.

Daylight requirements are for a 2% daylight factor at all desk positions, or, if this is not provided, the permanent artificial supplementary lighting is required to provide satisfactory levels of lighting. A minimum of 2% at any desk in the classroom is a stringent requirement; however, the use of artificial lighting will be the design solution that would be adopted in most cases to meet this requirement.

- **Ventilation**

The School Premises Regulations state:

> “Every part of the school building shall be provided with means of adequate ventilation, having regard to the use for which it is intended.”

Although no specific ventilation rates are defined, the section on heating infers ventilation volumes for spaces, e.g. Classrooms need at least two air changes per hour. Guidance on complying with the ventilation requirements of the Building Regulations is given in the relevant *Technical Handbooks.*

Generally, user expectations have resulted in the standards for environmental conditions being improved beyond the levels given in the School Premises Regulations. This section examines the current guidance. Initially, the importance of each environmental factor is considered in isolation.

4.2 THERMAL COMFORT

Thermal comfort is a measure of how people interact with their thermal environment and is predominantly a function of temperature, humidity, air movement and air quality.[8]

A successful environmental control strategy should be capable of maintaining an internal environment that is neither too hot nor too cold and in which the occupants are broadly satisfied with the conditions, i.e. they are comfortable.

Thermal discomfort will arise when conditions are too hot or too cold. Under such conditions occupants will suffer symptoms such as tiredness, irritability and loss of concentration.

The majority of new schools throughout Scotland have generally been designed in accordance with the *DfES Building Bulletin 87: Environmental Design Guidelines for Schools (BB87*). Most environmental control systems for classrooms were designed on the basis of the following criteria: Winter 18°C and summer 28°C (not to be exceeded for more that 80 occupied hours throughout the year).

Although winter conditions of 18°C are stated in *BB87*, currently this temperature would be considered cold by many users.

For the summer operating condition, overheating is said to occur if the number of hours above 28°C exceeds 80 occupied hours. This is equivalent to approximately 15 days (3 school weeks) with temperatures above 28°C (based on 9.00-15.30 with a one hour lunch break). No maximum temperature is stipulated within *BB87*.

The *DfES Building Bulletin 101: Ventilation of School Buildings (BB101)* has now revised the summer overheating criteria to read as follows:

Operating Condition	Temperature	Notes
Summer	28°C	Not to be exceeded for more than 120 hours during the occupied period of 09:00-5:30, Monday to Friday, from 1 May to 30 September
Summer	32°C	Maximum internal temperature

[8] CIBSE Knowledge Series KS6: Comfort

Operating Condition	Temperature Difference	Notes
Summer	5°C	The average external to internal temperature difference should not exceed 5°C during occupied hours

In certain circumstances it could be considered that approximately one-third of the 120 overheating hours defined in *BB101* occurs during the 6-week summer break which may be unoccupied. This revised criterion could be considered as equivalent to the *BB87* criterion of 80 hours outside of the 6-week summer period.

Although the DfES guidelines are well established there still appears to be some dissatisfaction with some new school buildings in terms of their summertime performance. There is evidence to suggest that dissatisfaction is experienced even though the summertime temperature profiles are in accordance with the *BB87* and *BB101* design criteria. This suggests that the design intent and user expectations are not in alignment.

However, it should be understood that the summer overheating criteria in *BB101* represent the "minimum" that should be achieved and should not be thought of as a maximum standard. Design teams and clients might seek to improve the performance of schools beyond the minimum requirements of *BB101*. The climate in Scotland, which is generally cooler than the UK average, allows the achievement of lower temperatures in the summer to be a more realistic aim without the use of cooling or mechanical ventilation.

Section 6 of the non-domestic *Technical Handbook* refers to CIBSE guidance, suggesting that the number of occupied hours above 28ºC should not exceed 1% of the annual occupied period. Credit is also given in the Simplified Building Energy Model (SBEM) for natural ventilation control which achieves an occupied temperature that is always less than 28°C.

CIBSE Guide A[9] stipulates that the benchmark summer peak temperature for schools should be 28°C and that overheating will occur if this temperature is exceeded for more than 1% of the occupied hours throughout the year. For a school with an annual occupancy period of 1800 hours this overheating criterion equates to 18 hours above 28°C (approximately 3 days). This is a far more stringent requirement than the *BB87* and *BB101* criteria, and if adopted should ultimately lead to improved performance in terms of limiting summer overheating.

CIBSE Technical Memorandum 36[10] also recommends that a target criterion of a 1% exceedance of 28°C be adopted. This criterion should be achieved using the

9 *CIBSE Guide A* (2006) Environmental Design

10 *CIBSE Technical Memorandum TM36: Climate Change.* Both available from www.cibse.org

CIBSE design summer year (DSY) weather file rather than the test reference year (TRY) used by *BB101*. This also represents a more stringent test of overheating risk, since the peak summer temperatures in the DSYs are significantly warmer than the TRYs, which are composed of representative average months from the 1976-1990 period. TM36 also assumes that the schools are in continuous use thus leading to inclusion of warm periods that fall within the summer holidays. The computer modelling results in Appendix 1 show the importance of weather data selection when validating design solutions.

It is not the purpose of this section to promote mechanical cooling but to encourage designers to provide more information on environmental performance and to manage the expectations of end-users.

4.3 ACOUSTICS

The importance of acoustic design to the usability of a school building is easy to recognise in some cases; music departments or sites close to major transport noise sources are clear, cases where design effort is required. However, acoustic design is an important part of the whole school environmental design process as it affects the usability of all spaces. Acoustic design is not inherently complex, but complexity is introduced by the sub-division and specification of the various space uses. More importantly, acoustic parameters are often expressed as single figure numbers to describe very complex physical situations (noise is time variant as well as space and frequency variant). This frequently leads to confusion for non-specialists.

The key design issue should always be borne in mind – the ability of pupils and staff to communicate verbally within teaching spaces. In principle, the audibility is a function of the relative level of the sound that is being listened to compared to the level of noise from other sources (background noise). The background noise results from activities within the building and external to the building. The design of internal partitions and floors, together with the façade design are central to minimising such noise ingress to individual teaching spaces.

Within a room, speech reaches the listener directly, or via reflections from the surfaces of the room. Acoustic energy travels in the air at the speed of sound (nominal 343m/s) and hence reflected energy from the room surfaces arrives at the listener after the direct sound. Where the reflection reaches the listener within a short time period, this reflected energy increases the audibility of the speech; and when it arrives significantly later it reduces intelligibility. Each time the acoustic energy is reflected by a surface within the room (such as wall/floor/ceiling or contents), part of the energy is dissipated (absorbed) and part reflected. The acoustic absorption of the surface is a measure of the amount of energy that is absorbed rather than reflected. The reflected energy results in a reverberant noise field. The combined effect of the acoustic absorption within the room can be measured and quantified by a reverberation time measurement or calculation. The reverberation time is the time (in seconds) that the reverberant noise field takes to decrease by 60 dB when the sound source is stopped.

The acoustic design of the building therefore focuses on maintaining a level of background noise and reverberant noise control that is sufficiently low to enable effective communication.

Pupils with additional support needs such as dyslexia, autism or a hearing impairment are particularly sensitive to both background noise and reverberation times. Pupils having such needs must therefore be taken into account when considering acoustic design issues.

Extensive and detailed assessment has been undertaken by DfES, culminating in *Building Bulletin 93 (Acoustic Design of Schools)*[11], which provides extensive guidance and performance standards for school design. *BB93* details performance criteria for many areas that are commonly found in school designs, which can be summarised as:

- Noise ingress from external sources
- Noise transfer between spaces
- Acoustic absorption within spaces

BB93 is considered the most comprehensive single source of guidance to designers and clients. *BB101* also provides additional guidance on background noise levels at higher ventilation flow rates. However, both of these documents should be used as the starting point for design guidance, not as absolute requirements. School buildings that are successful need to meet a range of design outcomes. This inevitably means that many areas of the design are compromises between conflicting objectives. This does not, however, mean that *BB93* should be derogated in its entirety.

Key to all successful designs is the retention of a competent acoustic engineer in the design process. *BB93* makes reference to Members of the Institute of Acoustics. Other documents make reference to the United Kingdom Accreditation Service (UKAS) or Association of Noise Consultants (ANC) members with appropriate approvals as competent to test completed residential developments. It is suggested that the experience of education building design of the individual acoustic consultants advising the design team and the client are paramount.

[11] *BB93* is downloadable from www.teachernet.gov.uk

The following comments are intended to highlight specific conflicts and practical considerations that affect typical projects.

Background Noise

External Noise Ingress
BB93 identifies various teaching space use categories and noise ingress limits for each use type. These limits apply with the 3 litres/second/person ventilation flow rate, while *BB101* provides noise limits for the 8 litres/second/person case, which in general are 5 dB(A) higher.

Most schemes commence with an assumption that natural ventilation will be used via opening windows (in single sided or cross ventilation configuration). It is possible to estimate the resultant internal noise levels at an early stage of the scheme definition, using the simplification that the measured level difference (outside to inside) is some 10 to 15 dB (A) with windows open to provide 3 litres/second/person. Some 8 to 10 dB (A) with windows open to provide the 8 litres/second/person can be expected. For general teaching spaces the BB93 noise limits are 35 dB(A) $L_{Aeq,30\ mins}$ at 3 ltr/sec/person with an increase of the noise limit by 5 dB(A) for 8 ltr/sec ventilation rate.

In practice, simple natural window-based ventilation is unlikely to result in internal noise levels that comply with *BB93/BB101* if external noise levels are above 45 to 50 dB(A) $L_{Aeq,30\ mins}$. It is unusual to find a site with noise levels this low, even in rural areas. The orientation of the building can, however, be used to provide beneficial screening in many cases.

For many schemes it is very likely that window-based natural ventilation and compliance with *BB93/BB101* noise limits are mutually incompatible. Numerous ventilation strategies are available that increase external to internal acoustic separation. Use of attenuated air inlets can be combined with cross ventilation, or attenuated outlets can be considered. Alternatively windcatcher type solutions can be considered. Windcatchers are roof-mounted passive ventilation units that use wind pressure to provide supply and extract air to a space.

The ventilation schemes shown in section 6 of this document show both compliant and non-complaint acoustic conditions.

Clients are encouraged to undertake site noise measurements and hence will have an indication in the initial project brief of the likely acceptability of natural ventilation-based schemes. Scheme designers should be required to undertake more detailed site measurements and design studies to conclude the ventilation design.

Specific care should be taken to identify the needs of pupils with additional support needs when considering external noise ingress.

Mechanical Ventilation

If mechanical ventilation is used as an alternative to window or louvre-based natural ventilation, the *BB93* table 1 limits are applicable to the noise from the ventilation system. This is re-stated in *BB101*. However, these noise limits are very restrictive and often preclude the use of simple individual room-based mechanical ventilation systems.

An alternative approach, for example, is to require the design of mechanical ventilation to be compliant with CIBSE design recommendations.

Orientation of Buildings and Internal Space Planning

Very often sites are noisy due to a noise source on one side of the site only, for example sites adjacent to major roads. The large volume spaces, such as halls, can often be used to provide acoustic screening that is beneficial to the rest of the site, enabling natural ventilation to be used.

BB93 identifies that some spaces are less sensitive to background noise levels – for example practical spaces such as science labs and CDT (Craft, Design and Technology) tend to generate significant background noise levels due to equipment used in the classrooms (for example dust/fume extraction). Location of these to the higher noise level façades, with more sensitive general teaching spaces to the rear façades, often leads to more coherent overall designs.

Music and Drama departments require low internal noise levels, which would tend to lead to their location to the quiet side of the site, often the rear. If natural ventilation is proposed, care should be taken to orientate windows to minimise noise transmission between adjacent spaces. Successful designs often have music located in a single story element of the design. Where this is not possible attenuated inlet and outlet ventilation can be considered. In some cases it may be a better solution to provide mechanical ventilation as this can be designed to provide very high attenuation, eliminating concerns about noise transfer to other teaching spaces (and external spaces used for teaching). Where this design approach is used it may be beneficial to locate these departments on the noisiest façade. An appropriate design of the vent system would be likely to result in the windows to these rooms being the weakest acoustic part of the façade. Window performance can be maximised by the use of timber (or composite) window frames with acoustic laminate glass. Often equal or better performance can be obtained by using thermally compliant façade glazing with a secondary glazing system.

External Space

BS8233 sound insulation and noise reduction for buildings. *Code of practice: 1999* identifies that 55 dB L_{Aeq} (i.e. "average" noise level) is the upper limit for good external "amenity". The standard considers external space to residential properties in advising this criterion, where communication distances can be expected to be short. In many respects the criteria set out in *BB93* at 40 dB L_{Aeq} for indoor general teaching spaces can be considered appropriate criteria against which to view the design. However, on many sites such low levels will not be achievable. The external space will still be suitable for a wide range of activities. The external landscaping, and more importantly, the building form (in providing both screening and separation from nearby window-based natural ventilation spaces) should be considered.

It should be noted that acoustic design considerations of prevailing noise climates are generally undertaken in calm weather conditions. Even low to moderate wind speeds lead to elevated noise levels due to wind noise from nearby trees.

The importance of external teaching spaces and the spatial linkage to internal areas should be considered by the client, and guidance provided to the design team. Examples of typical use pattern aspirations of the external space are likely to lead to better focused designs.

Internal Noise Transfer

Traditional Cellular Space

BB93 provides a mechanism to evaluate the acoustic separation between learning and teaching spaces. The procedure is simple in concept, and competent design teams are readily able to implement the requirements. Traditional masonry and dry-lining walls can be used to achieve compliance.

Open Plan Spaces

BB93 recognises and provides a criterion for open plan space acoustic design – achievement of an sound transmission index (STI) of 0.6. The achievement of these criteria is not however subject to Building Regulations. The Scottish Executive commissioned a study[12] that assessed three Scottish Primary schools with varying degrees of open plan design. The report provides guidance on the impacts of sample open plan designs and makes good reference to the issues and questions that should be considered. Benefits are documented and discussed in this report, together with some of the disadvantages of each approach.

A key conclusion is that open plan design impacts on the teaching and management styles within the school, and hence it is considered very important that teaching

12 *Design for Educationally Appropriate Acoustic Characteristics in Open Plan Schools,* Research report to the Scottish Executive, 2005 available on www.scotland.gov.uk/schoolestate

staff are involved in the project briefing stage and that the brief identifies the degree to which open plan design has been and will be supported by the staff.

Other conclusions are:

- **Good control of background noise levels are required**
- **Low reverberation times are required**
- **Fixed Furniture and Equipment (FF&E) impacts the achieved performance**
- **Standard Speech Transmission Index (STI) (or similar) design techniques do not adequately reflect the voice effort or spectral content of pupils in verbal communication**

Clients should consider retaining specialist advisors at the briefing stage to aid the process of defining the brief to design teams.

Internal Glazing

Internal glazing can provide benefits to supervision of pupils and open architectural design. Furthermore, internal glazing can be of benefit to wheelchair users, visually impaired pupils, and a range of other pupils with additional support needs. Designing and procuring internal glazing to achieve *BB93* compliance is feasible for corridor walls, but very often such glazing is adjacent to doors which are acoustically weaker and hence it may be appropriate to consider a lesser standard of glazing performance for these windows.

Where internal glazing is between teaching spaces, it can be difficult (and often impossible) to procure glazing that achieves *BB93* compliance. The benefits and disadvantages of internal glazing should be reviewed and the client should make a positive decision to guide the team on the general acceptability of such glazing.

Internal Doors

BB93 states that all teaching spaces should have acoustic door sets rated to at least 30 dB R_W performance. Doors of this type require perimeter and threshold seals. Compared to non-acoustically rated door sets, opening forces tend to be higher and may conflict with the objectives of the Disability Discrimination Act. The requirements of pupils with additional support needs should be taken into account when considering internal doors. In many cases the use of such doors is of marginal benefit. For example a corridor within a teaching wing (where the corridor is only used for access rather than teaching) should not have high noise levels during teaching times – acoustic doors provide little real benefit.

The provision of acoustic doors can be reviewed on a practical basis for each scheme. Care should be taken to consider the location of and impact on rooms used for examinations.

Reverberation Times

BB93 states requirements for reverberation times in teaching spaces. The use of absorptive ceiling tile systems can be expected to achieve compliance with the requirements for most areas. However, a number of issues do arise that can complicate the matter.

Exposed Soffits for Thermal Mass

Traditional ceiling tiles act as an insulator and prevent the air within the room reaching the soffit, preventing the structure from absorbing and radiating heat to control over-heating. As noted in Section 6 this should be a major environmental design driver. It is possible to design ceiling systems that partially cover the ceiling, but retain thermally exposed soffits and examples are shown in Section 6. Such coverings do not provide the same level of acoustic absorption to the space as a fully tiled ceiling. Carpets also provide acoustic absorption and often this additional absorption is sufficient to achieve compliance. Where absent, additional acoustic wall panels are likely to be required.

In many cases, providing a reflective ceiling (i.e. exposed soffit) (particularly in the centre of the room) provides beneficial reflection of speech that increases the audibility.

Clients should confirm that achieving *BB93* reverberation criteria for class bases can and should be achieved by school design teams.

Sports Halls

The design of sports halls in many cases has comprised acoustically hard floor finishes (timber) with acoustically hard wall finishes (masonry) and a composite roof system including perforated steel liners, with fibrous backing material providing acoustic absorption. This can be expected to result in reverberation times of 2 to 3 seconds, compared to the *BB93* criteria of 1.5 seconds. To achieve a lower reverberation time additional acoustic absorption can be provided to the walls using proprietary acoustic panels. However, to maintain re-bound surfaces the absorption cannot extend to floor level. The hard surfaces at low-level result in reverberation time measurements that do not reflect predicted performance. When in use however, people and equipment provide additional reflective (and absorptive) surfaces that tend to reduce the measured reverberation time.

Clients may also wish to consider requiring such spaces to be tested for air tightness. Where this is specified it may alter the design approach, as achieving air tightness with such a design has to rely on the outer roof surface (and eaves detail) or the vapour check membrane (installed as part of the roof build up) as the air tightness barrier. Recent experience has shown that contractors view the risk of failure to achieve the air tightness requirements to be considerable with such a design. An alternative design approach is to use a solid roof liner system, combined with a ceiling system that withstands impact (e.g. tile ceiling with appropriate mechanical restraint against dislodge due to impact, or a perforated plasterboard ceiling that provides acoustic absorption). This can be combined with high-level acoustically absorbent wall panels.

It is suggested that clients specify if air tightness testing is required, and also consider an approach that requires design teams to demonstrate appropriate reverberation times using Sabine[13] calculation methods, rather than reverberation time performance of the completed space.

"Large" Common Spaces
Many modern school designs include a "street" concept of learning and teaching spaces leading from common multi-use areas. Large volume spaces naturally exhibit a long reverberation time, and it is only to an extent that this can be controlled by room treatments. For dining and circulation spaces this is generally not a significant issue, however, particular care should be taken where learning and teaching spaces lead directly from such areas. It is even more important where elements of the space are intended primarily for group communication or quiet study. Key to a successful design is the provision of as much acoustically absorbent treatment as is reasonably feasible.

Areas within the overall space can be locally treated to provide a "micro-climate" of lower reverberation times compared to the overall space. The use of carpeted floor finishes/acoustically absorptive ceilings and fabric covered screens as well as furnishings can all contribute to the resulting environment. The benefits provided by fixed furniture and equipment (FFE) should not be ignored.

Impact Noise
BB93 details performance criteria for impact noise. These are reasonable and stand comparison with other impact noise requirements such as those on housing developments. However, *BB93* states that achieving these criteria needs to be demonstrated in the absence of floor finishes. In practice these finishes will be present in a completed building, providing significant benefit, and would be expected to remain in place in the short and long term.

Clients may wish to consider allowing the designers to take account of the positive benefit these finishes provide in achieving *BB93* criteria.

[13] The Sabine calculation is a simple method of estimating the reverberation time using an area-weighted factor for the acoustic absorption properties of the space

Testing
Testing is not mandatory under *BB93*, but is encouraged. In practice an element of acoustic testing is beneficial to most schemes. The measurement programme detailed in *BB93* is extensive and hence can be time consuming. For the testing to be undertaken, the building needs to be completed and hence often needs to be undertaken at a time of high site activity.

Clients are encouraged to specify a requirement for the building to be tested on completion, but that the scope of testing can be considered at a lesser scope than detailed in *BB93*. The testing should encompass the sample testing of: noise ingress; Mechanical and Electrical (M&E) noise levels; sound transmission; reverberation times; impact noise.

Flexible-Use Spaces
Increasing use is being made in modern designs of flexible-use spaces. Almost inevitably the acoustic requirements for these uses are different. As noted previously, the guidance provided by an experienced acoustic consultant is highly beneficial in identifying and resolving potential conflicts. The following are some typical examples:

- **Sports halls used for examinations**
  In some instances it is unavoidable that sports halls are used for examinations. Sports halls are tolerant of relatively high background noise levels from ventilation systems, whereas exam use requires low levels of background noise. Exam use should be a clear requirement within the brief, but clients should recognise significant additional cost may be incurred in designing the ventilation system to suit.
- **Drama rooms connected to main halls**
  It is a common design approach in many schemes to connect a drama or dance studio to the main hall via a moveable wall. Such a design provides flexibility to use the drama space as the stage during performances. However, a moveable wall in this location that is practical to move on a regular basis will not provide the level of acoustic isolation that *BB93* suggests. Consideration should be given to the concurrent use of the two spaces, particularly examination use in the hall. The school staff need to be consulted to ensure timetabling can accommodate the restrictions that result.
- **Kitchen to hall**
  It is common practice for serving hatches to be separated from dining areas by roller shutter-type hatches. Where the dining room is only used for dining significant issues do not arise. However, in many school designs this is not the case and the dining area is also used as a secondary hall as part of a “street” common space. Careful spatial layout can mitigate the situation and should be

considered early in the concept design stage. In primary schools it is common to use the main hall for dining and also for timetabled teaching (such as PE). In this situation it is often difficult to achieve good acoustic separation. Location of the chair store immediately in front of the kitchen (acting as a buffer space) combined with moveable walls can often be a good design approach.

- **Moveable partitions between teaching spaces**
  Moveable walls between classrooms are often desired to provide flexibility. For standard classrooms these can achieve *BB93* criteria and should be installed to achieve such.

  It should, however, be noted that the achieved performance in the closed position is sensitive to staff following the correct manufacturer's procedures.

- **Multi-use halls**
  Halls used for a variety of uses require differing reverberation times. To provide flexibility the use of drapes can be considered, in addition to acoustic ceiling and wall treatments.

4.4 VENTILATION AND INDOOR AIR QUALITY

The prime function of ventilation is to provide good Indoor Air Quality (IAQ). A secondary function of ventilation can be to provide cooling to a room; this is achieved by bringing outdoor air through the room to remove unwanted heat gains, thus preventing an excessive rise in room temperature. Both of these functions are a fundamental requirement of ventilation design for schools.

IAQ is important in schools as poor levels will affect learning. Poor IAQ can be caused by a number of factors such as:

Period of occupation
External air quality
Number of students and level of activity
Indoor air pollutants

The *DfES Building Bulletin 101: Ventilation of School Buildings (BB101)* contains a full list of pollutants that need to be considered/avoided.

Classrooms typically have a high density of occupants, and ventilation levels for improving IAQ need to be relatively high. Ventilation for IAQ is required all year round and not just in summer. The provision of the necessary ventilation in the winter is especially problematic when provided via a natural ventilation solution that uses opening windows as the means to bring air into the room.

Although a complex set of factors are involved with IAQ, it is accepted that if CO_2 (carbon dioxide) levels are kept low, then good IAQ will probably be achieved.

Levels of CO_2 will reduce as higher levels of outdoor air are passed through the room. As a guide, levels of between 1000 ppm CO_2 and 1500 ppm CO_2 will generally indicate good IAQ in classrooms.

Research[14] has shown that levels in excess of 4000 ppm CO_2 have been found in UK schools, indicating unacceptable levels of IAQ. This normally occurred during winter periods and was largely due to windows not being opened during teaching sessions. The reasons given in the research for the failure to open windows were the siting of the windows, making opening difficult, and draughts generated by open windows in the winter.

A successful strategy for IAQ would result in good levels of IAQ throughout the classroom, particularly in winter, without causing cold spots or draughts. IAQ can be reduced by the use of finishes and fittings with high emissions of volatile organic compounds (VOCs). No or low VOC paints and furnishings should be used, and it is important that maintenance and future reprovision of finishes and fittings recognise the importance of VOCs to IAQ.

A secondary function of ventilation is the prevention or reduction of summer overheating. The volumes of air needed to achieve this are generally in excess of those needed for good IAQ standards. A natural ventilation solution needs to be controllable to allow the air flow volumes to be increased in summer to prevent excessive temperature increases.

A successful strategy for summer overheating would include simple controls and instructions for the teacher that indicated the two principles of the ventilation strategy and how to switch between them.

BB101 requires a ventilation rate of 8 litres/second/person in classrooms to provide acceptable levels of IAQ. The Bulletin states that classrooms should be capable of providing this ventilation level, but must provide 3 litres/second/person at all times during occupied periods. Combining the various functions of the ventilation strategy gives the following three clear design requirements:

14 Beisteiner, A & Coley, DA (2002) *Winter Time Ventilation Rates in UK Schools.* Centre for Energy and the Enviornment, University of Exeter

Requirement	Natural Ventilation Approach	Mechanical Ventilation Approach
3 litres/second/person during occupied periods	Permanent/controllable [open/close] openings in façade. Generally they need to be much bigger than traditional trickle vents	Background ventilation setting
8 litres/second/person-capability to be available at all times	Adjustable openings under the control of the teacher. Generally to be open for more than 50% of the teaching period	Boost setting. Under the control of the teacher
Summer overheating reduction	Larger openings under the control of the teacher. Generally to be opened to relieve temperature in summer	Possibility to use natural ventilation in summer or a further boost to the mechanical system

Notes:

1. For a classroom with typical dimensions of 7.5m D x 8.0m W x 2.7m H, 3 litres/second/person equates to 2.1 air changes per hour and 8 litres/second/person equates to 5.7 air changes per hour.
2. *CIBSE Guide A* currently recommends 10 litres/second/person for schools.

Recent research[15] also raises the issue of outdoor air quality when determining the correct ventilation rate for controlling indoor air quality. City centre locations, for example, can have high levels of CO_2 in the external atmosphere. This means that ventilation rates in excess of the 8 litres/second/person (as stipulated within *BB101*) may be required to control indoor CO_2 levels to 1000ppm or less. Consequently, it may be necessary to undertake outdoor air quality tests to ascertain the basis for determining ventilation rates in school buildings.

4.5 LIGHTING

Daylight is considered an essential component of school building design. The availability of daylight in a space creates a link with the outside environment and an opportunity to reduce or omit the reliance on artificial lighting and its consequent energy usage. The benefits of daylight are more than just the reduction of energy use for artificial lighting. It is considered that the quality of natural light is far superior to that produced by artificial lighting.

[15] Pearson, A (2006). Manchester breathes easy. *Building Services Journal*. Vol 28, No.6

Good levels of daylight will be achieved by the use of large window areas and roof lights. The daylight factor is commonly used to quantify daylight in an internal space. In simple terms, a daylight factor is the percentage of outside light available within an internal space. A 2% daylight factor would mean that 2% of the external light level is available at the position in the internal space. The use of average daylight factor for a classroom is a method of specifying the amount of daylight required. As the external levels of daylight are very high, the average daylight factor does not need to be higher than 5% to allow the artificial lighting to be switched off. A further criterion for daylight is uniformity. As average daylight factors are often specified, it is important that the uniformity of the daylight is also considered. The uniformity of the daylight is the ratio of the minimum to the average daylight factor within the space.

Established guidance on daylight for schools is found in *Building Bulletin 90: Lighting Design for Schools.* This states that a space with an average daylight factor of 5% or more will not normally need to use artificial lightning during daylit hours, rooms with an average daylight factor of 2% or less will need frequent use of artificial lighting and rooms with average daylight factors between 2% and 5% will need artificial lighting between October and March and should have automatic daylight control linked to the artificial lighting. *BB90* also recommends daylight uniformity ratios of 0.3-0.4 for side lit rooms and 0.7 for top lit rooms.

The use of artificial lighting throughout the day will be common in most schools. Standards for artificial lighting are defined by the following characteristics:

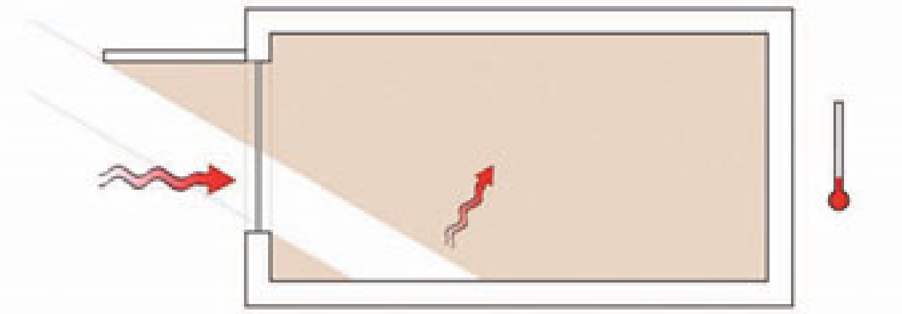
- Lux levels – Brightness
- Glare index – The measurement of discomfort glare from artificial lighting
- Colour rendering index – The measure of the ability of the artificial lighting to reproduce good colours
- Uniformity

The guidance in *BB90* should be used to identify the standards required for learning and teaching spaces. This information can easily be coordinated by the use of room data sheets (see section 7.2).

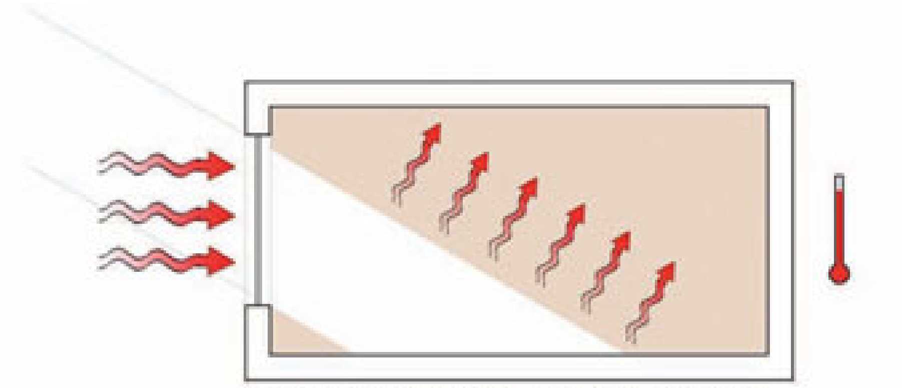
4.6 INTERRELATIONSHIPS

The interrelationships between the four primary environmental factors (thermal comfort, indoor air quality, lighting and acoustics) are important. They need to be considered at an early stage and any hierarchy between the criteria developed. It is not always practical or economically viable to satisfy all of the individual environmental standards in a single design solution. A pre-engineering exercise allows an informed decision to be made on the hierarchy of environmental conditions for an individual school project. For example, on a city centre site the external acoustic environmental can be measured and the feasibility of natural ventilation can be examined. The pre-engineering may conclude that acoustically-treated ventilation openings are required should natural ventilation and the *BB93* acoustic standards be desired. This should inform the cost plan and the potential floor area requirements of the school. A full range of environmental criteria can be explored without a detailed school building design. Care should be taken at this stage to manage the expectations of the end-users so that they fully understand the capabilities and limitations of what their new or refurbished facility will deliver.

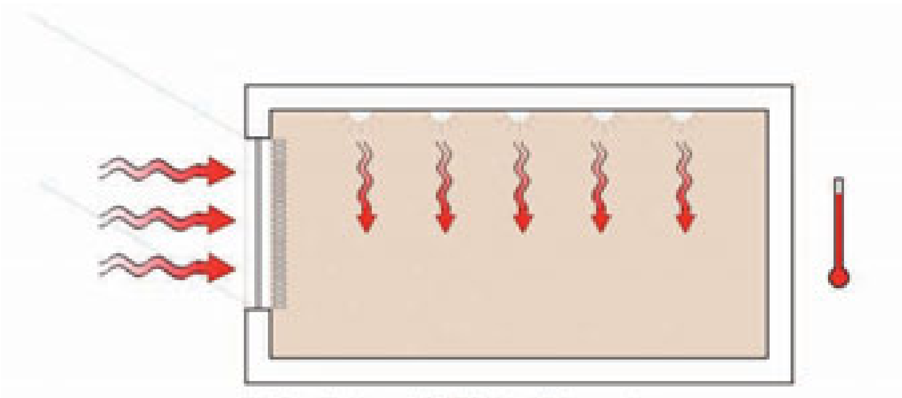
These interrelationships are illustrated with the relationship between good daylight and the prevention of summer overheating. Larger windows create better daylight factors, but allow more solar heat gain to enter the room in the summer. These interrelationships are understood by designers, but in some cases environmental design briefs do not acknowledge them. For example “maximise the use of daylight”, can be found in the same brief as “limit the maximum summertime temperature to 24°C” and “natural ventilation is the preferred solution”. It is not always possible to keep below 24°C in the summer with a naturally ventilated classroom that has large areas of glazing. Additionally, statements such as “maximum use of daylight” should be quantified as a specific daylight factor requirement.



light shelf: optimal, permits light whilst shading the glass surface

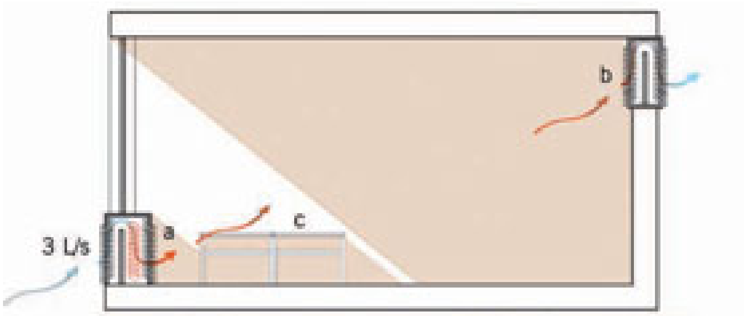


no shading: permits light but also heat from the glass surface



blinds: reliant on artificial lights which generate heat internally

The interrelationship between acoustic performance and natural ventilation has been recognised in many publications. *BB93* has set acoustic performance standards that are conducive to the learning and teaching environment. One of these standards relates to the amount of external noise that enters the school space. Clearly the use of simple window openings for natural ventilation will result in increased noise ingress into the space. This means that for many sites with high ambient noise levels, the use of simple window openings will not be possible. Indeed it has been found that the majority of schools in England[16] have external noise levels that would preclude the use of natural ventilation by opening windows on some orientations of the school due to the acoustic standards required by *BB93*. The solution to this apparent conflict is to use attenuated natural ventilation openings in the façade to provide the ventilation standards as opposed to using opening windows. This solution can also be beneficial in terms of helping to reduce the problems of winter draughts from poorly positioned window openings, e.g. the openings can be positioned/designed to introduce the air in a controlled manner and/or be integrated with heat emitters to facilitate tempering of the incoming air. It can, however, have an effect on the daylight factor as the façade space used for the attenuated louvres creates spatial pressures on the overall façade design.



winter: good thermal comfort at the expense of poor (mechanically aided) ventilation

a) acoustically attenuated air intake with heating coil; b) acoustically attenuated air extract to atrium or exterior; c) required daylight factor of 2-3%

These design conflicts can be difficult to resolve and sometimes the use of mechanical ventilation could be used to solve a number of interrelated problems. Mechanical ventilation has the advantage of being able to deliver the correct amount of fresh air (for IAQ purposes) in a controlled manner. The supply air can be tempered during winter months (ideally via heat recovery methods) thus eliminating problems associated with cold draughts. Supply air can also be filtered thus enabling airborne contaminants (dirt, pollen, etc.) to be removed from the air before being supplied to the space. It is also relatively straightforward to acoustically treat mechanical systems so they can be readily applied to sites that have high ambient noise levels. Mechanical ventilation solutions are generally considered more expensive in terms of initial capital expenditure and life cycle costs. Initial capital expenditure needs to be weighed against the cost of

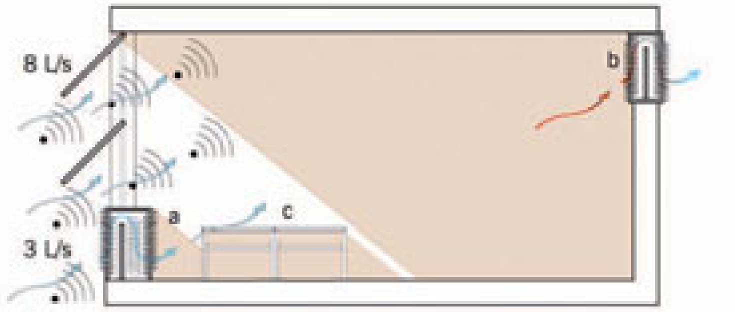
16 Parkin, A (2005) Sound Insulation and Ventilation in Schools: A coordinated approach, *Acoustics Bulletin,* July/August 2005. Institute of Acoustics

acoustically engineered façade solutions and the cost of details associated with integrating natural ventilation openings with heating systems to avoid draughts. In terms of life cycle costs some research suggests that overall running costs (energy and maintenance) are less when compared with a natural ventilation solution. For example, if not properly managed, natural ventilation solutions can result in buildings being over-ventilated in winter, leading to excessive heating demand.

Another problem associated with simple natural ventilation solutions is that they may not be operated correctly by the end-users. For example, windows are not opened in winter due to the potential for draughts. IAQ suffers as a consequence as CO_2 concentrations rise beyond their recommended threshold values. Winter ventilation requirements provided by natural ventilation solutions generally result in large heat emitters being required. The use of natural ventilation in classrooms requires the room heating system to be capable of heating the incoming winter air to room temperature. Typically designers use a figure of two air changes per hour as an amount of ventilation air that needs to be heated. In a new building with high levels of insulation this can result in heat emitters up to 60-70% bigger than they would need to be with a mechanically ventilated solution. This creates pressure on wall space should radiators be the chosen heating method and the control of heating systems of this larger capacity can be problematic if not addressed as part of the control strategy. The use of under floor heating is often proposed to "free up" wall space. However, with a naturally ventilated solution, the heat output needed to cater for the ventilation air can cause difficulty with the capacity of the under floor heating system.

These interrelationships will often lead to compromise solutions, for example, a classroom solutions could be as follows:

Daylight – 2-3% daylight factor.
Winter ventilation – via acoustic louvres, supplying air behind the heat emitter and discharging air to the atrium.
Summer ventilation – through opening windows with no acoustic treatment.



summer: good thermal comfort at the expense of intrusive noise from exterior

a) acoustically attenuated air intake; b) acoustically attenuated air extract to atrium or exterior; required daylight factor of 2-3%

SECTION 5 BRIEFING AND DESIGN PROCESS

The briefing and design processes are key to delivering the desired environmental standards for schools. Two elements are needed; consultation with the users in the development of agreed standards and the translation of these standards into documents and specifications for designers.

PRIOR TO CONSULTATION BETWEEN THE DESIGN TEAM AND END-USER, A SET OF BRIEFING EVENTS SHOULD TAKE PLACE THAT EXPLAIN THE PROJECT CONTEXT TO BOTH PARTIES. THESE WILL HELP TO MANAGE EXPECTATIONS AND GIVE A CLEAR INDICATION OF WHERE FURTHER INFORMATION CAN BE GAINED TO HELP CREATE A WELL INFORMED PROJECT TEAM.

BRIEFING AND DESIGN PROCESS

5.1 OVERVIEW

This section gives an overview of the briefing and design process. Consultation and communication with users, specification of requirements, design process and design validation are all considered important activities in the achievement of agreed environmental standards.

5.2 CONSULTATION WITH END-USERS

Once a design brief has been initiated it is important that this is developed in consultation with the end-users to ensure that any design strategies developed for the building meet the local authority's vision, capabilities, and expectations. The consultation process should be about keeping the whole team (including the end-users) informed about the progress of the project as it is about gaining feedback on any design decisions that are made. *Designs on my Learning*[17], published by The Lighthouse gives an excellent account of consultation with school pupils and gives examples of tried and tested methods for evaluation and management of the consultation process.

Pre-consultation
Frequently, the time period allocated for consultation can be limited by constraints of programme and budget. If those involved in the project are aware of these constraints and the context within which the project is operating then strategies can be put in place to involve users and this will help to bring about a successful consultation process.

Undertaking consultation
Consultation is likely to occur throughout the briefing, feasibility, design and construction phases of the project and should evolve to suit the changing needs and requirements of the project team as a scheme develops. While it is impossible to set a complete consultation agenda at the start of a project, each event or discussion should have a clear intended outcome and should be limited in the number of consultees in order to help make rapid and well informed decisions about how best to progress the project. For example, in developing the environmental strategy for the building, it may be essential to undertake discussions between the school, Building Services Engineer and Architect. This should be undertaken early in the design phase to help establish a sustainable building solution which provides an exciting, creative learning environment to help the school successfully deliver its curriculum.

[17] The Lighthouse (2005): *Designs on my Learning: A guide to involving young people in school design* (available from www.scotland.gov.uk/schoolestate)

Consultation strategies
May include:

- Visits, fun days, role-play, storytelling
- Workshops and events such as music, dance, drama, mime, games
- Meetings, discussions and memory triggers
- Models, art and drawing
- Exhibitions and presentations.

While there are other methods that could be added to this list, it is likely that the design team working on the job will have been involved in previous consultation exercises and may therefore be able to offer some advice on the best means of progressing the project within the available timescales.

Feedback
In undertaking any form of consultation strategy it is important that decisions that are made are formally fed back to all of those involved to ensure that the progression of the design can be monitored and end-users can recognise their own positive contribution to the design process. Feedback can take a number of forms but should be undertaken in a way which gives all of those involved a clear and simple explanation of any decisions that are made and how these are to be progressed.

It should be noted that the consultation process should not be limited to a short phase at the beginning of the project but should continue throughout the process into the construction period to ensure that the project team are kept up to date with the progression of the scheme and that those who will use the building continue their “ownership” of the building.

5.3 DESIGN PROCESS

This section gives an overview of the process through which the project will progress. Although the overview of the process provides a basic guide to how a project could develop, it is often the case that the activities do not occur in a linear sequence and aspects of a project are re-visited and re-assessed. These stages therefore give an understanding of a school building project but should be considered in the light of a context specific programme and procurement strategy.

New schools being procured by design and build or Public Private Partnerships (PPP) procurement routes require a design process that is different to the traditional method. The provision of an environmental specification for the school is always required. However, in design and build or PPP procured projects, the specification is based on outputs (performance) rather than input. Detailed and fully designed solutions for the school will be undertaken by a contractor. This creates a clear division between local authorities and contractors in the delivery of the required environmental standards. The following guidance is aimed at the provision of the performance specification for those types of projects.

The production of the performance specification requires some design work to be carried out in order to test the feasibility of the requested performance in the specification. This requires an examination of the various environmental parameters for the school in addition to discussion and consultation with the users on any compromises that are needed. This work is complex as it can in some cases require consultation with users without the assistance of a detailed architectural plan or model. It requires strong skills in communication and management of information to use these consultations and convert them into an agreed performance specification.

The pre-engineering study needs to examine the following:

Acoustics – A study should be carried out on the existing acoustic environment at the site. This will allow a judgement to be made on the likelihood and cost of achieving good internal acoustic standards with a natural ventilation solution. A range of options will arise and consultation with the users should allow an informed judgement to be made on a preferred solution.

Daylight – An agreement is needed on the likely levels of daylight that can be achieved and the importance of this to the school users. Overshadowing of the site, if present, will preclude good daylight in some of the spaces. Any spaces requiring a priority for good daylight should be identified at this point. An interrelationship exists between good daylight, summer overheating and acoustically treated natural ventilation openings. This must be examined at this stage, for example, including acoustic natural ventilation openings in the façade can reduce the amount of available wall space for windows and hence reduce the level of daylight than can be admitted into the room.

Summer overheating – An analysis should be carried out to determine the likely internal summer temperature conditions with a range of ventilation solutions. The results may indicate that a cross flow solution is required to meet the expectations of the users. This will require an initial examination of the likely internal heat gains for a range of internal spaces. This analysis should also explore the possible interaction of the building users and manual controls, should such a solution be desired.

Winter ventilation – An approach to winter ventilation should be explored. The reduction of CO_2 levels in the winter when using a natural ventilation solution can be partly achieved through purging of the classroom space at various times, but this requires teacher interaction. Permanent levels of winter ventilation through either opening windows or purpose made louvres need to be discussed with the users.

The outcome of this should be a more informed client and a clearer performance brief to the design teams who will undertake the detailed design work.

5.4 DESIGN SPECIFICATION

Output Specification: Building our Future, Scotland's School Estate (2004)[18] published by the Scottish Executive, gives specific guidance on developing an output specification for Public and Private Partnership (PPP) school projects. It acknowledges that output specification is complex and has a range of purposes:

> "It is a considerable challenge to set out all the requirements in the output specification in a way that is clear, and can form the basis for monitoring performance with facility and service standards which will trigger payment deductions if the contractor fails to meet these" - (Page 3).

For environmental conditions, the lack of a clear and non-contradictory output specification has been considered a weakness in the delivery of good standards in some new and refurbished schools.

The specification for the works needs to be clear and allow designers to meet your expectations. Statements such as "maximise the use of daylight" may be acceptable as an early aspiration for the client and the design team, however, this is not an acceptable way to pass expectations to a design team in a contractual document. The specification of your environmental requirements needs to be clear and based on the pre-engineering that has been carried out.

Many specifications for environmental conditions for schools include statements asking the designers to make the building comply with the various *Building Bulletins* for schools. This is not a clear way to specify conditions; the *Building Bulletins* are guides for designers, but are not specifications. For example, *Building Bulletin 90* states that daylight should always be the prime source of lighting during daylight hours; however, this requires a daylight factor of 5% or more. It is much clearer to use the specified daylight standards based on a pre-engineering study. Section 7.1 of this guide provides some draft specification clauses.

[18] Available at www.scotland.gov.uk/schoolestate

5.5 DESIGN VALIDATION

Design validation is the process of finding out whether the proposed school design complies with the performance requirements. For internal environmental performance standards, designers will need to carry out a number of analyses to determine whether the design can provide the necessary environmental standards. This is an important early design activity and a full simulation software analysis should be carried out. The pre-engineering study would be the first stage of design validation for the purposes of feasibility, but a more detailed approach will be needed, once a complete school plan is available.

All of the analyses are similar in nature, in that they need data input about the building and its components and a simulation of the external conditions (climatic conditions). The key issue is to define the external conditions clearly to the designers, especially when a number of competing designs are involved.

Briefly, the approach for external conditions for each distinct environmental issue is as follows:

Acoustics
Acoustic calculations are needed and should normally be carried out by an acoustician. The calculations normally form part of an overall acoustic report for the site and the proposed building.

Daylighting
The calculation of daylight factors is based upon a standard external sky; full details of this are contained in *BB90*. Key factors in this analysis are the size, location and type of glazing, internal reflectance of the surfaces and any external obstructions.

Summer overheating and Indoor Air Quality (IAQ)
Although this involves a complex set of interactions for the specifying authority, *BB101* gives a clear methodology. If a clear design or output specification has been prepared, then the information to be extracted for the validation will be clear. For example, we would expect the number of hours above a range of internal temperatures to be extracted from the simulation results by the designers.

SECTION 6 GOOD PRACTICE DESIGN SOLUTIONS

The design of schools needs to consider the environmental standards that need to be met. Many design solutions exist, and compromises on the full range of environmental standards are likely to be needed. This section examines solutions for all of the main criteria individually. Design solutions are also presented that indicate some of the compromises that may need to be considered.

A WIDE RANGE OF ENVIRONMENTAL SOLUTIONS EXIST, HOWEVER ALL THE ENVIRONMENTAL CRITERIA CANNOT BE FULLY MET AND THIS CONFIRMS THAT COMPROMISES NEED TO BE CONSIDERED.

GOOD PRACTICE DESIGN SOLUTIONS

6.1 OVERVIEW

The main considerations are lighting, ventilation, acoustics, and thermal comfort. In a classroom with only one exterior wall, which is often the case, it is nearly impossible to achieve the requirements for all of these factors simply using passive systems. Unfortunately, mechanical systems are not always economically feasible. In light of this it is imperative that all four factors are considered early on in the design and planning stages, and, depending on site conditions, budget constraints, and specific user requirements, a strategy toward the importance and impact of each factor is developed. The following are the basic requirements and conflicts when dealing with light, ventilation, acoustics, and thermal comfort in a classroom with a single exterior wall.

6.2 LIGHT

As previously stated, maximising the use of daylight in order to improve student performance and reduce energy demand is an absolute imperative. *BB90* asks for a 5% daylight factor, In art, craft, design, and technology rooms, the required daylight factor would be even higher.

Good quality daylight is given by north-facing windows and general teaching spaces that face north will receive even, consistent light through all seasons.

East-facing classrooms are also good, providing an abundance of daylight during morning hours when students are most alert and temperatures are cooler, and avoiding too much heat toward the end of the day when external and internal (occupants, computers, lights) temperatures rise. However, an east-facing scheme should consider the glare of low light at sunrise and early morning and may require the use of shading devices to temper the effect. South and west-facing classrooms cannot always be avoided, and direct light can produce a large amount of glare and provide substantial amounts of solar heat gain.

However, if a specific site results in south and west-facing classrooms, then the area, type and height of glazing should be carefully considered to mitigate heat gain and minimise glare. The choice of the type of rooms to locate on the south and west orientations should also be considered at an early stage and in relation to the management practices of the school. Equally, art rooms may require particular types of light and should be given priority when allocating spaces to specific orientations. Furthermore, it is important to take account of any shadows from surrounding buildings, rises in topography, or heavily forested areas when considering natural lighting.

Clearly an average daylight factor of 5% or more is desirable, assuming that the associated issues of summer overheating and glare can be overcome. However, it should be realised that to achieve 5% or more with a single side of wall glazing in a classroom is not possible. To achieve 5%, roof lights or clerestory windows would be needed at the rear of the classroom. Although the use of atria spaces with good daylight penetration can help, they generally do not allow enough light to penetrate the rear of the classroom. The computer modelling results in Appendix 1 give indications of daylight factors for typical classroom designs.

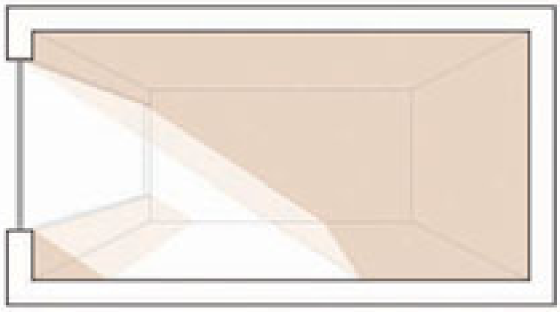
It should be recognised that achieving a 5% daylight factor throughout all the school spaces is very unlikely, especially when the school is not of single-storey construction.

For this reason a technical brief should not ask for a 5% daylight factor throughout and an exercise should be undertaken to determine priorities for such requirements.

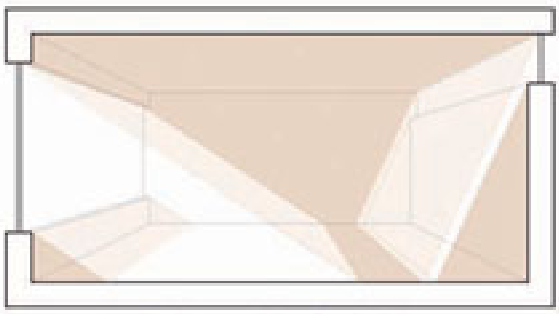
A good strategy for daylight briefing would be to identify those spaces that would benefit from the higher levels of daylight and accept that those rooms not on the top storey will not achieve the highest standards of daylight indicated in *BB90*. A pre-engineering task could identify the levels of daylight expected in the majority of spaces and a clearer brief could be written containing minimum daylight factors and uniformity standards. Circulation spaces also benefit from daylight penetration. Without daylight, access corridors can be gloomy spaces.

In some spaces it is not possible to have any daylight. This creates inner spaces without any view of the outside or connection to the external conditions. In such cases it is important that the proposed use of the space considers this aspect. These internal rooms would not be a good space for a permanent staff location, but may be more suitable to a meeting room or other transiently occupied usage.

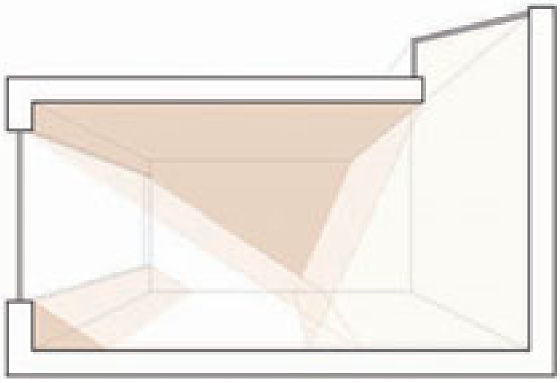
It is also important to understand where elements such as whiteboards and computer screens will be located, in order to avoid reflections which cause glare. This also affects the performance of thermal mass, since an applied reflective surface will prevent absorption. This is why it is suggested that thermal mass be on ceilings and high up on walls.



single aspect lighting: insufficient daylight to far side of classroom

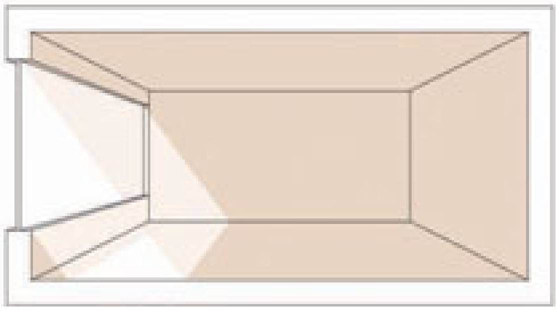


dual aspect lighting by way of clerestory to atrium:
eye level glare with insufficient daylight factor from atrium

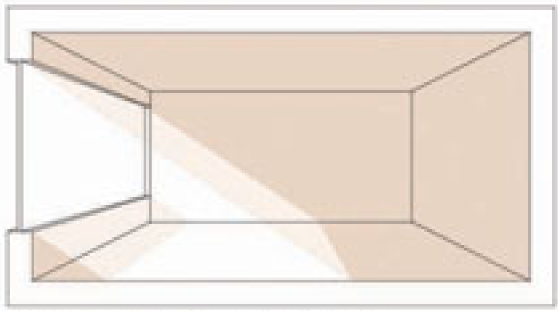


dual aspect lighting by way of skylight: optimal

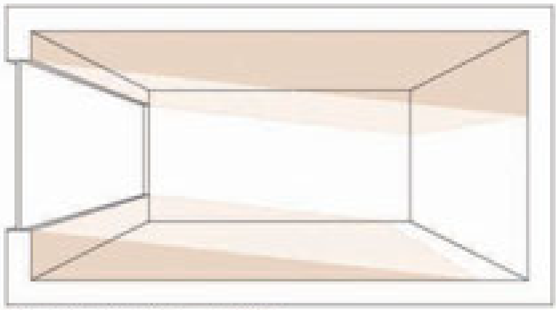
In addition, depth of sills, height and area of glazing and the inclusion of sun-shading devices all need to be considered. The following diagrams illustrate general sun angles during different seasons. The issue of glare in winter is illustrated in the winter conditions diagram.



June noon (Orkney, 59°N)



March and September noon (Orkney, 59°N)



December noon (Orkney, 59°N)

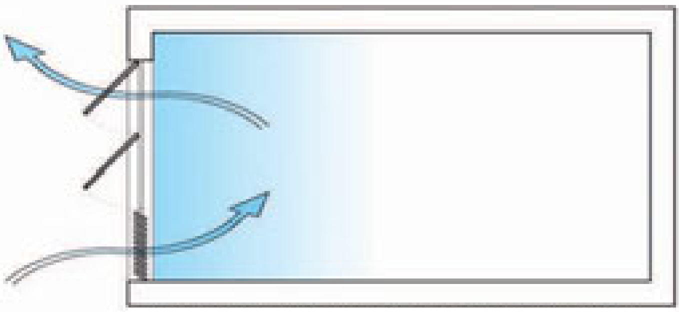
6.3 VENTILATION

The primary purpose of ventilation is to moderate indoor air quality (IAQ). The secondary purpose is to prevent summer overheating; this demands the largest ventilation requirement.

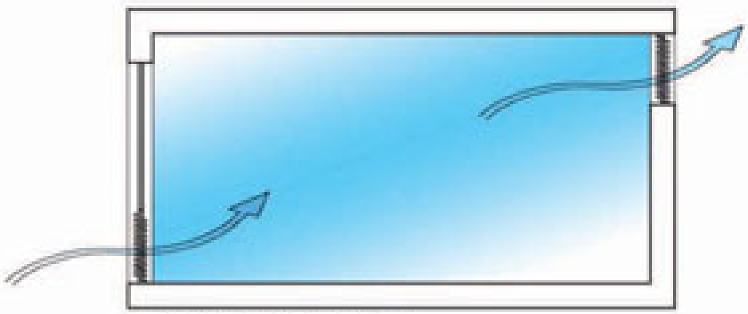
It is important to understand that all the ventilation requirements are unlikely to be achieved by opening windows alone, and, although opening windows can aid in passive ventilation (depending on external air quality, temperature, noise sources, internal acoustic requirements), opening windows during the winter can create draughts and lead to significant heat loss.

It is therefore imperative that the ventilation strategy is able to function at its optimum during cold external weather conditions and that any window openings are arranged in a suitable manner to avoid draughts. However, this does not mean that passive principles cannot be used.

Essentially, passive ventilation works on the following principle: taking air from the outside (mediating its temperature), pulling it across the space, and extracting it at a second point. Because hot air rises, the intake vent is usually placed low on the exterior wall, and the extraction vent/chimney is up high. The higher the vent/taller the chimney, the greater the force of the air being pulled across the space, and the greater the air exchange rate. The system will work most efficiently when the whole classroom is sealed (i.e. all windows and doors are closed) so that the air has only one place to come in, and one place to go out. The ventilation openings must be acoustically attenuated (sound-dampening) should the external noise levels be high. This means that sound from outside is absorbed, while air is still allowed to pass through. Double-sided or cross-flow ventilation will perform to higher standards than single-sided ventilation. The results in Appendix 1 give an example of the scale of improvement that cross-flow ventilation will achieve.



single-sided ventilation: poor ventilation on the far side of room



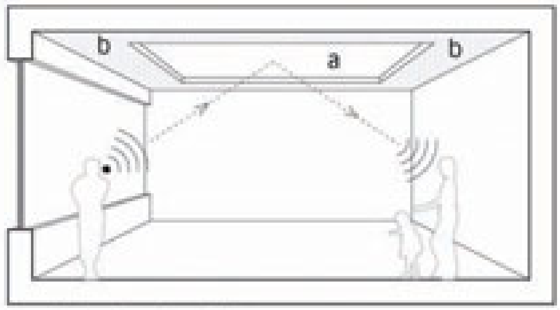
double-sided ventilation: optimal

6.4 ACOUSTICS

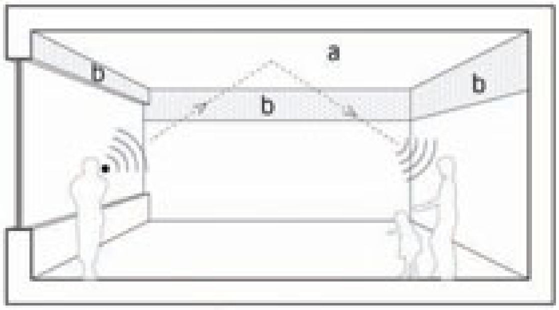
Acoustic performance is an issue that can be poorly understood, greatly underestimated, and most often derogated. As such, acoustics is a factor often left far too late in the design process to become an integral part of the dialogue between light-thermal-ventilation-acoustics. The requirements laid out in *BB93* are difficult to meet when acousticians are not brought in until ventilation and daylight considerations have already been designed. It is imperative that acoustic performance is considered early in the design process and in conjunction with light and ventilation.

In terms of acoustics, there are two major sources to be considered: the reverberation of noise from inside the classroom; and the transmission of noise from outside to inside, and between classrooms.

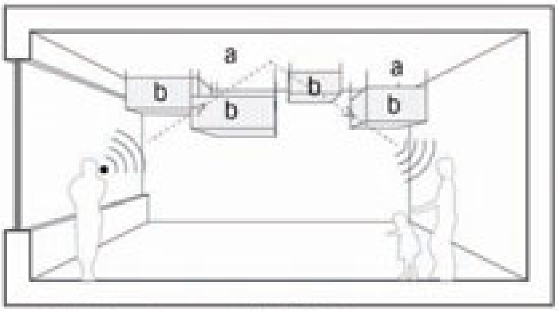
Acoustic performance guidelines have become very stringent in consideration of the hearing impaired. Performance is considered in terms of reverberation time, which is the time it takes for a sound to stop reverberating. In a $60m^2$ classroom, the standard reverberation time is 0.6 seconds, however, different spaces require different reverberation times. Minimising reverberation means minimising the amount of sound reflective internal surface area. Plasterboard, for instance, because of its smoothness and shallow depth, is quite reflective. Brick, on the other hand, due to its mass, insulative properties, and texture, absorbs sound. This is called acoustic value. In addition to material selection, modulating surfaces (i.e. breaking up a smooth surface), suspending elements from the ceiling (i.e. lights or panels), and carpeting the floor are all ways to increase acoustic value. However, like thermal mass, it is important to remember that covering a sound-absorptive material (i.e. with white boards or posters) will negate its effect. As a general principle, a classroom of $60m^2$ will require 40 to $50m^2$ of internal acoustic absorption (i.e. acoustic ceiling tiles or panels).



acoustic treatment on ceiling
a) hard surface for sound reflection
b) acoustic treatment for sound attenuation



acoustic treatment on high level walls
a) hard surface for sound reflection
b) acoustic treatment for sound attenuation



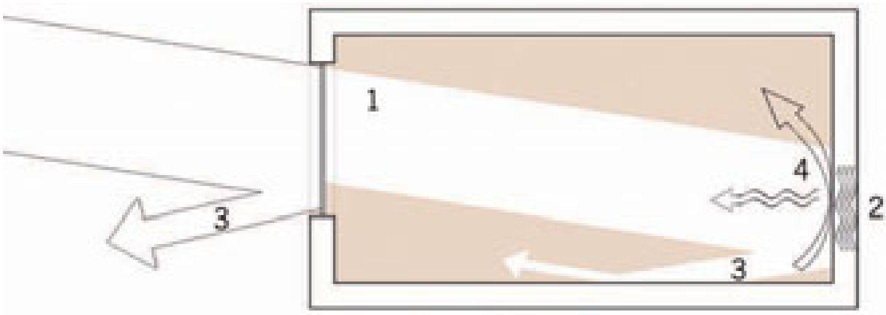
acoustic treatment on suspended objects
a) hard surface for sound reflection
b) acoustic treatment for sound attenuation

There is generally little conflict between cost and acoustics. Designing surfaces for acoustic attenuation is fairly simple and inexpensive, achieved in the form and material of the interior surfaces.

6.5 THERMAL COMFORT

In terms of thermal comfort, overheating issues are the main problem. Although *BB101* has defined the number of acceptable occupied hours allowable above an internal air temperature of 28°C, it is important to consider, in light of global warming, that the number of days in a year that will exceed 28°C may only increase.

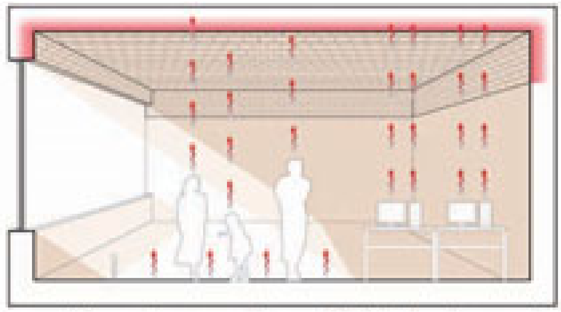
In calculating heat gain, it is important to know that primary heat gains are caused by the direct contact of sunlight with the floor, while secondary heat gains are caused by hot air rising from the floor. Internal heat gains from lighting and



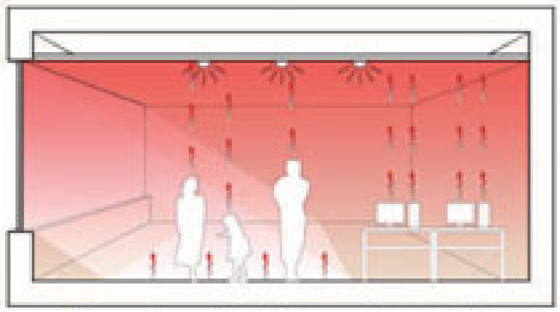
processes of passive solar heating:
1. transmitted 2. absorbed and stored 3. reflected
4. released by convection and radiation

equipment also contribute to the rise in room temperatures.

A passive means of absorbing some of this heat is the use of thermal mass. Thermal mass in association with high levels of summer ventilation (e.g. cross-flow ventilation) is a good method of reducing the summer overheating conditions. In Appendix 1, computer modelling results indicate the benefits of a range of solar control technologies with both single-sided and cross-flow ventilation.



exposed thermal mass on ceilings and high level walls serves to retain heat generated internally and moderate room temperature

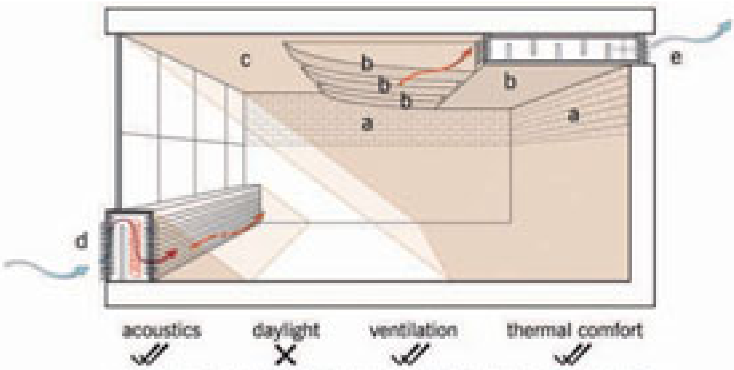


drop ceilings are thermally inefficient causing peaks in internal temperatures

Thermal mass works best on ceilings and high up on walls, as floors and lower walls, especially in classrooms, tend to become covered by carpets, furniture, white boards, computer screens, posters, etc.

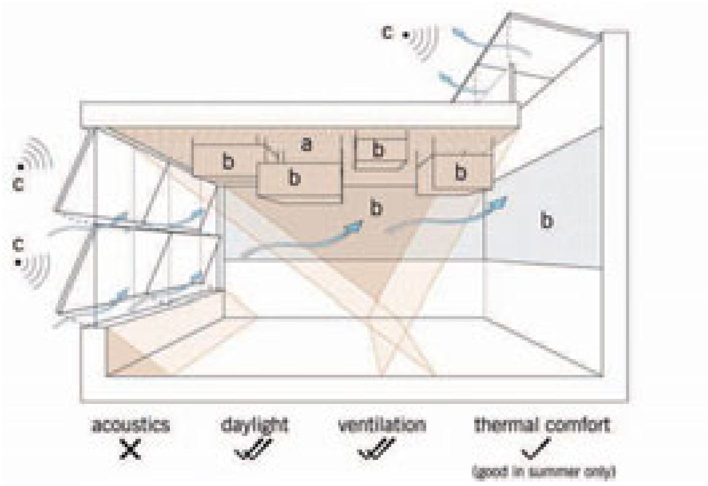
6.6 DESIGN SOLUTIONS

A wide range of environmental design solutions exist and the following examples illustrate some of the approaches that can be used. In each case all the environmental criteria cannot be fully met and this confirms that compromises need to be considered.



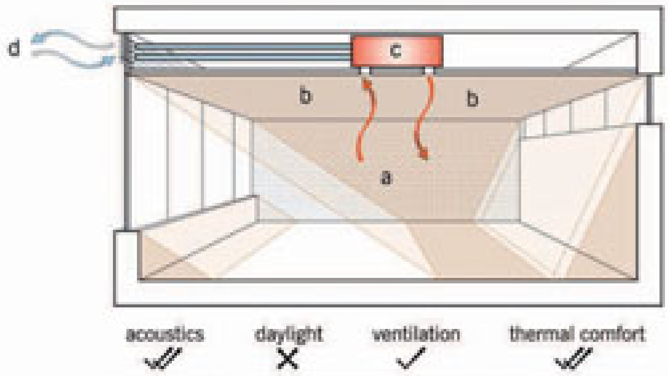
a) thermal mass; b) soft surface for acoustic absorption; c) hard surface for acoustic reflection; d) acoustically attenued air intake with heating coil for winter; e) acoustically attenuated air extract with fan for higher levels of venitation

This solution will provide good internal acoustic conditions, especially with high external noise levels. The ventilation system is cross-flow through an attenuated louvre, the incoming ventilation air can be heated. The ventilation systems could be supplemented with a fan for higher ventilation rates which would work in conjunction with the exposed thermal mass to reduce summer overheating. The cross-flow ventilation is also attenuated to reduce sound travel between the spaces. Reverberation times are controlled by the provision of some absorption surfaces at high level that also allow for services distribution without a full drop ceiling. The daylight standards would not be high due to the provision of glazing on one side only.



a) thermal mass and hard surface for acoustic reflection; b) soft surface for acoustic absorption (minimum 2m if only on high level walls); c) external noise sources
(note: noise of rain on skylight, even when unopened)

This solution would provide high levels of daylight. Ventilation is provided by a cross-flow route and, together with exposed thermal mass, will provide good summer overheating protection. Acoustic conditions would be compromised by the non-attenuated window openings and rain noises from the skylight. Reverberation times would be controlled by the inclusion of absorption surfaces. The skylights will require cleaning and there are restrictions on the window opening sizes for safety reasons. When opening widows are used as a prime component of the ventilation strategy the teacher should have good access to the windows and they should be easy to control.



a) thermal mass; b) soft surface for acoustic absorption and sound insulation; c) carbon dioxide sensor and heat recovery system; d) air intake

Although this solution will improve daylight standards due to the clerestory windows, the level of light and its penetration would not create such good standards as the skylight solution. A full mechanical ventilation solution would allow good acoustics and CO_2 sensing would lead to energy efficiency by only running the ventilation system when it is needed.

SECTION 7 SPECIFICATION CLAUSES

The specification of environmental conditions for schools is a key factor in the communication of the standards that have been agreed. Clear and non-contradictory specifications are needed to allow design teams to deliver solutions that meet the user's needs. This section details some of the approaches that can be used to produce clearer specifications.

WHEN SPECIFYING ENVIRONMENTAL CONDITIONS FOR SCHOOLS MANY SPECIFICATION DOCUMENTS HAVE USED STATEMENTS SUCH AS "SHALL COMPLY WITH BB87". THIS IS CONSIDERED TO BE TOO LOOSE TO FORM THE BASIS OF A PERFORMANCE SPECIFICATION AND CAN RESULT IN COMPROMISES BEING MADE LATE IN THE DESIGN PERIOD.

SPECIFICATION CLAUSES

7.1 OVERVIEW

When specifying environmental conditions for schools many specification documents have used statements such as “shall comply with *BB87*”. This is considered to be too loose to form the basis of a performance specification and can result in compromises being made late in the design period.

This does not allow thoughtful and informed discussion to be held with the users and the wider design team. A more detailed performance specification would result in a more considered decision making process being undertaken. The interrelationships between environmental design criteria would be discussed and a more thorough analysis would lead to clearer briefing.

A good approach would be to carry out a pre-design study which would facilitate discussion with the end-users on the issues relating to internal environmental standards. Also some initial modelling using site and location data will help in understanding the design options available and their financial and environmental consequences. Compromises can be discussed and resolved via a more structured/considered approach.

This would lead to a clearer specification being written and, in the case of a bid/tender situation, a more consistent approach to the analysis of design proposals by the bid evaluation team.

7.2 SUMMER OVERHEATING

The specification of criteria for reduction of summer overheating requires the definition of the number of hours acceptable above defined temperatures. The criteria in *BB101* allow 120 hours above 28ºC, whilst *CIBSE Guide A* stipulates that the benchmark summer peak temperature for schools should be 28°C and that overheating will occur if this temperature is exceeded for more than 1% of the occupied hours throughout the year. The CIBSE criterion equates to 18 hours above 28°C.

If there is a preference to define more exacting standards than these, it will probably result in a move away from the common single-sided natural ventilation approach. The summer overheating study in Appendix 1 indicates that higher standards for summer overheating can be achieved, for example by using cross-flow natural ventilation. It should be recognised that the adoption of higher standards will probably result in defining the ventilation solution approach during the pre-engineering exercise. An assessment of the increase in the required floor area over that for a single sided ventilation solution should also be carried out. Indications from other projects suggest a 5% increase in floor area would be needed to allow for the inclusion of ventilation stacks/towers.

The specification should identify the following:

Hours above temperature standards
Weather criteria to be used
Internal gains
Peak temperatures
Internal to external temperature differentials
The applicable rooms
The initial ventilation strategy (from pre-engineering study)

Example of improved summer overheating criteria in advance of *BB101* standards

> *All teaching spaces shall have no more than 40 hours above 25ºC and no more than 5ºC above the external air temperature. This is to be based upon the CIBSE Glasgow Design Summer Year (DSY) weather file. The equipment and occupancy internal gains for the space are to be taken from the room data sheets. The ventilation strategy in the pre-engineering model was cross-flow ventilation.*

7.3 ACOUSTICS

The specification of acoustic standards should be carried out with an acoustician and the advice in Section 4.2 should be used to compile a set of agreed standards for a given project and site.

7.4 DAYLIGHT

The specification of daylight standards needs to be realistic; the achievement of a 5% daylight factor in all teaching rooms in a school is very unlikely. The final design of the school will also define the relationship between the spaces and the amount of overshadowing by adjacent blocks of the school. A specification that states a minimum of 2% daylight factor is not likely to result in a significantly day-lit school. An approach to daylight would be to identify those spaces that have been identified as having a priority for daylight and give standards for those rooms. The pre-engineering study should illustrate the implications of a daylight factor of 5% for a space (e.g. use of roof lights for those spaces). This information could appear on room data sheets, but a specific specification section should also be written.

7.5 INDOOR AIR QUALITY (IAQ)

It is generally accepted that IAQ standards will be acceptable if the ventilation volumes in *BB101* are provided. These are detailed in Section 4. The specification should state these volumes, but it should be recognised that the air volumes necessary for control of summer overheating will be sometimes be in excess of these and will be determined by the designers. The specification should state that the ventilation control (manual or automatic) should allow clear operational phases between these stages of ventilation.

7.6 ROOM DATA SHEETS: INTERNAL ENVIRONMENTAL CRITERIA

The room data sheets are an important component of the specification and contain a large amount of data about the individual spaces within the school. They are one of the key ways in which the client's requirements are communicated to designers.

It is important that the overall specification and the room data sheets do not contradict each other. For example, daylight factors of 5% or more for the art classrooms should be in the general specification and repeated in the room data sheets for those spaces.

Internal environmental criteria needs to be included on the room data sheets and should be clearly defined.

The sample room data sheet in Appendix 2 gives a good standard of internal environmental data and should allow the designers to respond to the specific requirements for the scheme. The sample room data sheet in the appendix is part of a package of school room data sheets. A full range of room data sheets are available for use by local authorities and can be obtained from the Carbon Trust.

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The Technology Centre
Scottish Enterprise Technology Park
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SECTION 8 CONCLUSIONS

The delivery of sustainable good learning and teaching environments is difficult without full consideration of the various interrelationships, at an early stage in the development of refurbished or new schools. Disappointment expressed by some users in schools conditions is evidence that these requirements can be overlooked or not sufficiently understood. The recommendations of this guide are intended to help understanding and provide guidance for briefing teams on the delivery of acceptable conditions.

Interrelationships exist between the various environmental criteria and in some instances compromises may be needed. The compromises will arise from technical or affordability issues. An informed discussion on these compromises should form part of the early discussions between project teams and users.

This work will involve some pre-engineering design studies to be undertaken. The outcome of these studies should lead the discussions with the users on the potential environmental standards for their school and the choices they have.

The key lessons contained in this design guide are summarised in Appendix 1 “Design Process”.

APPENDICES

APPENDIX 1 – DESIGN PROCESS

This section relates specifically to environmental conditions and it is suggested that a single point of ownership for environmental conditions is created throughout the process. Consultation and communication with the users is clearly an important activity and should be identified in the project programme. The key lessons from this guidance are summarised in this appendix, together with checklists that will assist project teams. Although this section relates to a PPP procurement method, it should be easily applied to other procurement types.

Concept
The design process starts with concept design and the following checklist can aid consideration of the main issues related to the delivery of acceptable internal environmental conditions. The use of the checklist will assist in the preparation of an initial environmental brief.

Concept Design Checklist

- Discuss with users expectations of the new school/refurbishment
- Investigate climatic aspects of the chosen site (temperature, sunlight, wind, air quality and precipitation)
- Examine site topography and site location (sheltered, noisy, air pollution and odours)
- Site adjacent, proximity and orientation of surrounding buildings
- For refurbishment examine the limitations of the existing building form and location on the environmental strategy
- Orientation of the school spaces – minimise south and west facing classrooms
- Building form – if a natural ventilation solution is required, then airflow paths are needed and this may increase the initial floor areas calculated for the school
- If the site is noisy consider the use of the building as a noise screen and how to locate spaces in the building to minimise the impact of the external noise.

Once a site has been chosen and an initial brief has been prepared the environmental standards can be examined and explored in more detail.

Pre-Engineering

A pre-engineering exercise will examine the site and building design proposal for their implications on the internal environmental strategy; this would include acoustics, summer overheating, daylight and the potential for natural ventilation solutions. The pre-engineering exercise should produce confirmation of the environmental standards expected and implications for the cost plan. This should be developed together with the users.

The pre-engineering exercise should assist in the response to the following check list

Environmental Design Checklist

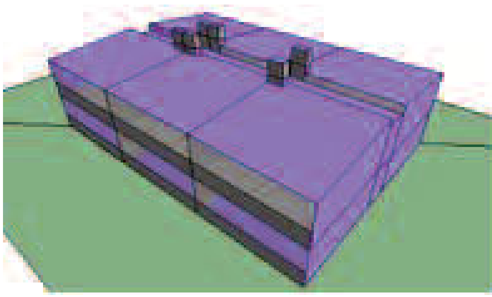
- **Acoustics**
  - External noise levels and the potential for natural ventilation and the relationship to building orientation
  - Acceptable standards for acoustics for the higher ventilation rate in summer
  - Flexibility and acoustic standards
  - Cross-talk attenuation requirements
- **Ventilation**
  - The requirement for three key ventilation standards – 3 and 8 litres/second per person and summer overheating ventilation levels
  - User interface with a manually and automatically operated systems
  - The mechanism and the scenarios that would cause the switching between the modes for mechanical or natural ventilation systems
  - The operation of natural ventilation systems in winter conditions for the 3 and 8 litres/second per person ventilation levels
- **Summer overheating**
  - The standards to be applied
  - Which rooms are the standards to be applied?
  - External weather conditions to be used in analysis
  - Method of evaluation, e.g. hours above a defined temperature or range of temperatures, internal – external temperature difference
  - User interface with a manually operated system
  - Level of internal equipment heat gains that should be included in the analysis
- **Daylight**
  - The standards to be applied for both daylight factor and uniformity
  - Which rooms are the standards to be applied?
  - Are the requirements reasonable? What does the pre-engineering indicate?

The pre-engineering exercise can produce useful information that will assist in the production of the output specification. Computer modelling can be used at this stage and the following simple example indicates the type of options that can be examined. Not all projects will need a pre-engineering computer modelling exercise, but it can assist in the discussion of the potential standards and interrelationships with the users and the wider team.

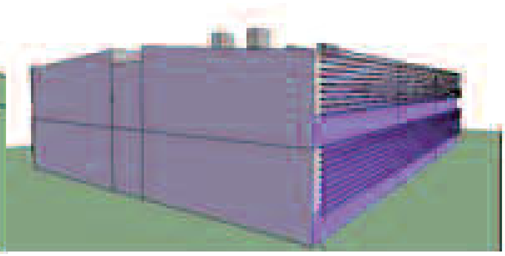
Pre-Engineering Modelling Example

A series of classroom building simulations were carried out using Integrated Environmental Solutions (IES) Ltd Virtual Environment (5.6.0.)[19] to assess the general impact on the internal environment conditions of a range of building design solutions with a range of shading and ventilation strategies. The simulations were used to investigate the impact of the various solutions on summer overheating, and daylight performance. This type of information can be useful in the initial ideas of solutions for schools, but would not replace the full modelling or pre-engineering by the project team.

A two-storey classroom block was modelled. The model was chosen for simplicity and the ability to manipulate a wide range of variables. The floor to ceiling height was chosen as 2.7 m with a glazing percentage of 67%. The top floor classrooms have clerestory windows. Classvent and Classcool[20] software tools were used to determine the opening areas for the natural ventilation design.



General model



Model with fixed Brise soleil

[19] Available from http://www.iesve.com

[20] Classvent and Classcool can be downloaded from www.teachernet.gov.uk

The data used in the model was as follows:

Gains		
Classrooms		
Lighting	$12W.m^{-2}$ Sensible	*(CIBSE Environmental Design Guide)*
Occupancy	$45W.person^{-1}$ Latent	*(CIBSE Environmental Design Guide)*
	$75W.person^{-1}$ Sensible	*(CIBSE Environmental Design Guide)*
	$1.88\ m^2.person^{-1}$	(Gives 32 people per class, 30 students, 1 teacher, 1 assistant)
Computers	$31.6W.m^{-2}$	5PCs per class *(BB101)* at 110W.ea *(CIBSE Environmental Design Guide)*
		1 Whiteboard at 1005W *(BB101)*
		1 Laser Printer 100 *(BB101)*
Circulation		
Lighting	$12W.m^{-2}$ Sensible	*(CIBSE Environmental Design Guide)*
Occupancy	$45W.person^{-1}$ Latent	*(CIBSE Environmental Design Guide)*
	$75W.person^{-1}$ Sensible	*(CIBSE Environmental Design Guide)*
	$30\ m^2.person^{-1}$	(Rarely used during class time)

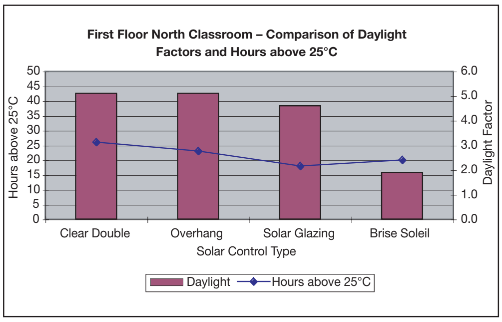
Glass for Solar Control Glazing - Pilkington comprising Insulight SunCool High Performance 6mm 70/40.

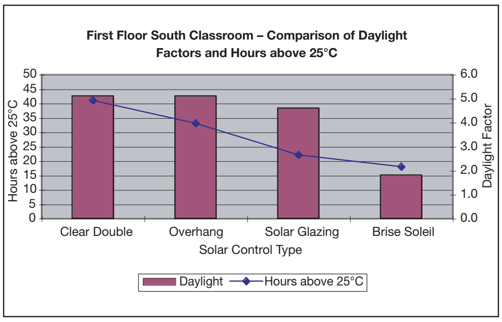
The weather data used for the simulations was the Edinburgh test year. The test year data set is recommended by *BB101*.

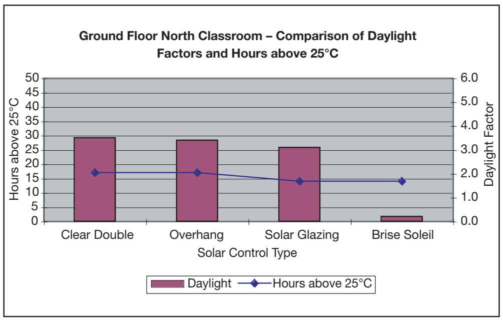
Single-sided ventilation solution

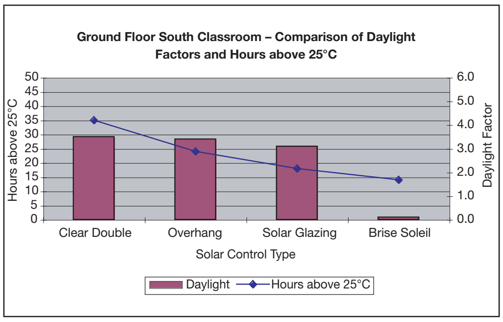
A series of simulations were run to determine the general effect on daylight factor and summer overheating hours of a range of solar control strategies. The solar control strategies were compared to a base solution using standard clear double glazing. Three strategies were examined:

Overhang
Solar control glazing
Brise soleil



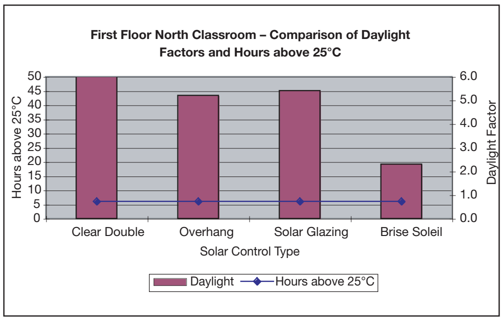


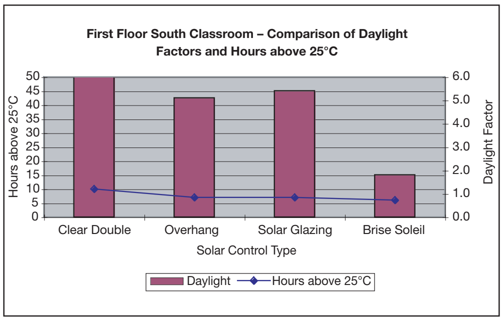




The results show that reductions in hours above 25°C, particularly on the south-facing classrooms, will be achieved with the solar control solutions; but daylight performance is reduced, particularly with the brise soliel solution. It should also be noted that the first-floor room daylight performance on both north- and south-facing rooms is much better due to the clerestory glazing contribution. The levels of daylight on the north and south first-floor rooms would allow significant reduction in artificial lighting levels and this could lead to a further reduction in summer overheating hours, this benefit is not reflected in these results. These results indicate that with solar glazing good summer overheating performance should be possible with good retention of daylight standards.

Cross-flow ventilation solution



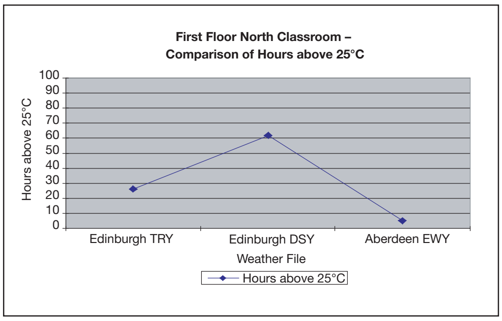


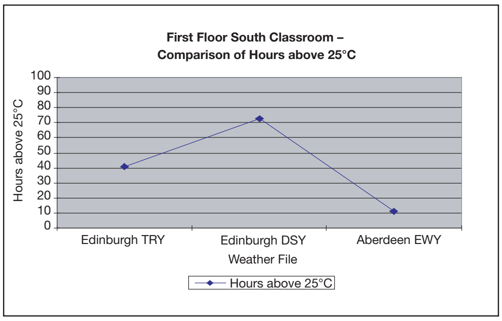
The cross-flow ventilation is provided by the opening of the clerestory windows in the first-floor classrooms. The reduction in summer overheating hours is significant with this solution. It should be noted that to provide cross-flow ventilation on the lower floors would require the provision of stacks within the building and this would create a demand on the available floor area on the upper floor.

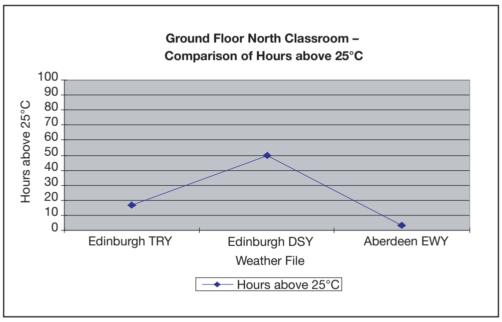
The selection of weather data

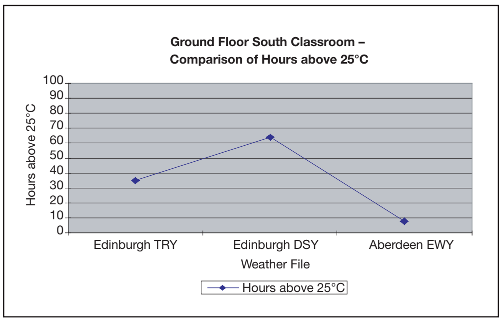
The results generated by a simulation will vary with the weather file chosen. Test and design weather files exist for use in IES. It is generally accepted that test weather should be used to determine energy prediction as it represents a statistical representation of the past weather conditions. The design weather year includes high summer conditions and should be used to assess summer overheating risk. *BB101* suggests that test weather should be used to determine summer overheating standards, however, a more robust analysis would be given by the use of design weather data.

The following simulations show the changes to the hours above 25°C for the single-sided ventilation solutions with test and design weather data. The Aberdeen weather file was also used to show the results for another geographical location. The Aberdeen weather is not a test or design year and direct comparison should not be made with the Edinburgh results.









The results show that using the Edinburgh design year data would result in the single-sided solution with clear glazing failing a requirement for less than 40 hours above 25°C, whereas it would have satisfied the requirement with the Edinburgh test year data.

Development of the output specification

The pre-engineering exercise should lead to an agreement on the environmental standards that will be required for the project. The agreement of specific standards for spaces will allow the production of room data sheets for the project. The issue of different standards needs to be fully agreed with the users and the production of the room data sheets will assist in the management of this stage of the project. The output specification should clearly explain the general standards and the reason for the adoption of any variations in requirements for specific spaces.

The users should be involved in the development of manual and automatic approaches to environmental conditions, particularly the issue of control of summer overheating and CO_2 levels in learning and teaching spaces. The pre-engineering exercise should be revisited as the output specification is finalised.

The production of evaluation criteria for the environmental criteria will need to be included in the output specification. Consideration should be given to the method of evaluation of the environmental standards of the returned designs.

The use of the following checklist should aid the development of the evaluation criteria.

Design Validation Checklist

Summer Overheating	BB101 Standards	Comments	Design Validation Requirements
Maximum peak summer temperature	32°C	Consider lowering the peak allowable temperature	Building simulation analysis with initial calculation based upon DfES Classvent and Classcool spreadsheet tools
Summer temperature profile	120 hours above 28°C	Consider full profile demand requirement based upon temperature range standards. Consider reduction of summer overheating hours profile	Building simulation analysis with initial calculation based upon DfES Classvent and Classcool spreadsheet tools

Daylight	BB90 Standards	Comments	Design Validation Requirements
Daylight factors and uniformity criteria	A range approaches are given, with a minimum of 5% Daylight Factor being associated with using daylight as primary lighting method. Uniformity standards are given in *BB90*	Consider identifying rooms that should be prioritised for natural light and hence a 5% requirement. In other rooms a factor between 2-3% may be more appropriate especially when the school is more than single storey	Building simulation analysis with initial calculation based upon the simplified formulae in *BB90*

IAQ	BB101 Standards	Comments	Design Validation Requirements
Ventilation volumes	Volumes of 3 litres/second/ person at all times and the capability of 8 litres/second/ person to maintain CO_2 levels below 1000 ppm when required	Consider whether it is advisable to assess external air quality for the site and hence increase the air volumes because of poor quality external air standard	Building simulation analysis with initial requirements based upon the Classvent tool. The "ability" to provide 8 litres/second/person requires designers to make assumptions on the frequency of window opening to provide the 8 litres/second/person
Winter ventilation	Volumes of 3 litres/second/ person at all times and the capability of 8 litres/second/ person to maintain CO_2 levels below 1000 ppm when required	The provision of the required ventilation air during winter results in a potential issue with cold drafts	As above, but with the additional requirement to predict cold draught conditions during winter operation

Issue of output specification

Clarifications and queries from the designers will need to be responded too. It is expected that a thorough output specification would minimise clarifications and queries.

Evaluation of designs

The evaluation of the environmental conditions expected by the competing design solutions should be carried out based upon an agreed methodology that is reflected in the output specification requirements.

Meetings should be held with the users to summarise the environmental standards being proposed by the designer.

APPENDIX 2 – ROOM DATA SHEETS

The following example is taken from the Low Carbon Design Initiative (LCDI) specification document – room data sheets. This is an example of a room data sheet for a classroom.

CLASSROOM – GENERAL	
IMPORTANT NOTICE – Any person intending to make use of this example data sheet must carefully consider its contents, and make modifications/additions/deletions as necessary, ensuring all persons involved are appropriately skilled, to ensure that it meets their needs.	
Planning	Requirements
Room activities	General teaching.
Occupation	Staff, child and adult students.
Occupancy	In accordance with the 'Room occupancy schedule'.
Internal environment	Classroom.
Relationship to other rooms	(Identify adjacencies).
Building planning	(Identify functional grouping within building).
Re-configurability of space	(Identify extent to which rooms may be changed in the future by movement of partitions/non-load bearing walls).
Access	Level access for wheelchair use. Direct from main circulation.
Occupation hours	To 'Occupation Hours Schedule'.
Cleaning hours	To 'Cleaning Hours' schedule within 'Occupation Hours Schedule'.
General guidance	Good guidance on design approach is available from the Scottish Executive, DfES, especially *BB87* Environment, *BB90* Lighting, and *BB93* Acoustics. This is in addition to publications from professional institutions associated with building design, construction and specification:- e.g. CIBSE, RICS, RSUA and RIBA.

Internal Environment	Requirements
Acoustics reverberation time RT_{60}	<0.8 seconds for mid-frequencies when un-occupied. (NB <0.6 seconds for primary classrooms)
RASTI Index	Higher than 0.65.
Background noise level maximum during heating season	$35dBL_{Aeq, 30 min}$. This figure excludes the contribution from ICT and office equipment installed by the occupier.
Background noise level maximum during hot summer days	$35dBL_{Aeq, 30 min}$ (must be achieved with maximum ventilation rate operational).
Daylighting quantity	Daylight factor not less than 4%. Preferably 6%. Dim-out (to achieve daylight factor less than 0.1%) to be possible. NB. Dim-out means must not restrict ventilation air.
Daylighting quality	In accordance with BS EN12464.
Daylighting uniformity	Uniformity ratio better than 0.4. Preferably >0.6. NB. needs top-lighting.
Maximum insolation	$25W/m^2$ averaged over the room area.
Artificial lighting lux	>300lux at the working plane. Higher levels needed for more visually demanding tasks.
Artificial lighting uniformity	0.8 or better.
Artificial lighting colour rendering	R_a not less than 80.
Artificial lighting colour temperature	Within range of 3500K to 4000K.
Artificial lighting quality	In accordance with BS EN12464.
Artificial lighting ceiling luminance	Not less than 30% of luminance at the working plane with a uniformity not less than 0.6.
Glare Index	Not more than 19.
Artificial lighting – required controls	Light level sensing – zones must include window area, mid room, and rear of room. Occupancy sensing – maximum area covered by any one sensor not to exceed $50m^2$.
Maximum lighting energy W/m^2	$4W/m^2$ average over annual occupied hours.
Lighting for cleaning	Only in immediate work area plus areas for safe circulation.

Desired inside temperature range during occupied hours in the heating season	Air temperature measured at 1m from floor in the centre of the room shall be within the range of 19°C to 22°C. Radiant temperatures of at least 90% by area of the opaque fabric (excluding the floor if under-floor heating is the main emitter of heating energy) must be within range of 19°C to 23°C. If under-floor heating is used, floor surface temperatures shall not exceed air temperatures (at 1m from floor in the centre of the room) by more than 3.5°C for more than 2 hours each working day, or by more than 2.5°C for the remainder of the working day.
Maximum temperature in heating season to be achieved by paid-for heating energy	18°C. (Note: if self-regulating under-floor heating is used, deemed compliance will be achieved if the floor surface temperature more than 2 hours after the start of occupation is less than or equal to 23.5°C).
Summertime maximum environmental temperature	Whenever the outside air temperature is above 23°C, and the diurnal temperature range (lowest temperature from the previous night to the maximum daytime temperature the following day) exceeds 4°C, the internal environmental temperature shall not exceed the outside air temperature by more than 1.5°C for the first 8 hours of substantive occupation each day. This shall apply for internal gains (excluding insolation) up to $80W/m^2$.
Maximum heat gain from non-fixed equipment – design data	$20W/m^2$ during occupied hours.
Ventilation during occupied hours	Sufficient ventilation shall exist to ensure that carbon dioxide level in this space does not exceed 1,500ppm for more than 20 minutes each day, with an operational target of 1,000ppm (1,000ppm approximates to a fresh-air ventilation rate of 8litres/person/second). The required ventilation shall be maintained during room dim-out/blackout, and shall not be impaired by security or safety requirements. Cold draughts from incoming ventilation air in cold weather shall not cause thermal discomfort to occupants.
Ventilation outside occupied hours	Fresh air rate must be within the range of 0.1 ach to 0.3 ach. This may be achieved by passive infiltration means such as by trickle vents in windows.
Volatile Organic Compounds (VOC)	At no time during occupied hours shall the total indoor VOC exceed $200µg/m^3$.

Building Fabric	Requirements
Walls	Durable, smooth, painted. No surface mounted cables, conduits, pipes or ducts unless explicitly permitted by client. Guidance on surface reflectance: not less than 0.6. Acoustic treatment to conform to acoustics requirements. Thermal mass in accordance with summertime requirements related to over-heat. Wall construction must provide the required acoustic isolation between spaces.
Floors	Durable, resistant to wear, easy to clean. Wooden floor, pvc, good quality carpet, plus wet area flooring (state area), or other surfaces as required. Guidance on surface reflectance: not less than 0.3. Flush joints between different finishes. (NB: floor construction must provide acoustic insulation of X[21] impact noise such as from footfalls).
Ceiling	Light in tone. Acoustic tiled. No surface mounted cables, pipes or ducts unless explicitly permitted by client. Thermal mass, and thermal accessibility to that mass, in accordance with summertime requirements related to over-heat. Minimum floor to ceiling height = (3.2)m. (Interacts with daylighting displacing artificial light, and lighting energy consumption W/m^2, and room acoustics). Guidance on surface reflectance: not less than 0.7.
Doors	Durable, resistant to wear, easy to clean. Vision panels at heights to suit all occupants. Sign to identify room name. (NB – door selection may link with acoustic isolation).
Windows	Durable, resistant to wear, easy to clean. Window frames and bars must be white. Restricted opening. (Positioning, extent and number of opening areas, and means of obtaining secure overnight ventilation may all interact with ventilation and summertime over-heat) Window head height must be adequate to provide required level of daylighting. Privacy from exterior (particularly ground floor.

21 Insert project specific data.

Ironmongery	Doors and windows lockable at adult height. Operation of opening windows must be safe for occupants. Doors emergency release from inside. Durable, resistant to wear, easy to clean. Suiting of locks.
Fixtures & Fittings	(Define).
Storage	Storage in accordance with 'Storage Schedule'.
Acoustics	Compliance with DfES Building Bulletin 93 under Part E of Schedule 1 to the Building Regulations 2000 (for England and Wales).

MECHANICAL AND ELECTRICAL SERVICE PROVISIONS	
Electrical	Requirements
Public Address	(Ability to hear selective announcement)
Clock	Electrically/battery operated and visible from all areas of the room. Accuracy better than 1 minute from GMT/BST as appropriate.
TV/Video Facilities	(Specify)
General lighting	Daylight shall be the prime source of lighting energy, supplanted as necessary with artificial lighting. Visual comfort and lighting levels shall be in accordance with BS EN12464. Must comply with Display Screen Equipment Regulations 1992, requirements for 5-hrs use/day, with LCD screens. Glare and colour rendering to be appropriate to functions. No direct light from luminaires onto whiteboard/screen.
General lighting control	As a minimum, individual light switches for window area, mid room, and rear of room. Maximum area per light-switch is 25m^2. Light switches located adjacent to door from corridor, to be operable by users.
Specialist Lighting	None.
Emergency Lighting	To Code compliance BS5266.
Specialist Containment	Dado/floor trunking to (one) (two) (three) full wall(s) (floor areas).
Small Power	Support cleaning activities, equipment power, general use and ICT support. Outlets for computer equipment shall comply with BS 7671 section 607 (earthing arrangements for high leakage equipment).

Fire detection and Alarm	To Code compliance BS5839 Part 1 Cat. L1. To Code Compliance BS 5588, Part 8: Code of Practice for Means of Escape for Disabled People.
Telephone	To telephone schedule.
ICT provision/data outlets	To ICT schedule.

Mechanical	Requirements
Room temperature °C	To the temperatures, times and provisions defined above. Note that under-floor heating not operating in self-regulating mode, i.e. surface temperature more than 3.5°C above room air temperature during occupancy is unlikely to achieve the required control accuracy and response time.
Room temperature optimum start accuracy – heating by radiators and air handling	Except where self-regulating under-floor heating is the main heating source, the desired room temperature is to be achieved within 30minutes of occupation start on 60% of occupied days in the heating season.
Room temperature optimum start accuracy – space heating by self-regulating under-floor heating	Unless a statutory requirement exists, no requirement if self-regulating under-floor heating is the main heating source during occupied hours.
Pre-heat rate of temperature rise when un-occupied	The minimum rate of rise of room environmental temperature under design conditions, with the space un-occupied, must be >0.3°C per hour.
Room heating response to internal gains	Heating emitter/controls response time for 63% change in heating output shall be less than 20 minutes for both increase and decrease of output.
Heating controls location and authority	No room occupant control over heating temperature, start time, finish time, regular day omission, holiday days omit. All these controls to be centrally operable by facilities management.
Heating zoning	This space is to be part of (X[22] whole building/first-floor offices, etc.) heating zone.

22 Insert project specific data

Room ventilation	In accordance with requirements stated above, statutory requirements and CIBSE guidance. Noise from mechanical ventilation/noise transfer from other internal and external spaces, must not cause the required background noise level to be exceeded.
Specialist ventilation	None. (Consider ducted extract from heat producing overheating.)
Heating	To maintain the above temperature.
Cooling	To requirement if necessary. Mechanical cooling must not be used if cooling is possible using external air or zero carbon impact sources such as groundwater.
Potable water services	Identify any required services and the means of economical operation.
Fire services	Identify fire detection/suppression means (Sprinkler System).
Above ground	As required to match needs from potable water services.
Drainage	Otherwise none.
Miscellaneous other	Pipe/radiators surface temperature must not exceed 43°C during occupation.

A full range of room data sheets are available for use by local authorities and can be obtained from the Carbon Trust.

The Carbon Trust in Scotland
The Technology Centre
Scottish Enterprise Technology Park
East Kilbride
G75 0QF

Tel: 01355 581816
Email: scotlandoffice@carbontrust.co.uk

APPENDIX 3 – WEBSITES

WEBSITE: Scottish Executive
URL: www.scotland.gov.uk/schoolestate

WEBSITE: Scottish Building Standards Agency
URL: www.sbsa.gov.uk

WEBSITE: The Carbon Trust
URL: www.carbontrust.co.uk/

WEBSITE: Department for Education and Skills
URL: www.dfes.gov.uk

WEBSITE: Teachernet – for Building Bulletins
URL: www.teachernet.gov.uk/management/resourcesfinanceandbuildings/schoolbuildings

WEBSITE: US Environmental Protection Agency School Design Tool
URL: www.epa.gov/iaq/schooldesign

WEBSITE: Partnership for Schools
URL: www.p4s.org.uk

APPENDIX 4 – GLOSSARY OF TERMS

Building (Scotland) Regulations (2004) – they are legal requirements laid down by the Scottish Parliament that are intended to provide reasonable standards for the purpose of securing the health, safety, welfare and convenience of people in and around buildings, for conserving fuel and power and for furthering the achievement of sustainable development. The guidance contained in the *Technical Handbooks*, for domestic and non-domestic buildings, will assist you to comply with the Regulations.

DDA – Disability Discrimination Act (1995)

Design and Build – A procurement route where the construction team also carry out a design role. The client's requirements for the design are given to the construction team in a performance specification. The construction team will include designers.

Design team – The design team for the school. This would consist of a wide range of specialist. However for the internal environmental conditions the key players are Architects, Building Services Engineers and Acousticians.

Pre-Engineering – Pre-engineering is an analysis of the site and building's ability to deliver internal environmental standards with defined constraints.

Project Team – The group that will manage the project, this will probably include a project manager, cost consultant and a representative of the users in addition to design specialists.

PPP – Public Private Partnerships (also known as PFIs – Private Finance Initiatives) are contractual partnerships between procuring public authorities and private consortia for the provision and maintenance/servicing of infrastructure, such as schools, hospitals, roads, etc. for a fixed period of time. Payment is linked to timely and efficient delivery of the services. At the end of the contractual period (typically 30 years) ownership of the facilities will transfer to the procuring public authority.

Speech Transmission Index (STI) – This is a measure of the intelligibility of speech in a space. The index ranges from 0 to 1, the higher the index the better the intelligibility of speech in the space.

Technical Handbook – The *Technical Handbooks*, published by the Scottish Bullding Standards Agency (SBSA), provide guidance on achieving the standards set in the Building (Scotland) Regulations 2004 and are available in two volumes, for Domestic buildings and for Non-domestic buildings.

Value management – This is the involvement of a wide range of stakeholders in assessing what is best value for a given project. Best value is not the same as lowest cost.

SCOTTISH EXECUTIVE

This document is also available on the Scottish Executive website:
www.scotland.gov.uk

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