GUIDELINES FOR ENVIRONMENTAL DESIGN AND FUEL CONSERVATION IN EDUCATIONAL BUILDINGS

Department of Education and Science

Design Note 17
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CONTENTS

INTRODUCTION TO 1981 EDITION

1 These Guidelines make recommendations for the standards to be achieved in the design of educational buildings. They supersede the "Guidelines on Environmental Design and Fuel Conservation" published in 1979 and the Supplement issued in July 1979.A calculation sheet, suitable for photocopying, which gives the step by step method of estimating the energy values has been included in Appendix 2.

2 They are intended in the first instance to apply to the design of new buildings but may also be used as a broad framework for the improvement of existing buildings as and when funds become available.

3 The emphasis of the Guidelines is on how to design to meet environmental needs and to conserve energy. However, in the conservation of energy, the management of the building is as important as efficient design and accordingly a brief section on management is included.

4 The main aim is to save energy in ways that are cost-effective. The Department of Energy Circular 1/75 states: "It is Government policy that energy conservation measures taken should be fully justified in economic terms, their cost being completely covered by the fuel saving achieved so that there is no waste of resources as a whole." When evaluating energy conservation measures it is therefore important to consider the length of the period within which any capital outlay may be recouped. Building Bulletin 55 illustrates ways of doing this.

5 Information is being collected on the energy used in kitchens for cooking, hot water and other services and this will be the subject of a later publication.

6 A more detailed explanation of the standards contained in the Guidelines and the methods for achieving them may be found in the following publications:
Building Bulletin 51: Acoustics in Educational Buildings
Building Bulletin 55: Energy Conservation in Educational Buildings
Design Note 16: Energy Conservation in two Oxfordshire Schools
Reference is made to these and other publications in the text as necessary.

A. ACOUSTICS

Main Recommendation

In every part of a school building the acoustic conditions and the insulation against disturbance by noise should be appropriate to the normal use of that part.

1. General

Acoustic conditions should be appropriate to the range of activities within the various spaces and should take account of their relation to adjacent spaces and outside conditions.

Notes

1.1 The aim is that the users of the building should hear clearly what they need to hear without this being swamped, or their attention distracted, by intruding noise. Successful acoustic design is achieved in three main ways: by planning, by adopting measures for noise control, and by giving the spaces suitable reverberant characteristics. Detailed explanations of criteria and methods of calculation are given in Building Bulletin 51, Acoustics in Educational Buildings.

2. Planning

Noise producing and noise sensitive spaces should be so positioned, designed and detailed as to minimise interference between them.

Notes

2.1 There is a variety of means of reducing the impact of noise producing spaces on noise sensitive ones. The first step is to consider at an early stage in planning whether they can be kept apart. If the spaces are diverse in acoustic requirements, eg a metalwork shop and a large lecture theatre, it is seldom practical to provide the necessary degree of sound insulation in a single wall. Such spaces must therefore be planned well apart, separated by either an external space or a 'neutral' area such as a store or circulation space. In other cases it is possible to achieve the necessary degree of sound insulation between two activities by interposing a suitable wall or screen. Part 2 of Building Bulletin 51 describes appropriate measures and the method of calculation. In a large space containing two activities which may conflict, the problem is reduced if adequate distance can be provided between them. Table 3 of Building Bulletin 51 gives guidance on the compatibility of activities.

3. Noise Control

In each unoccupied space the noise generated from all other sources should not be greater than the Background Noise Levels specified in Table 1 and Figure 1. Ways in which this can be achieved and external noise such as that from heavy road traffic reduced are described in Part Four of Building Bulletin 51.

TABLE 1 Maximum Background Noise Levels (BNL)

Type of space	BNL
Music and Drama spaces	25
Teaching groups of more than 35 people (communication distance of over 8m) Large lecture rooms Language laboratories	30
Teaching groups of between 15 and 35 people (communication distance of not more than 8m) Small lecture rooms Presentation rooms Offices Medical inspection rooms Seminar rooms	35
Teaching groups of less than 15 people (communication distance of not more than 4m) Sports Halls*	40
Resource areas Libraries Individual study areas (large area containing a number of small groups) Practical areas Workshops (equipment not in use) Circulation areas	45

*If multiple use is envisaged, the acoustic conditions may only satisfy one particular activity. See Building Bulletin 51, part 3.

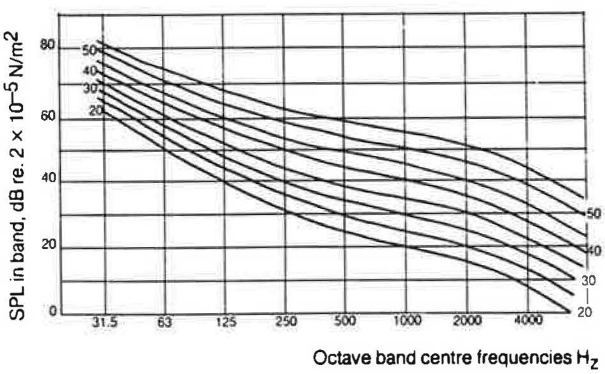


Figure 1
Background Noise Level Curves (BNL)

4. Volume and Optimum Reverberation Time (Tr)

The room volume and optimum reverberation time at 500Hz in any space primarily used for speech or music should be in accordance with the appropriate graphs in Figure 2.

Notes

4.1 The design tolerance limits for reverberation time should be within 10% of that shown in Figure 2 and should have the same value throughout the frequency range.

4.2 It is not possible, nor is it meaningful, to calculate reverberation times for large open areas and interconnected spaces. With normal ceiling heights, where such spaces are designed to accommodate a number of small groups they should be provided with one absorption unit per square metre of floor area, eg an absorbent ceiling together with some absorbent material on other surfaces. These spaces also work better if the ratio of the smallest plan dimension to ceiling height dimension is greater than 5:1 and if they are linear rather than square on plan.

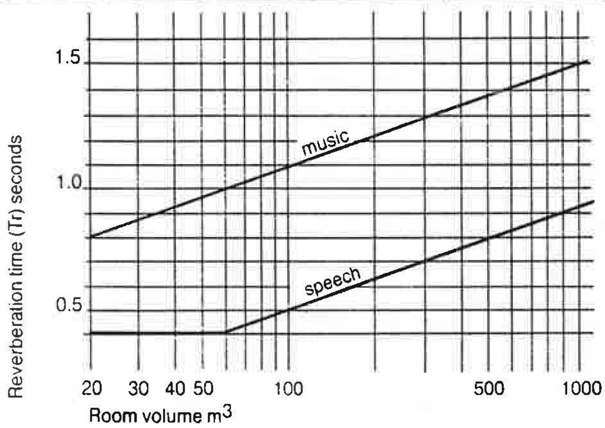
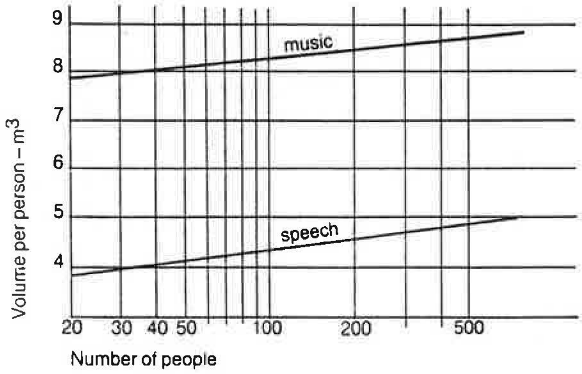


Figure 2
Optimum Reverberation Times
above – relation between room volume and optimum reverberation time for speech and music throughout frequency range.
below – volume required per person to achieve optimum reverberation using normal building finishes



(Further detailed design information is given in Parts 1 and 3 of Building Bulletin 51: Acoustics in Educational Buildings.)

B. LIGHTING

Main Recommendations

a Each room or other space should have lighting appropriate to the normal use for which it is designed.

b In daytime, daylight should be the main source of light in working areas except in special circumstances. Every teaching space should have a window area of at least 20% of the internal elevation of the external wall, and through which an adequate view out can be obtained.

c The lowest level of maintained illumination, whether daylight or electric light, at any point on a working plane should not be less than 150 lux and where fluorescent lighting is used the general level of illumination should not be less than 300 lux.

d The Glare Index[1] for electric lighting should not be more than 19 in teaching spaces, and due regard should be paid to the control of glare from daylight.

e In the design of lighting regard should also be paid to the need to conserve energy.

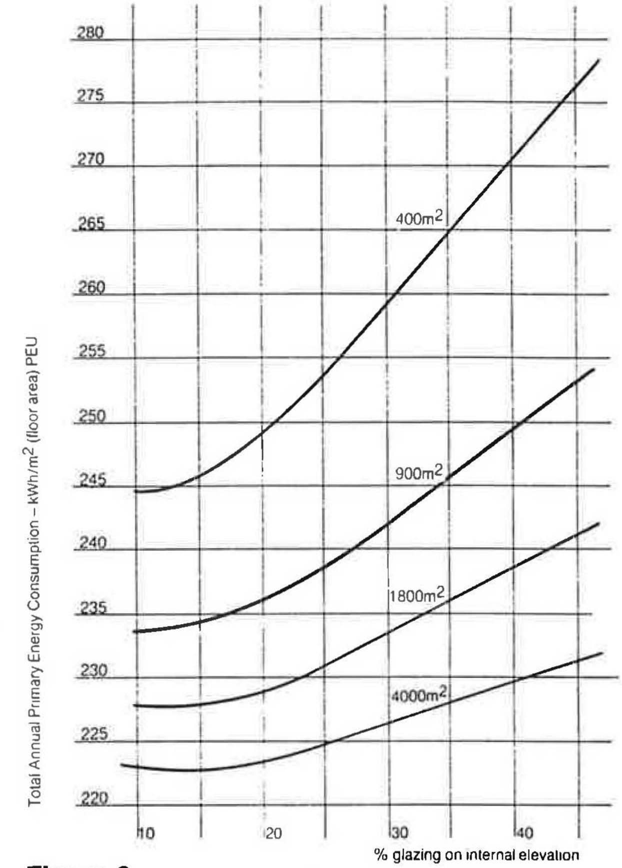


Figure 3
Total Annual Primary Energy Consumption for various building areas in relation to nett window/wall ratio (internal elevation of external wall) (Based on model year as described in Section 'D', 2:1 Aspect Ratio (relation of building length to width) and single storey only)

1. Type of Illumination

The type of illumination provided should be daylight or daylight supplemented by electric light depending upon the activities within a space, its character and its relationship to adjacent areas both inside and outside the building.

Notes

1.1 The area and disposition of the glazing should be arranged to ensure a satisfactory external view and to provide maximum daylight penetration and uniformity over the working area, with the object of minimising the length of time for which electric lighting is required. If the minimum Daylight Factor in a working area of a school used for 7 hours per day is 2%, electric lighting is only required for about 400 hours during the school year to maintain the minimum recommended illuminance.

1.2 In schools where the hours of use are longer, or where the planning of close relationships between various activities necessitates deeper and more complex spaces, requirements for lighting will be more varied. Even so, daylight will still be appropriate for most activities. Where it is not possible to use daylight as the sole source of illumination in working areas, well designed electric lighting can supplement the daylight.

1.3 In considering the lighting of a building regard should be paid to overall energy consumption. Figure 3 shows the annual primary energy[2] consumption in relation to the ratio of the glazing and external wall[3] areas for single storey buildings of various sizes and an aspect ratio[4] of 2:1. From this it will be seen that above 40% the energy requirement rises significantly whereas below 20% there is no corresponding saving in energy. Where glazing is on average between 20% and 40% of the external wall of the building as a whole the energy requirement varies by only about 5%. It is therefore proposed that windows should normally be provided with these limits.

1 Illuminating Engineering Society – Code for Interior Lighting Design 1977.

2 See BRE Current Paper 56/75 and BB 55 page 10.
3 Internal elevation of the external wall.
4 Ratio of building length to width.

1.4 In circumstances where solar gain and heat loss through windows can be controlled, it may be economic to increase the glazed area above these limits on south-east to south-west facades. Nett heat losses through horizontal or near horizontal single glazing is proportionately much higher than through vertical glazing, and in this case maximum area should not exceed 8% of ceiling area.[1] Where double glazing is used either vertically or horizontally larger areas may be contemplated, but this cannot at the moment be considered cost effective.

2. Quantity of Light

The lowest level of maintained illumination, whether daylight or electric light, at any point on the working plane should not be less than 150 lux.

Notes

2.1 About 85% of school children will be able to see easily for their normal work if the illumination is of the order of 100 lux. If the illumination is raised progressively above this, more children will see more easily, but the 100% level is not attainable because it is not possible to compensate fully for visual defects by increasing illumination levels.

2.2 In schools for younger pupils, where the hours of use are shorter, filament lighting can be designed to a more domestic and appropriate character. A recommended minimum level of 150 lux is acceptable for the majority of tasks and activities in primary schools.

Where visual tasks are more exacting, as in schools for older pupils, colleges and any buildings with extensive evening use, the general level of illumination should not be less than 300 lux. In such installations fluorescent lighting is generally more economical than tungsten to operate.

2.3 In schemes which rely on combined daylight and electric lighting, an illumination level of not less than 350 lux will generally be required of the electric lighting in order to achieve a good balance of brightness with the daylighting levels. In particular, care should be taken to ensure good illumination of vertical surfaces, preferably between 0.5 and 0.8 of the working plan illuminance, in order to maintain the daylight quality of the space and reduce silhouette effects, and improve the appearance of the space after dark.

Electric lighting in secondary schools commonly accounts for 30%–40% of the annual consumption of fuel and power in terms of primary energy and it is well worthwhile considering how greater economy in the use of lighting can be achieved. The switching of lighting should be planned so as to encourage users to switch off lights when not needed. In some cases, particularly in deeper and more complex interiors, the use of automatic dimming control may be considered which ensures that electric light is only used to compensate for daylight when it fails to provide the required illuminance at any time.

2.5 In a recent survey by BRE it was found that the average use of electric lighting in teaching spaces designed to be 'daylit' amounted to about 400 hours per annum, 75% of which was between 9am and 4pm. However, in spaces with exceptionally good daylight distribution and a well controlled luminance pattern, the use of electric lighting can be as low as 100 hours per year.

3. Lighting Quality

The Glare Index in working areas lit by electric lighting should not exceed 19. In areas lit by daylight or combined light due regard should be paid to the control of glare by good window design and the provision of blinds.

Notes

3.1 In conventional electric lighting installations a Glare Index of 19 can normally be met with fittings rated at BZ4/5[2]. Where the view is usually across the room, ie in formal teaching situations viewing the chalkboard, the installation should be designed to a Glare Index of 16. At the same time it is important to recognise that the Glare Index is an assessment of the whole environment and is not only related to the photometric distribution of the fitting. Glare will be reduced if attention is paid to the brightness of the general background, the colour, size and contrast of the immediate task surroundings and the position of the viewer. The perceived amount of light in a space depends on the brightness of the visible surfaces. These are mainly the walls, ceiling and floor and for a good distribution of both daylight and artificial light these should be finished in light colours.[3]

3.2 Glare from daylight may be controlled if good practice is followed in window design[4] and

1 See Appendix 2 BB 55 for further details.

2, 3 Illuminating Engineering Society – Code for Interior Lighting Design 1977.
4 IES Technical Report No.10.

in particular if proper use is made of adjustable blinds and other means of reducing excessive sky brightness. This applies to all facades. The use of curtains and blinds can also help fuel conservation as they can be drawn at night to reduce heat losses. Easily adjustable sunlight screening is specifically required on facades with a south west to south east orientation to prevent excessive heat gains during the summer and can also aid the operation of the building as a solar collector during the heating season (see Section C paragraph 4.2). Sunlight screening to prevent solar gains must be outside, while screening to aid the operation of the building as a solar collector should be inside.

View Windows

Windows through which an adequate view out can be obtained should be provided in all teaching areas unless there are educational reasons for not doing so.

Notes

3.3 One wall of every teaching space should have a window of effective glass area not less than the percentage of the area of the internal elevation of the external wall given in the table below.

	Maximum perpendicular depth of the teaching space from an external wall (in metres)			
	less than 8m	8-11m	11-14m	more than 14m
Minimum percentage of internal elevation of the external wall area	20%	25%	30%	35%

The proportions of the windows and their placing in the external wall should be such as to provide a satisfactory view out from as many working positions in the space as possible, taking into account any internal obstructions. The orientation of the space in relation to the sun, and any requirement for natural ventilation, should also be considered. The directional component which the light from windows gives help to provide a lively and interesting interior, as well as to sustain an impression of daylight to a reasonable depth within the space.

C. THERMAL ENVIRONMENT

Main Recommendations

HEATING

a. The system should be capable of heating a minimum of $10m^3$ of fresh air per person per hour and the following resultant temperatures[1] at a height of 0.5m above floor level should be maintained during normal hours of occupation when the external temperature is –1°C[2]:

21°C in areas where occupants are lightly clad and inactive (eg medical inspection rooms)

18°C in areas where there is an average level of clothing and activity (eg classrooms)

15°C in dormitories

14°C in areas where the occupants are lightly clad and where activity is vigorous (eg gymnasia)

b. The temperature in circulation spaces should not be more than 3°C below the temperature of the spaces they serve.

VENTILATION

a. All working areas, halls, sick rooms and dormitories should be capable of being ventilated at a minimum rate of $30m^3$ of fresh air per hour for each person normally occupying these areas, or such highe rates as may be necessary to maintain comfortable conditions.

b. Adequate measures should be taken to prevent condensation in, and to remove noxious fumes from, every kitchen and other room in which there may be steam or fumes.

c. All lavatory accommodation, changing areas and cloakrooms in which adequate cross ventilation to give at least 6 air changes per hour cannot be achieved by natural means should be mechanically ventilated.

ENERGY CONSERVATION

In the design of the thermal environment due regard should be paid to the need to conserve energy.

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1 These temperatures have been revised from those given in School Premises Regulations 1972 in the light of recent work on comfort conditions. For definition of 'resultant temperature' see paragraph 3.

2 This is the average external design temperature for England; particular areas may need different temperatures, as given in the IHVE (CIBS) Guide.

1. Thermal Conditions

The thermal conditions within education buildings should be appropriate to the activities and clothing of the occupants. Good control of the heating system is essential not only to maintain comfortable conditions but also to eliminate waste of fuel.

Notes

1.1 Thermal comfort is achieved when a balance is maintained between the heat produced by the body and the loss of heat to the surroundings. The rate of heat loss is dependent upon the amount of clothing worn and the temperature of the air and surrounding surfaces. The rate of heat production by the body depends upon the degree of activity. An adolescent body at rest generates 70 watts, working at a desk increases this to 100W and further increases ensue as activities become more vigorous. This heat is lost to the surroundings by the normal processes of convection, conduction, radiation and evaporation. It is therefore necessary for the designer to take account of the functions of spaces and the activities that they contain, and the type of clothing likely to be worn by the occupants. Allowing for the metabolic heat gains and designing suitably responsive heating systems will also help to reduce fuel consumption.

2. In the Heating Season

The heating system should be capable of maintaining the resultant temperatures listed at the head of this section. It is desirable that any swing in temperature should be within 2°C of these levels.

Notes

2.1 The resultant temperature of 18°C is to be regarded as normal except where special considerations indicate that other temperatures are appropriate. High levels of activity, as in gymnasia, demand a lower resultant temperature (14°C) whereas minimal clothing as in medical inspection rooms demands a higher temperature (21°C). Additionally, where children have a lower rate of activity due to physical disability a normal resultant temperature of 21°C is recommended. Temperatures in excess of those recommended waste fuel, so effective control is necessary in all instances.

2.2 Multi purpose spaces should have heating equipment capable of adjustment throughout the required temperature range, so that the space is kept at the temperature required for the activity and not at a higher level than is needed. This will require adjustable controls to limit the operation of the heat emitting apparatus in any particular space.

3. Resultant Temperature

It is desirable that the joint effect of the mean radiant temperature and air temperature should ensure comfortable conditions. This is ensured by specifying resultant temperature. The resultant temperature[1] is that measured with a globe thermometer 0.5m above floor level, but the temperature at other heights should not differ greatly from this value. In particular, excessive vertical temperature gradients should be avoided and the resultant temperature at 2.0m should not exceed that at floor level by more than 3°C. In some schools, including nursery schools and schools for severely handicapped, it is necessary to protect children from direct contact with heated surfaces. If an accessible metallic surface is likely to have a temperature greater than 43°C it should be protected by suitable screens or guards.

4. Outside the Heating Season

During the summer, when the heating system is not in operation, the recommended design resultant temperature for all spaces should be 23°C with a swing of not more than 4°C about the optimum. It is undesirable that the resultant temperature should exceed 27°C during normal working over the school year but an excess for 10 days during the summer is considered a reasonable predictive risk.

Notes

4.1 An undesirable rise in temperature during warm weather can be caused by uncontrolled heat gains from various sources, eg by teaching equipment such as cookers and furnaces, solar radiation, light fittings used continuously during the day, or by high densities of occupation, eg in lecture rooms. In these circumstances sufficient ventilation is particularly important and mechanical ventilation may be necessary in some instances to help to control air temperature. Additional mechanical ventilation to the roof void can be effective in reducing solar gain into the space below. White or very light roof surfaces also reduce the solar gain through the roof as well as reducing the thermal stresses in the weatherproof covering.

4.2 Solar heat gain through windows can be minimised by the use of louvres, blinds or curtains, as well as by the design and orientation of the window itself. Shading the glass from the outside is the most effective method of control, but weather conditions in this country fluctuate in a way that calls for careful design of ecliptic shading plus adjustable devices.

5. Ventilation

All working areas, halls and dormitories should be capable of being ventilated at a minimum rate of 30m^3 of fresh air per person per hour, or such higher rates as may be necessary to maintain comfortable conditions.

Notes

5.1 The ventilation system should be designed to ensure that air movement at the occupants' level is at such a temperature and velocity as to ensure comfort. It may be necessary to increase the ventilation rate to maintain the recommended air temperatures in spaces with high functional heat gains, eg kitchens, home economics rooms, or some types of laboratories. Spaces where there is a risk of condensation or where noxious fumes may be generated will also need additional ventilation. All lavatory accommodation and changing areas in which adequate cross ventilation to give at least 6 air changes per hour cannot be achieved by natural means should be mechanically ventilated and the air expelled from the building. For this purpose air may be taken from the surrounding spaces, unless the effect will be to increase the ventilation of the teaching areas beyond that required, in which case a secondary supply should be provided.

5.2 In a well insulated building, ventilation accounts for a major part of the heat losses. It is important therefore to reduce uncontrolled ventilation, eg through joints between components in the external envelope and around opening doors and windows.[2] Much used external doors should be draught-stripped and fitted with closers and where possible provided with draught lobbies of sufficient size to be effective. Control of temperatures by opening windows should be discouraged as this will only cause the thermostats to call for more heat, thus wasting fuel.

6. Heat Loss from the Building Fabric of New Buildings

a. The average thermal transmittance co-

1 See BRE Current Paper CP9/78. Optimum diameter for a globe thermometer for use indoors.

2 Refer to BS Code of Practice BS5925:1980.

efficient for opaque areas of walls and roofs should not be greater than $0.6 W/m^2K$.

b. Vertical single glazed areas (including clerestorey or monitor lights) should not normally exceed 40% of the internal elevation of the external wall. Horizontal or near horizontal single glazing should not normally exceed 8% of the ceiling area.

Notes

6.1 General. Adequate thermal insulation of roof and walls is necessary not only to reduce heat loss but to make internal surfaces of the building warmer and to reduce the risk of condensation. It is important however that the vapour barrier should be correctly positioned and that the performance of the covering should be compatible with the degree of insulation beneath.[1]

6.2 Temperatures greater than normal will occur at ceiling level in buildings with spaces higher than 3m. In these cases greater roof insulation is necessary in order to avoid excessive heat loss.

6.3 In addition to insulating the building fabric it is important also to insulate adequately all heating mains and hot water storage tanks.

6.4 Every opportunity should be taken to improve the thermal insulation of existing buildings so that they are as close as reasonably possible to these standards.

7. Heating Installation

The installation should be capable of heating a minimum of $10m^3$ of fresh air per person per hour from a total ventilation requirement of $30m^3$ per person per hour. The remaining ventilation losses are made up by occupational and other adventitious gains.

Notes

7.1 The shorter the heat-up period prior to occupation, the greater the potential fuel saving. This is the case particularly in buildings with intermittent occupancy such as schools where warm air systems have a clear advantage in this respect. There is considerable potential for energy conservation in the recovery of heat from exhaust air and progress in this field is being kept under review.

8. Choice of Fuel

In principle the selected fuel should be that giving the lowest present value[2] taking into account capital, maintenance and operating costs. In practice the selection procedure is complicated by the unpredictability of fuel price trends in the short term and fuel availability in the long term. Building Bulletin 55 (Chapter 3) gives the present ranking order of conventional fuels and it seems unlikely that this order will change in the near future.

Notes

8.1 In the choice of heating systems the option should be kept open where possible to change from one type of fuel to another during the life of a building. For example, electric off peak storage installations cannot be adapted to any other fuel use, whereas systems where heat is delivered by hot water or warm air could be converted to coal, gas, oil or electricity. Of the alternative energy sources at the present time only heat pumps, supplemented by lower priced fuels (or electricity where this is the only fuel available) are likely to prove cost effective for educational buildings, and only after further development work. Current energy conversion efficiencies of heat pumps are on a par with solid fuel boiler installations.

9. Heating Control

The type of space heating control and the way in which it is operated have a significant influence on fuel consumption. Because of the recent change in fuel costs relative to control system costs, it now pays to invest more money in control equipment than hitherto. Space heating controls should be reliable and as far as possible automatic. Adjustable components (such as thermostats) should be accessible only to authorised persons, and should be tamper-proof. Heating controls which respond to local changes in heat demand should be used; they should be set to give the minimum acceptable room temperature. A single overall control is not usually economic except in very small premises and normally a building should be divided into heating zones which can be isolated to suit circulation and use.

Notes

9.1 When unoccupied a building should be heated only for frost protection or during the pre-occupation heat-up period. The use of an optimum time start controller ensures that the

1 See BB 55 paragraphs 4.11–4.15.

2 See BB 55. Appendix 4.

building is not at its operating temperature earlier than needed; frost protection thermostats should be set at levels that do not hold the building at an unnecessarily high temperature overnight. 5°C should be adequate for most buildings where condensation is not a problem. Good design of heating controls alone is not sufficient to ensure economy in fuel usage. It is also necessary for the controls to be properly commissioned and maintained in good working order. Manuals for the user should be available.

9.2 One of the most effective ways of conserving energy in existing schools is to improve the efficiency and responsiveness of the heating installations so that it comes as close as possible to the performance of a well designed new installation. Improvements that may be worthwhile range from the re-design and renewal of plant to the re-assessment of its operating pattern. Fuller details are given in Building Bulletin 55 and Design Note 16.

10 Management

The management of a building can enhance or nullify the design effort expended to achieve efficiency and low fuel consumption. As these Guidelines are intended to aid energy conservation in existing buildings as well as in new, a short summary of good management practice is appropriate. Reference should also be made to Chapter 1 of Building Bulletin 55.

Checklist of Measures

i In the heating season, overheated rooms should not be cooled by opening windows or using extractor fans. The heating system should be adjusted instead and where possible thermostats should be set to give the recommended room temperatures (see Section C on Thermal Conditions and Ventilation). If additional ventilation is still required, windows should be opened the minimum amount or fans used for the minimum period. Excess ventilation leading to over-cooling will switch thermostats to 'on' thus calling for more heat.

ii Economy should be exercised in the use of hot water, subject of course to the need for cleanliness and hygiene. Thermostats controlling domestic hot water should be set at the lowest acceptable temperature, which should never exceed 40°C. Where warmer water is needed, for example in dishwashers, local 'topping up' or a separate supply should be considered.

iii Staff and pupils should be encouraged to wear clothes that are suitable for the required temperatures.

iv If separate zones of a building can be heated independently, the allocation of rooms for day time and any evening use should be made so that the plant is used economically, and heat and light are not supplied to unused areas.

v Heating plant should be started no earlier than is necessary to achieve normal working temperatures by the beginning of the occupation period. The plant can be turned off some time before the end of the occupation period. Plant and controls should be kept in good working order.

vi External doors should be kept closed as much as possible in cold weather and all windows closed overnight. Blinds or curtains drawn at dusk will help conserve heat overnight.

vii Equipment with high electric power consumption should not be used during winter months when the electrical load from other sources is near the Maximum Demand limit. The penalties for exceeding this limit can increase the cost of the electricity for the winter quarter by as much as three times.

viii For the same reason, the use of supplementary heaters such as electric fires should be avoided and all electrical appliances and lights switched off when not required.

D. ENERGY CONSERVATION

Main Recommendation

In the design of the building fabric and engineering services of new buildings, the Energy Design Value and the Annual Energy Consumption Value should not exceed the model values given in Figures 5, 6 and 7, when the environmental standards in Sections B and C have been achieved.

1. General

In the sections dealing with Lighting and Thermal Environment a number of measures for conserving energy have been recommended. This section considers how these measures can be made as cost-effective as possible within the design of the building as a whole.

To establish a basis for comparison between alternative methods of heating and lighting, Primary Energy Units[1] (PEU) in Watts per square metre of floor area have been used as they take into account the conversion efficiencies of the various fuels and thus the use of primary energy resources. Energy design values appropriate to educational buildings are suggested below. These are based upon current technology and good practice, and are open to modification as technology advances.

As discussed in Appendix 1 the aspect ratio has a considerable effect on the quantity of energy consumed by a building. The lower the ratio the lower is the quantity of energy needed (see Figure 11).

As the design of the building develops, alternatives (eg in the choice of fuel, fuel efficiency or the methods of heating and lighting) may present themselves. The most cost-effective of these should be chosen, provided of course that it meets the environmental and other design criteria for the building. Where alternative methods have comparable life costs,[2] then it is recommended that the method making least demands on primary energy should be selected.

2. Design Procedure

The following is a design procedure for new buildings which enables their total energy requirements to be estimated at an early stage in the design process. It also allows alternative designs to be ranked in terms of their cost-effectiveness and their primary energy requirements.

First, from a knowledge of the area and perimeter of the design under consideration the aspect ratio and average room depth should be calculated or read from Figure 4. Thus, if a daylit building is desired an average room depth of from 6m to 9m would be expected. The range of possibilities therefore is that lying between the 6m and 9m depth lines.

An instantaneous energy design value should be established by the method described in paragraph 3. It is also necessary to estimate the annual energy consumption value (see paragraph 4). Figures 5, 6 and 7 show respectively the energy design value and the annual energy consumption in primary energy units per square metre of floor area which it is recommended the designer should aim to achieve. Normally these values should not be exceeded but the design solution should be as cost-effective as possible provided that the capital cost complies with the latest issues of the DES Cost Guidelines and that the recommendations in Sections B and C of the Environmental Guidelines are observed.

Where the design has been sufficiently developed to ensure that the energy values calculated compare favourably with those in Figures 5, 6 and 7, then the running and capital costs of the energy related items – building fabric, heating plant, electrical system – for the various design options may be calculated together and the

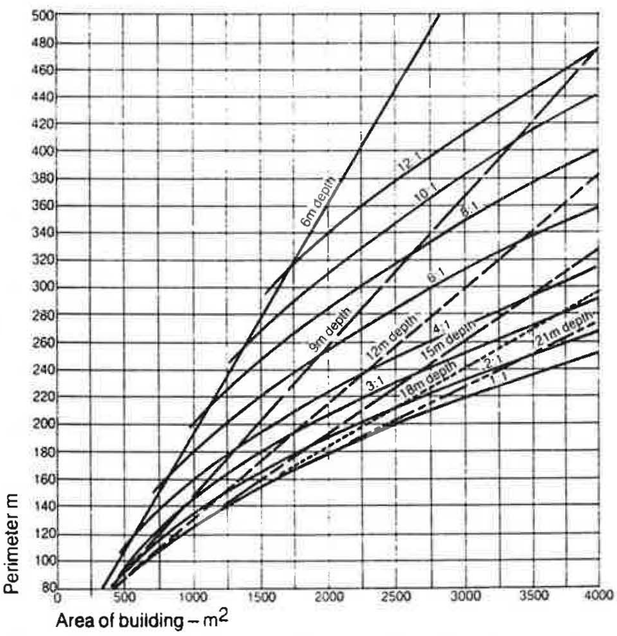

Figure 4
Aspect Ratio and Average Room Depth in relation to building area and perimeter

1 *See BRE Current Paper CP 56/75 and Building Bulletin 55 Chapter 3.*
2 *The life costs are the Present Value of discounted capital and operating costs over the life of the building.*

most cost-effective solution which at the same time satisfied the educational aims selected.

3 Energy Design Value

The Energy Design Value is the algebraic sum of the following:

i. Building fabric losses (paragraphs C2 and C6)
ii. Ventilation losses (paragraph C5)
iii. Occupational gains
iv. Electric lighting gains
v. Miscellaneous power gains
vi. Hot water service consumption
vii. Heating circulators consumption.

(Note: kitchen energy consumption and other "process" energy loads, eg kilns, are omitted from this exercise.)

This is expressed in PEU as Watts per square metre of floor area.

In converting to primary energy the conversion efficiencies of the various fuels have to be taken into account on an instantaneous efficiency basis, thus the following factors must be applied:

Fuel	Instantaneous Conversion Efficiency %	Primary Energy Input per Unit of Delivered Energy[1]
Electricity, normal tariff	100	3.73
Electricity, off peak	90	4.14
Manufactured fuels	74	1.89
Oil	75	1.44
Natural Gas	74	1.43
Coal	70	1.46

In the case of systems using heat pumps, the above factors for normal tariff electricity or gas (whichever fuel is used by the heat pump) should be divided by the coefficient of performance of the heat pump. Thus, for a COP of 2.5, the instantaneous primary energy factor if electrically driven is $\frac{3.73}{2.5} = 1.49$ and if gas driven will be $\frac{1.43}{2.5} = 0.57$.

Example

Calculate the Energy Design Value for a secondary, general teaching single storey school building with a gross floor area of 1500m^2, perimeter 270m. Assume gas-fired heating with radiators, temperature difference $\triangle t = 19°C$ (internal 18°C, external −1°C).

1 These values drawn from BRE Current Paper 56/75 need to be kept under review. Current figures may be slightly different but do not affect the basic approach.

Given:

Floor-ceiling height	= 2.4m
Overall height	= 3.0m
Aspect ratio (Figure 4)	= 10:1
Room Depth (Figure 4)	= 6.1m
Window: wall ratio	= 0.30 (internal elevation of external wall)
U value for opaque areas of walls and roof	= 0.6W/m^{2}K
U value for windows	= 5.6W/m^{2}K
U value for floor	= 0.3W/m^{2}K
Fresh air ventilation rate	= 30m^{3}h per person
Average density (Figure 5)	= 4.85m^2 per person

Heat losses:

Walls	= 3.45W/m^2 floor area
Roof	= 11.40W/m^2 floor area
Floor	= 5.70W/m^2 floor area
Windows	= 13.79W/m^2 floor area

$$\text{Ventilation} = \frac{30\text{m}^3\text{h per person} \times 0.33 \times \triangle t}{\text{density of occupation}}$$

$$= \frac{30 \times 0.33 \times 19}{4.85}$$

$$= 38.87\ \text{W/m}^2 \text{ floor area}$$

Total = 73.12 W/m^2 (delivered energy)(1)

Heat gains

Occupants (70W per person)	= 14.43W/m^2 floor area
Lighting	= 12.00W/m^2 floor area
Miscellaneous power	= 3.00W/m^2 floor area
Total	= 29.43W/m^{2}floor area ... (2)

Nett heating requirement is thus (1) – (2) = 43.69W/m^2 floor area

This figure must be converted to Primary Energy Units by multiplying by 1.43 – the gas conversion factor – and the value will = 62.48W/m^2. . . (3) floor area PEU

An allowance must also be made for the hot water service of 2W/m^2 floor area which, when converted in this case by the gas conversion factor, will = 2.86W/m^2 . . . (4) floor area PEU

The electrical energy will be

Lighting	= 12W/m^2 floor area
Miscellaneous power	= 3W/m^2 floor area
Heating circulators	= 2W/m^2 floor area
Total	= 17W/m^2 floor area delivered energy
or 17 × 3.73	= 63.41W/m^{2}PEU . . . (5)

The Energy Design Value
is (3) + (4) + (5) = 128.75W/m2PEU

The Energy Design Value in this example is less than the maximum value of 141.0W/m2 given in Figure 5 for secondary school general teaching and is therefore acceptable.

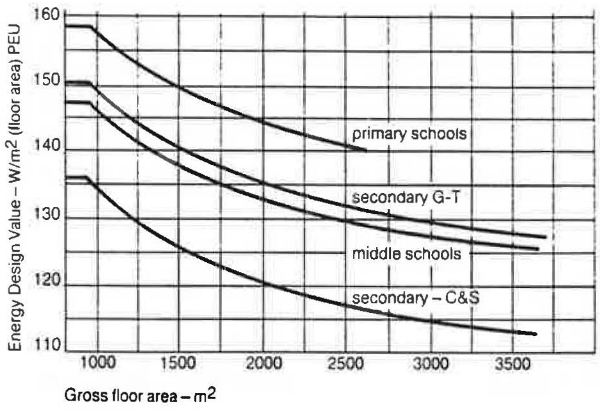

Figure 5
Maximum Energy Design Values for different building types

Basis:
primary schools – average density $3.72m^2$/pupil
middle schools – average density $5.0m^2$/pupil
secondary, general teaching areas (also HFE general teaching areas) average density $4.85m^2$/pupil (up to 4 storeys)
secondary, crafts and science (also HFE C&S) average density $8.48m^2$/pupil.
For PE buildings the maximum energy design value should be 108 W/m^2 PEU.

4. Annual Energy Consumption Value

The Annual Energy Consumption Value is the prediction of the overall energy performance of a design. It is expressed in kWh/m^2 of floor area in Primary Energy Units. Again this is the algebraic sum of the gains and losses over a model year and is corrected for seasonal efficiencies and converted to primary energy. For this, the following factors have been taken:

Fuel	Seasonal[1] Conversion Efficiency %	Primary Energy Input per Unit of Delivered Energy
Electricity, normal tariff	100	3.73
Electricity, off peak	75	4.97
Manufactured fuels	63	2.22
Oil	63	1.71
Natural gas	63	1.68
Coal	60	1.70

1 Reflects seasonal operating efficiency of whole system in the building.

It is necessary to construct a model year on which to base calculations so that comparisons can be made. For this purpose a normal school day is considered, as evening and holiday use could only be accounted on individual designs according to the expected use patterns which will vary from school to school. Likewise, kitchens and other process loads have been excluded from the calculations. Length of heating season, September – May = 195 working days, number of school days, including 9 days for cleaning and maintenance etc = 160.

From IHVE Guide B, UK average degree days over this period for normal working hours = 2231 (use local figure).

Assuming a medium weight building (most school buildings are) and intermittent use of plant, and disregarding occupancy and other miscellaneous gains, the base temperature = the internal design temperature.

∴ base temperature = 18°C
ratio Dd/D 15.5 = 1.30

Hence, equivalent annual operation E $= \frac{24 \times 2231 \times 1.30}{19}$
= 3664 hours

Correction for mode of operation
(a) 5 day week $= 0.8 \times \frac{160}{195} = 0.66$ (for school use)
(b) intermittent use . . . = 0.75
(c) 7 hour day . . . = 0.96
Corrected E = 3664 × 0.66 × 0.75 × 0.96
= 1731 hours.

The period of full occupancy at 5 hours per day is taken for metabolic gains at full density, that is 151 × 5 = 755 hours during the heating season.

Hot water and miscellaneous power requirements are assumed for 1400 hours per annum; heating circulators and fans for 1120 hours per annum. Annual lighting energy consumption can be taken from Figure 8 unless more accurate information relative to the proposed design is available.

Example

Taking the same building design as used for the Design Value (paragraph 3 above) calculate the Annual Energy Consumption.

	W/m^2		Running Hours		PEU Conversion		Total kWh/m^2 PEU
Heating Energy							
Losses							
Fabric & Ventilation	73.12	×	1731	×	1.68	=	212.64
Hot Water Service	2	×	1400	×	1.68	=	4.70
							217.34...(1)
Gains							
Occupancy	14.43	×	755	×	1.68	=	18.30
Misc. power	3	×	1400	×	1.68	=	7.06
Lighting – (80% of annual total from Fig 8[1], 30% glazing, 6m room depth)			$\frac{46 \times 0.8}{3.73}$	×	1.68	=	16.57
							41.93...(2)
Nett heating requirement, (1) – (2)						=	217.34 – 41.93
						=	175.41 kWh/m^2
Electrical Energy							
Lighting (from Fig 8)						=	46.00
Pumps	2	×	1120	×	3.73	=	8.35
Power	3	×	1400	×	3.73	=	15.67
							70.02
Thus the Annual Energy Consumption Value						=	175.41 + 70.02
						=	245.43 kWh/m^2PEU

This lies within the recommended value of energy consumption given in Figure 6. Had it been higher, the design would have been reconsidered in order to identify the factors leading to excess energy consumption and then to adjust them so as to come within the recommended value.

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1 Recent BRE survey shows that 80% of annual lighting use occurs during heating season.

Maximum Annual Energy Consumption Values in relation to area of building for different building types.

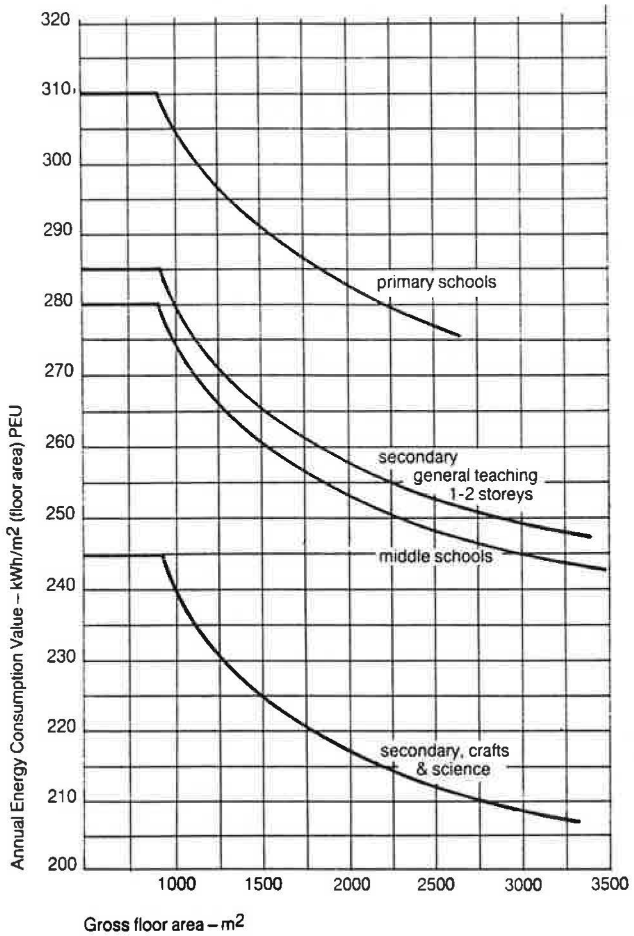

Figure 6

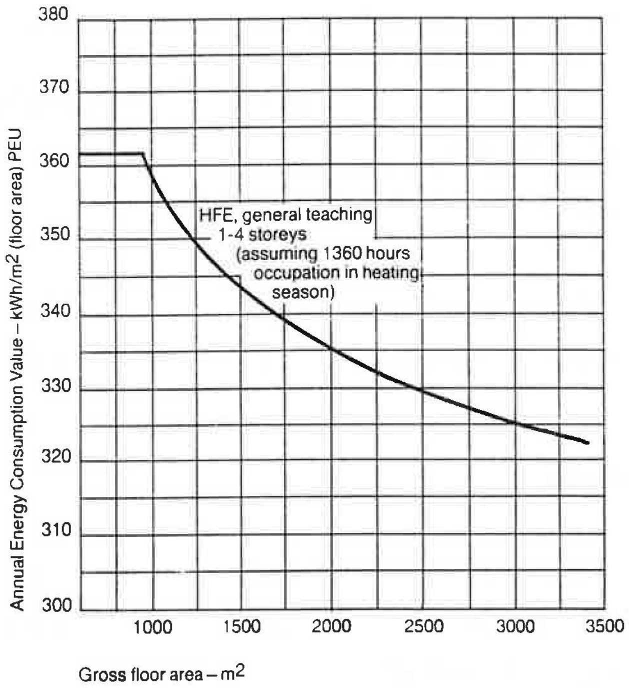

Figure 7

Note:
Maximum Annual Energy Consumption Value for PE spaces – 195 kWh/m^2

No allowance has been made in the computation of the curves in Figures 5, 6 and 7 for the effect of solar radiation, as it is not always available in urban sites, and because control of admission and utilisation is not always generally possible at the present time. Nevertheless solar gain can help to reduce energy consumption and it is hoped that improved techniques may allow the more effective use of the building as a solar collector during the heating season.

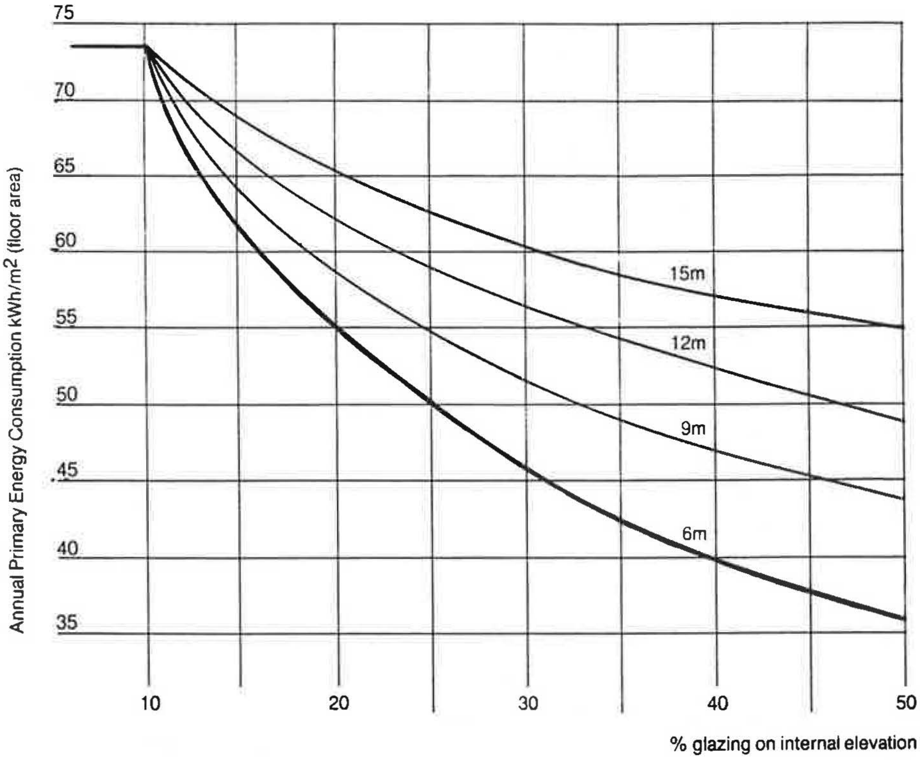

Figure 8

Annual Primary Energy Consumption for electric lighting in relation to vertical glazed area in external walls, for various depths of space from window wall. Based on the following assumptions.

That switching is logical in relation to daylight levels and that the hours when daylighting is below 300 lux at various Daylight Factors is:

DF below 0.5%	–1640 hours
DF 0.5 – 1.0%	–1600 hours
DF 1.0 – 2.0%	–1280 hours
DF 2.00 – 4.0%	– 700 hours
DF over 4.0%	– 250 hours

Base lighting level 300 lux at a loading of 12 W/m^2

Reflection factors – walls – 30% (average including pinboard areas etc)
ceiling – 70%
floor – 15%

Floor–ceiling height 2400mm, window height 1500mm, cill height 900mm.

5. Annual Energy Cost

Taking the same example from paragraph 3 above for annual energy consumption and costing the fuels at the appropriate rate, a total annual running cost can be calculated. This can then be updated when fuel prices change to give a design cost prediction. As with the Annual Energy Consumption Value, these figures are only for design purposes and may not correspond to actual running costs because of the great variations that are consequent on users' habits. There is also difficulty in accounting for the Maximum Demand rate on electrical costs which can be as much as twice the cost of the actual electricity consumed during the winter months. Some attempt has been made to indicate this effect by averaging the costs from a sample number of schools over a period of years, and it is suggested that a similar exercise is done in each case because rates vary throughout the country.

The costs taken for this example, based on prices ruling in September 1978, are as follows:

Gas	0.6 pence per kilowatt hour
Electricity	2.78 pence per kilowatt hour excluding MD
	3.5 pence per kilowatt hour including MD

As most schools will be on Maximum Demand meters, the final figure is taken in the example.

Example

The same basic figures that were used in the Primary Energy Calculations for gains and losses can be used, the only difference being that the PEU conversion is replaced by a cost conversion. As with the PEU conversion it is convenient to have seasonal efficiency included, thus a seasonal efficiency of 63% for gas will give a conversion factor of 0.95.p/kWh. Electricity for lighting is used at near 100% efficiency, so that the conversion factor is 3.5.p/kWh.

	W/m^2		Running Hours		Cost Conversion		Total pence/m^2.p.a.
Heating Costs							
Losses							
Fabric & Ventilation	73.12	×	1731	×	0.95	=	120.24
Hot Water Service	2.0	×	1400	×	0.95	=	2.66
							122.90
Gains							
Occupancy	14.43	×	755	×	0.95	=	10.35
Misc. power	3.0	×	1400	×	0.95	=	3.99
Lighting – (80% of annual total from Fig 8)			$\frac{46.00 \times 0.8}{3.73}$	×	0.95	=	9.37
							23.71
Nett heating cost			122.90 – 23.71			=	99.19 . . . (1)
Electrical Costs							
Lighting (from Fig 8)			$\frac{46.00}{3.73}$	×	3.5	=	43.16
Pumps	2.0	×	1120	×	3.5	=	7.84
Power	3.0	×	1400	×	3.5	=	14.70
Nett electrical cost						=	65.70 . . .(2)

The costs of related items of fabric and plant have now to be assessed. These are:

Fabric costs of windows, walls, floor and roof discounted at 5% over 60 years.
Plant costs including heating plant, lamp and fittings replacement, and rewiring discounted at 5% over 20 years.

In this example this amounts to fabric	=	171.55 . . . (3)
plant	=	81.94 . . . (4)
The total annual cost is the sum of (1), (2), (3) and (4)	=	418.38p/m^2 p.a.

This value is not more than the appropriate point on the curve of Figure 9. Other suitable fuels can be considered and a similar calculation carried out to assess the total costs of alternatives.

6. Annual Energy Consumption Values for Existing Buildings

The efficiency of an existing building may be assessed using the same method of calculation. The annual consumption figures (less any kitchen use) for the various fuels should be available. These will first need to be assigned pro rata on an area basis to the main uses (eg general teaching, science and craft, PE). It may also be necessary to correct for hours of occupation and weather so as to relate to the model. Each figure should then be converted to PEU and added to give the total annual energy consumption for each use.

Example

Consider a school of 11000m^2 floor area, 2:1 aspect ratio, 50% window to wall area which is situated in the Thames Valley. In addition to normal school hours of use, 500m^2 of the building is occupied during the evenings for 12 hours each week for 30 weeks.

During the 1977/78 heating season there were 1989 degree days in the Thames Valley area and the quantity of fuel oil used by the school during that period – September to May – was equivalent to 6112.8 GJ (1698 mWh). The electrical energy consumed during the year was 972.0 GJ (270 mWh).

Calculate the Annual Energy Consumption Value in kWh/m^2 of floor area in PEU and compare it to the value for a 2:1 aspect ratio given in Figure 10. Similar curves may be drawn for other aspect ratios and areas of glazing.

Heating Energy

The predictions of annual energy consumption in Figure 10 (as in Figure 6) are based upon an occupancy of 7 hours per day and upon the UK average number of degree days – see para. 4 – and so the energy figures given above must be corrected.

If the energy consumed during the evening use has not been separately metered, an average annual heating requirement per square metre of floor area may be calculated in order to determine the annual value due to the 500m^2 of evening use. Because the hot water service energy requirement is small – about 2% of the heating need – it may for this purpose be ignored.

Average annual heating per m^2 of floor area $= \dfrac{6112.82 \text{ GJ}}{11000\text{m}^2}$
$= 0.56$ GJ/m^2

Energy required for 500m^2 of evening use $= 0.56 \times 500$
$= 280.00$ GJ

Balance for school use 7 hours per day $= 6112.82 - 280.00$ GJ
$= 5832.82$ GJ

This energy figure may now be corrected to allow for 1989 degree days only compared to the UK average of 2231 days and becomes $\dfrac{5832.83 \times 2231}{1989}$
$= 6542.49$ GJ

and converted to kWh/m^2 and primary energy units $= \dfrac{6542.49 \times 1000 \times 1.08}{11{,}000 \times 3.6}$

Annual heating energy $= 178.43$ kWh/m^2 PEU

Electrical Energy

The figure given for electrical energy has also to be corrected to allow for 7 hours of occupation

Annual lighting for evening use at 12 W/m^2 floor area and 500m^2 $= \dfrac{500 \times 12 \times 12 \times 30}{10^6}$

$= 2.16$ mWh

and for miscellaneous power + heating pumps at 5 W/m^2 $= \dfrac{500 \times 5 \times 12 \times 30}{10^6}$
$= 0.90$ mWh

Balance for school use $= 270 - (2.16 + 0.90)$
$= 266.94$ mWh

Convert to kWh/m^2 and PEU $= 266.94 \times 3.73 \times 0.09$

Annual electrical energy $= 89.61$ kWh/m^2 PEU

then Annual Energy Consumption Value $= 178.43 + 89.61$
$= 268.04$ kWh/m^2 PEU

This figure is greater than the annual value for 11000 m^2 given in Figure 10 of 225 kWh/m^2 PEU. This suggests that this building would use energy more efficiently if energy conservation measures were carried out. Building Bulletin 55 gives detailed guidance on the effectiveness of various measures and Design Note 16 shows how they have been applied to two existing schools.

For a particular building with a different aspect ratio and glazing area from those given in the example, the model Annual Energy Consumption Value may be calculated using the method in paragraphs 3 and 4 and applying the standards for new buildings. The efficiency of the building may then be assessed by comparing its actual energy consumption to the model value.

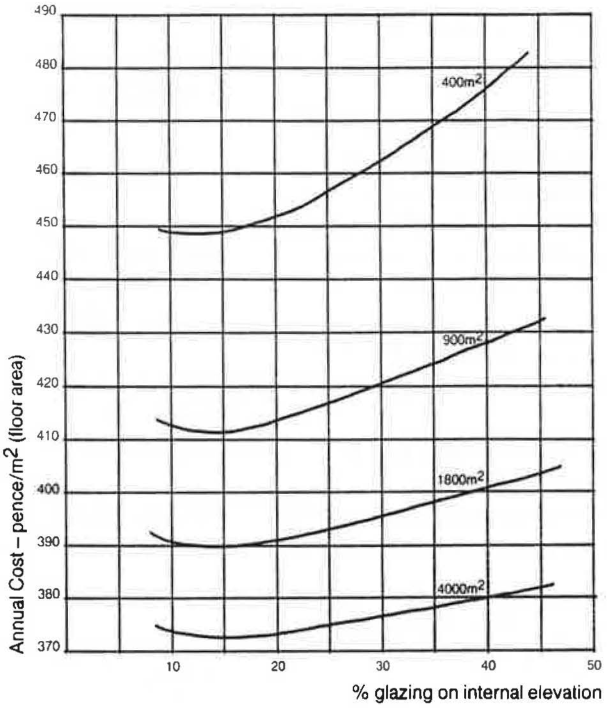

Figure 9
Annual cost of fuel (based on gas heating) and related items of fabric and plant for single storey buildings, 2:1 aspect ratio and gross area 400, 900, 1800 and $4000m^2$.
Discount rate at 5% over 60 years for fabric and 20 years for plant.
The relationship between area and cost for other fuels at present costs will be similar.

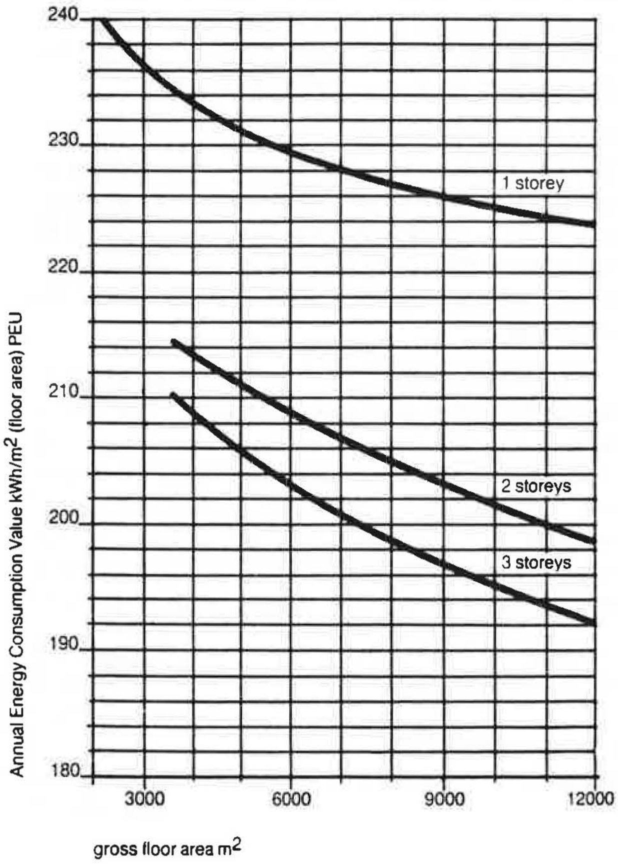

Figure 10
Annual Energy Consumption Value in relation to area of existing buildings. Criteria as for Figure 6 but with 2:1 aspect ratio and 50% glazing.

References

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APPENDIX 1

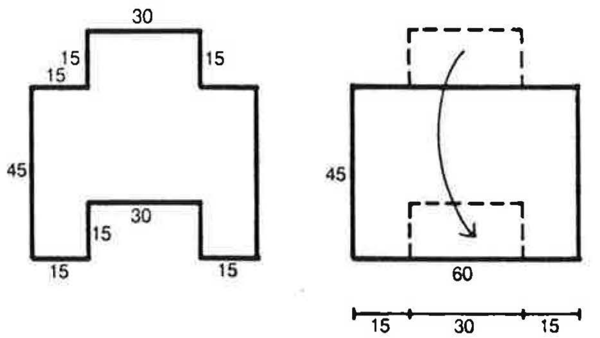
THE EFFECT OF ASPECT RATIO ON ENERGY CONSUMPTION

The plan shape of a school and the length of its perimeter will be determined by many factors, of which the need for energy conservation is only one. Aspect ratios are a convenient means of assessing the effect of various plan forms on energy conservation at an early stage in design.

The aspect ratio is the ratio of length (l) to breadth (b) of the rectangle that has the same area and perimeter as that of the proposed plan form of the building. Neglecting orientation and other site influences, the energy performance of this equivalent rectangle will be the same as that of the building to which it is related. Also, the average depth of room given in the equivalent rectangle will be the same as in the building design being examined.

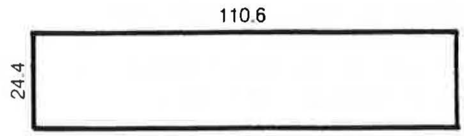
The shape of the equivalent rectangle determined by aspect ratio can be visualised more readily than that from the wall:floor area ratio. The aspect ratio may well indicate a shape not envisaged, thus giving a warning that a plan form may not be as efficient as was first thought.

For example, consider the building plan shape on the left below which has an area of $2700m^2$ and a perimeter of 270m. At first it may be thought that this plan shape is equivalent to the shape on the right.



However, closer examination will reveal that the perimeter of this rectangle is only 210m, that is 60m less than the design being analysed and consequently not representing the shape in every way. The true aspect ratio is found by solving the quadratic equation arising from the known details, $2(l + b) =$ perimeter and $l \times b =$ area. For a rectangle of area $2700m^2$ and perimeter 270m the aspect ratio is 4.5:1, but for the same area with a perimeter of 210m the aspect ratio is 1.3:1.

Thus the true equivalent rectangle of the plan shape being considered is as shown below and the average room depth is 12.2m or breadth divided by 2.



In order to provide an easily used design tool, the equations have been solved for a variety of areas and perimeters, these are shown in Figure 4 with the derived average room depths.

Figure 11 below demonstrates the effect of aspect ratio on the total annual energy consumption of a building. The effect over the whole range is about 15%, the effect over a more restricted range, of up to 12:1 aspect ratio, is about 7%.

The effect of reducing the 'U' value by half is also about 7%, all other factors remaining the same. Thus a high aspect ratio can have the effect of negating the possible energy savings from low 'U' values.

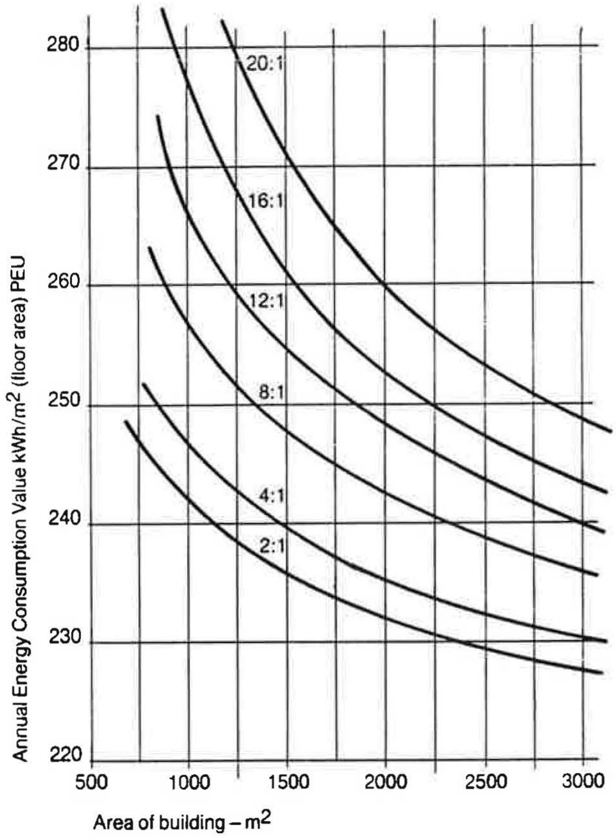


Figure 11
Variation of annual energy consumption value with building area and the effect of aspect ratio, % window in wall and U values to opaque areas of wall and roof constant.

APPENDIX 2

CALCULATION SHEETS FOR ENERGY DESIGN VALUE AND ANNUAL ENERGY CONSUMPTION VALUE
(Ref: Section D of DES Design Note 17, 'Guidelines for Environmental Design and Fuel Conservation in Educational Buildings'; 1981).

1. ENERGY DESIGN VALUE (see paragraph 3)

Basic Data

a. Assumed Conversion Efficiencies

Energy Source	Instantaneous Conversion Efficiency %	Primary Energy Input per unit of Delivered Energy
Electricity, normal tariff	100	3.73
Electricity, off peak tariff	90	4.14
Manufactured Fuels	74	1.89
Oil	75	1.44
Natural Gas	74	1.43
Coal	70	1.46

b. Typical Occupation Densities
These should be calculated by dividing the gross floor area of the proposed buildings by the actual number of pupils for which they are designed. For typical values refer to Figure 5.

c. Aspect ratio and average room depth to be derived from perimeter length and area (see Appendix 1 and Figure 4).

Calculation

i	Activity (eg secondary, general teaching)	=	
ii	Density of Occupation	=	pupils/m^2
iii	Number of Storeys	=	
iv	Gross Floor Area	=	m^2
v	Perimeter	=	m
vi	Aspect Ratio (Figure 4)	=	:
vii	Average Room Depth (Figure 4)	=	m
viii	Floor-Ceiling Height	=	m
ix	Window:Wall Ratio (internal elevation of external wall)	=	
x	Overall Height	=	m
xi	Roof Light Area	=	m^2
xii	Wall:Floor Ratio	=	
xiii	Design Temperature Difference (inside–outside)	=	°C
xiv	Ventilation Rate (see paragraph C5)	=	

Heat loss per square metre of floor area

U values		Heat Loss W/m^2
Opaque Area of Walls	W/m^2°C	
Opaque Area of Roof	W/m^2°C	
Ground Floor	W/m^2°C	
Windows	W/m^2°C	
Roof Lights	W/m^2°C	
Ventilation	30m^3 per person per hour	
Total Heat Loss	(W/m^2, floor area delivered energy)	(1)

Heat Gain per square metre of floor area	Heat Gain W/m^2
Occupants (70W per person)	
Electric Lighting	
Miscellaneous Power	
Total Heat Gain (W/m^2 floor area delivered energy)	(2)

NETT HEATING REQUIREMENT (1) – (2) = W/m^{2}floor area (3)

HEATING FOR HOT WATER SERVICE = W/m^{2}floor area (4)

Electrical Energy	W/m^2 floor area
Lighting	
Miscellaneous Power	
Heating System Circulators	

TOTAL ELECTRICAL ENERGY = (W/m^2 floor area (5)

CONVERSION TO PRIMARY ENERGY (see paragraph 1a)

(3) × heating conversion factor + (4) × hot water heating conversion factor + (5) × electrical conversion factor

= W/m^{2}PEU + W/m^{2}PEU + W/m^{2}PEU

ENERGY DESIGN VALUE = W/m^{2}PEU floor area

(Refer to Figure 5 for model value)

2 ANNUAL ENERGY CONSUMPTION VALUE (see paragraph 4)

Basic Data

a. Assumed Conversion Efficiencies

Energy Source	Seasonal Conversion Efficiency %	Primary Energy input per unit of Delivered Energy
Electricity, normal tariff	100	3.73
Electricity, off peak tariff	75	4.97
Manufactured Fuels	63	2.22
Oil	63	1.71
Natural Gas	63	1.68
Coal	60	1.70

b. Calculation of running hours (see page 15 for model year).

Number of working days = days. Number of Degree Days = days (1)

Base temperature = °C

Ratio Dd/D 15.5 = (2)

Equivalent annual operation $\frac{(1) \times (2) \times 24}{\text{Design temperature difference}}$ = hours (3)

Correction for mode of operation

i. 5 day week = (4)

ii. intermittent use = (5)

iii. length of day = (6)

Corrected equivalent hours of operation (3) × (4) × (5) × (6)	=	hours
Hours of occupancy for Metabolic Gains	=	hours
Hours running for Miscellaneous Power	=	hours
Hours running for Fans, Circulators etc	=	hours
Annual Lighting Energy Consumption (Figure 8 or actual if known)	=	kWh PEU

Other Energy Consumption
(for example, electric motors for mechanical ventilation)

	=	
	=	
	=	
	=	

Calculation

Heating Energy

Losses	W/m2 floor area	Running Hours	PEU Conversion (see paragraph 2a)	Total kWh/m2 PEU
Fabric and Ventilation (see 1(1))	x	x	=	
Hot Water Service (see 1(4))	x	x	=	
			Total Losses =	(1)
Gains				
Occupancy	x	x	=	
Misc. Power	x	x	=	
Lighting (see 2b) (80% of annual total in Delivered energy)				
			Total Gains =	(2)
NETT HEATING REQUIREMENT (1) – (2)			=	(3)

Electrical Energy

Lighting				
Pumps	x	x	=	
Power	x	x	=	
TOTAL ELECTRICAL ENERGY			=	(4)

ANNUAL ENERGY CONSUMPTION VALUE (3) + (4) = kWh/m2 PEU

(Refer to Figures 6 or 7 for model value)

Observations