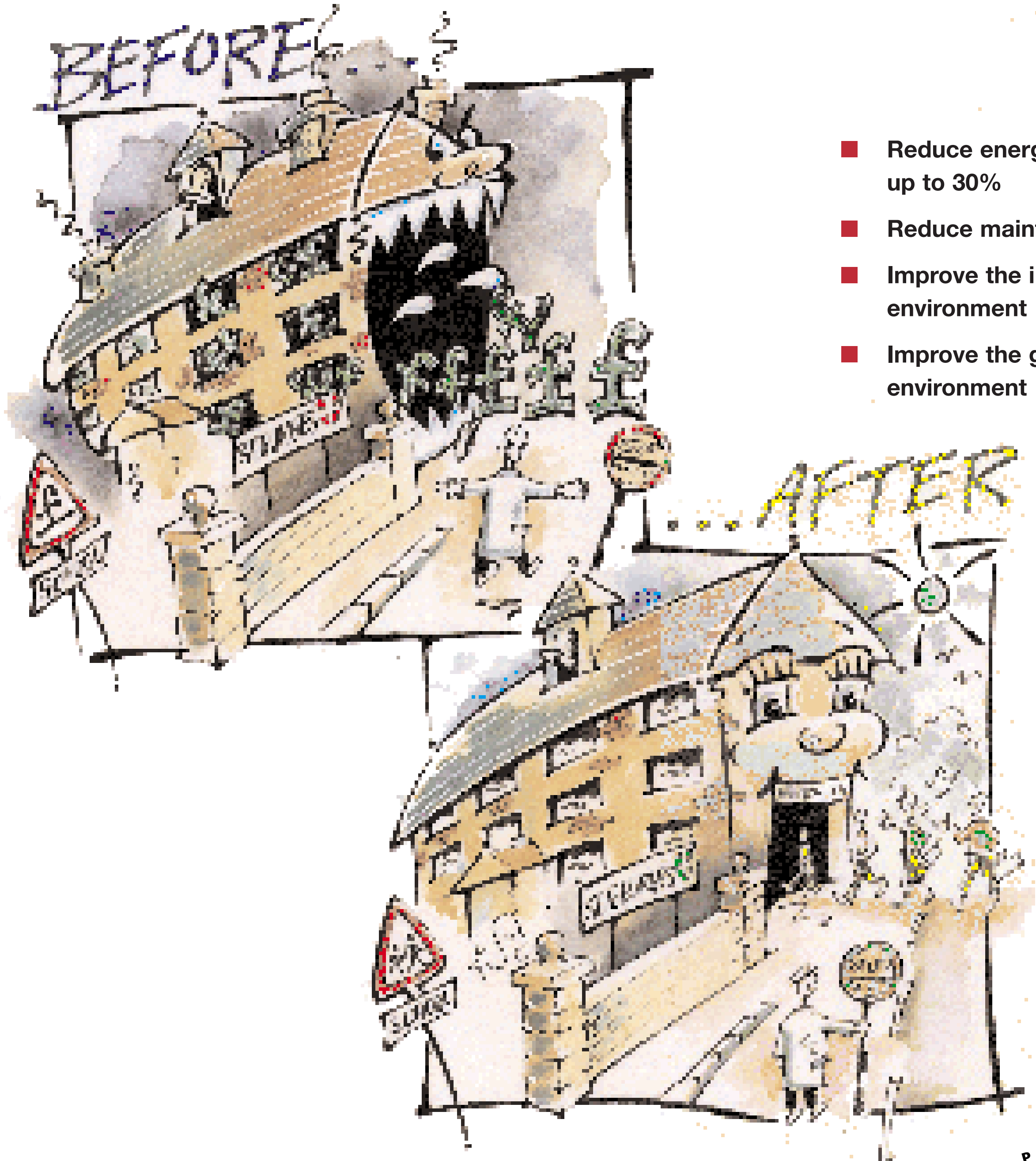
DEPARTMENT OF THE ENVIRONMENT, TRANSPORT AND THE REGIONS

GOOD PRACTICE GUIDE 233

Energy efficient refurbishment of schools



- Reduce energy costs by up to 30%
- Reduce maintenance costs
- Improve the internal environment
- Improve the global environment

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 233

CONTENTS

1	INTRODUCTION	4
2	CONSTRUCTION STYLES AND TECHNIQUES	5
3	FABRIC MEASURES	7
4	ELECTRICAL SERVICES	12
5	MECHANICAL SERVICES	16
6	ENVIRONMENTAL ISSUES	21
7	CONCLUSION	21
	REFERENCES AND FURTHER READING	22

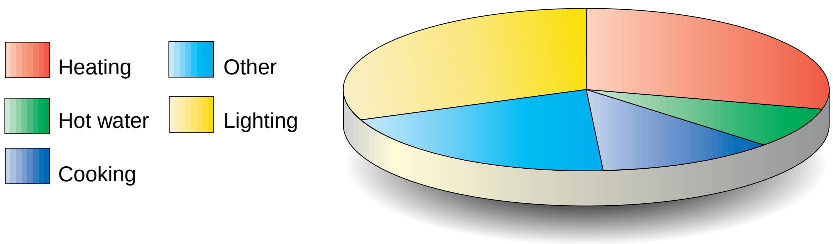
1 INTRODUCTION

Under Local Management of Schools (LMS) arrangements, a school's energy bill is one of the responsibilities that the Local Education Authority will have transferred to the school's governing body.

In the past it is likely that most schools have given a low priority to controlling energy costs. Now with LMS there is a real incentive to give it a higher priority. Energy is one area where costs can be reduced, while maintaining or even improving the school environment. If energy costs are not kept under control, overspending can force economies elsewhere.

The refurbishment of school premises provides an ideal opportunity for introducing energy efficient measures at low cost.

Where is energy used ? The pie chart indicates the split in energy costs for a typical school. Although electricity typically represents only 18% of consumption, electrical costs now usually exceed those of fossil fuel



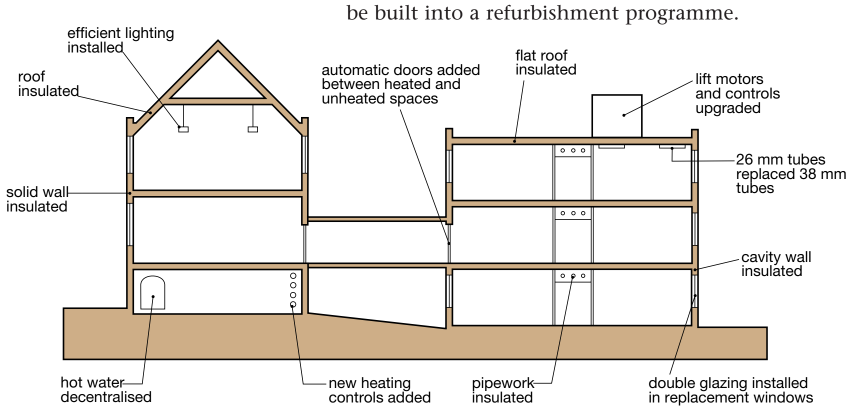
Energy efficient refurbishment:

- reduces energy costs
- reduces maintenance costs of building and plant
- releases money from energy and maintenance budgets for other services
- improves the quality of the internal environment
- reduces carbon dioxide (CO_2) emissions as a result of lower energy consumption, thereby improving the external environment.

How this Guide can help you

This Guide provides head teachers, governors and engineering staff with information on energy efficiency measures, and describes how they can be built into a refurbishment programme.

Figure 1 The opportunities for energy saving during refurbishment



Topics covered are:

- improving building fabric insulation
- the use of energy efficient technologies
- improving the efficiency of electrical services, such as lighting
- improving the efficiency of mechanical services, such as heating
- assessing the economic viability of incorporating energy efficiency measures during refurbishment.

The measures given in this Guide are classified by symbols:

A can be carried out at any time

M can be carried out with routine maintenance

P best carried out when plant needs replacing

R best carried out as part of a full refurbishment.

The measures covered in this Guide can be applied when refurbishing a single building or department but not when making major changes. In such cases reference should be made to Good Practice Guide 173 'Energy efficient design of new buildings and extensions – for schools and colleges' (GPG 173)[1].

Taking the opportunity

Energy efficiency measures can often be incorporated during refurbishment at marginal extra cost. A common example is the substitution of double for single glazing when replacing the windows of a classroom. Figure 1 shows some opportunities that consistently achieve high rates of return. Such opportunities should not be missed.

Maintenance and energy efficiency

Routine maintenance can also present opportunities for introducing energy efficiency measures. These measures have the attraction of not requiring capital investment, because they are financed out of the annual maintenance budget.

Energy saving measures incorporated into maintenance work provide very good returns, some costing no more than the conventional solution. For example, worn out 38 mm diameter (T12) fluorescent tubes can be replaced with slimmer 26 mm (T8) tubes which cost less to run and are more energy efficient.

2 CONSTRUCTION STYLES AND TECHNIQUES

Pages 5 and 6 briefly describe the main historical phases of school building, the type of constructions used and the resulting opportunities for refurbishment. The remaining pages in the Guide describe the refurbishment opportunities in more detail.

PRE-1919 SOLID WALL CONSTRUCTION

Buildings of this type are characterised by solid brick or stone external walls with timber pitched roofs covered with slates. The original sash windows and external doors are of timber. Ground floors are suspended timber, often with cellars. Floor to ceiling heights are typically 4.5 m and may be higher.

Heating is typically provided by low pressure hot water (LPHW) radiators supplied by a central boiler. The proportion of buildings of this type is reducing as older buildings in poor condition are demolished and replaced.

For all types of school buildings – Typical energy costs (£/m²)	
Fossil fuels	1.7
Electricity	2.3
Total	4.0

Energy efficiency opportunities

Many of these energy efficiency measures are applicable to all forms of school construction.

- Insulate the roof space.
- Insulate heating system pipework where it runs through unheated spaces as part of routine maintenance.
- Draughtstrip windows and doors that are in good condition.
- Replace single glazed windows with double glazed windows when necessary.
- Insulate timber ground floors where access is available from below.
- Replace general lighting service (GLS) lamps with compact fluorescent lamps and T12 fluorescent lamps with T8 lamps as part of routine maintenance.
- Upgrade lighting controls when refurbishing the interior of the building.
- Add internal insulation to walls when refurbishing the interior of the building.
- Add external insulation to walls when refurbishing the exterior of the building.
- Upgrade heating controls.

Pre-1919 school building – Vicarage Infant's School – London Borough of Newham

CONSTRUCTION STYLES AND TECHNIQUES

INTER-WAR CONSTRUCTION

In general, buildings of this period are similar in construction and services to pre-1919 buildings, except that they usually use metal casement windows and cavity wall construction. Many also have reinforced cast concrete upper floors and roofs.

Energy efficiency opportunities

Many of the measures listed for the pre-1919 school buildings are also applicable to inter-war buildings. In addition, the following measures are particularly suitable.

- Insulate flat roofs when carrying out repairs to the roof covering.
- Install cavity wall insulation where the walls are suitable.

POST-WAR BUILDINGS

Framed buildings have either a steel or concrete frame structure, enclosed by cladding panels or masonry. The roof structure is usually concrete or metal decking.

Buildings of masonry construction have brick cavity external walls, with blockwork inner leaf. Windows are either metal casement or metal windows in timber sub-frames. Concrete roofs were used before the 1980s, while pitched roofs covered in tiles predominate in the 1980s and 1990s.

The most common form of heating is LPHW radiators, with some buildings having LPHW convectors. Natural ventilation with local mechanical extract to WCs is the most common form of ventilation, although deep plan buildings are mechanically ventilated throughout.

Energy efficiency opportunities

The insulation opportunities will depend on the method of construction adopted. The following are the main opportunities.

Framed buildings

- Insulate walls when refurbishing the exterior or interior of the building.
- Include double glazing in replacement windows.
- Insulate flat roofs when carrying out repairs to the roof covering.

Masonry construction

- Top up insulation in pitched roof spaces.
- Insulate external cavity walls where they are suitable.
- Include double glazing in replacement windows.

Post-war Hardenhuish School – Wiltshire County Council

ROOFS

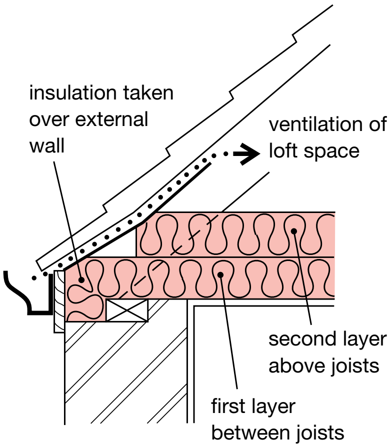
A R Pitched roofs

Insulating pitched roofs at ceiling level gives a good rate of return and can be carried out at any time.

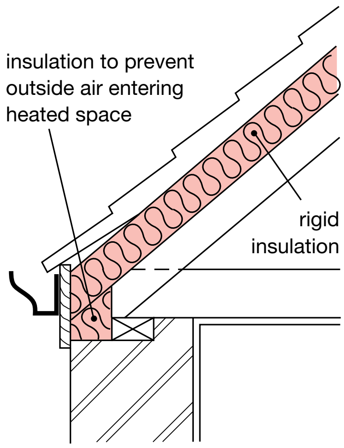
An insulation thickness equivalent to 150 mm to 200 mm of mineral wool is recommended. Mineral wool can be installed in quilt or blown form. Where existing insulation is less than the recommended thickness, it is also worthwhile topping up to the appropriate levels. To minimise thermal bridging it is preferable to lay the insulation in two layers, the first layer between ceiling joists and the second layer across the joists.

- Ensure the roof space is ventilated to avoid problems with condensation.
- Ensure water services and ducting within the roof space are insulated to avoid problems with condensation and freezing.
- Route highly rated electrical cables above the insulation to avoid overheating and deterioration of the PVC sheathing (or de-rate the circuit or run the cable in conduit).

Alternatively, a pitched roof can be insulated at rafter level using foam insulation boards with low vapour permeability or high density mineral wool slabs. This type of construction is usually only used where there is accommodation within the roof space. Insulating at this level is best carried out when re-roofing.



Insulation at ceiling level



Insulation at rafter level

Figure 2 Alternative positions for the insulation in a pitched roof

- The existing roof structure must be able to carry any additional weight.
- The height of upstands may have to be raised to take account of any increase in the thickness of the insulation.
- Care must be taken when existing insulation is retained. Ensure the greater thermal resistance is above the weatherproof membrane; a ratio of 3:1, above to below, is recommended.

R M Flat roofs

Flat roofs are more difficult and expensive to insulate than pitched roofs. It is not usually economic to add insulation unless carrying out repair or refurbishment work at the same time.

Rigid plastic or cork insulants are preferred and should be placed above the roof deck, as this keeps the roof structure warm and helps avoid condensation. The insulation thickness should be chosen to provide a U-value of 0.35 W/m^{2}K or better.

- A vapour barrier should always be placed on the warm side of the insulation.

R New false ceilings

Victorian school buildings often have high ceilings, 4.5 m floor to ceiling height is not uncommon. This leads to large heated volumes and high ventilation heat losses. Installing a new false ceiling with insulation at ceiling level can reduce the heated volume. This can be done as part of general refurbishment. Where false ceilings have been installed previously, check whether insulation has been included in the construction.

- Do not recess light fittings into the ceiling, because this can result in excessive air infiltration from classrooms into the ceiling void.
- It is important to ensure that the weight of additional insulation is acceptable.
- To minimise the risk of condensation, the roofspace should be ventilated to the outside.

FABRIC MEASURES

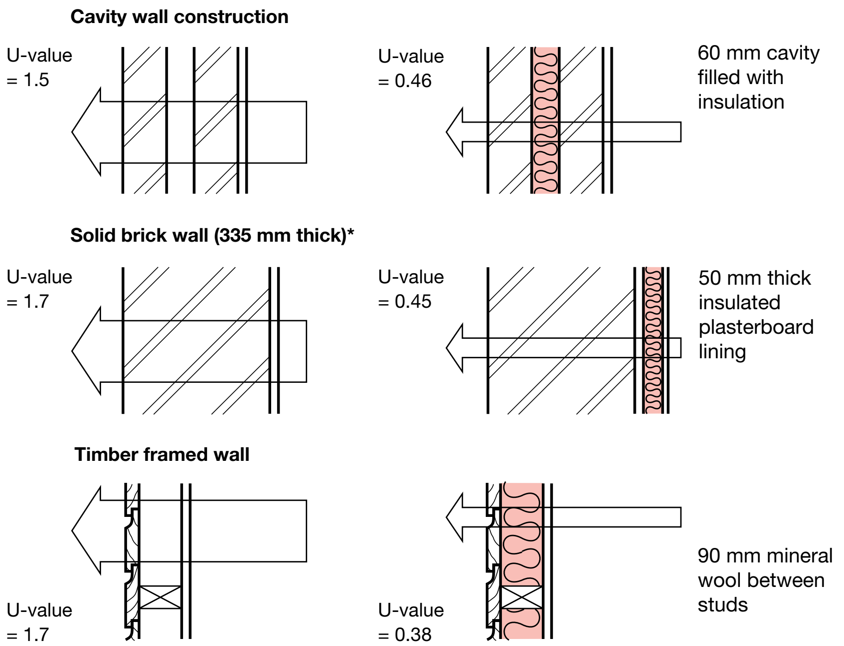
Design Note 17 (DN17)[2] contains guidance from DfEE for environmental design and fuel conservation

WALLS

A Cavity insulation

Insulating cavity walls is a very cost-effective measure that can be applied at any time. Insulation blown into the wall cavity improves the U-value to 0.50 W/m^{2}K or better. The DN17[2] requirement for new buildings is 0.40 W/m^{2}K. Expanded polystyrene beads or mineral wool are the most commonly used materials. Most cavity fill materials are restricted to buildings 12 m high, although some are acceptable up to 25 m.

- Cavities should be inspected before filling to ensure they are clean, because bridging by mortar droppings or other debris can lead to problems with damp penetration.
- If rain penetration is already a problem, cavity fill should be avoided.
- Air bricks penetrating the cavity should be sleeved and the cavity closed at the eaves to avoid insulation escaping into the roof space.
- Insulants used should be certified by the British Board of Agrément and installed by an approved installer.



*not cost-effective on energy efficiency grounds alone

Figure 3 Improvements in U-values (W/m^{2}K) achievable by adding insulation

R External wall insulation

The high capital cost of external insulation prevents it being cost-effective on energy saving grounds alone. However, for structural or other reasons, where the external wall surface requires attention, insulating the wall at the same time should be considered. A number of proprietary insulating systems are available. Insulation is applied to the external surface of masonry walls and finished with cladding, render, propriety surface coating or tile hanging. These systems are best applied to walls which have a minimum of architectural projections and external services.

- The proposed new surface finish should be acceptable to the planning authority.
- Precautions should be taken against fire spread where combustible insulation is used or cavities are to be left in the construction.
- The space behind impermeable cladding should be ventilated.
- Insulation should be returned into window reveals to avoid thermal bridging, provided it does not obstruct the window frames.

R Internal wall insulation

The addition of insulation to the internal face of solid external walls is less expensive than external insulation. However, disruption to occupants when installing internal insulation should be avoided by carrying out such work during holiday periods or as part of an internal refurbishment. But, as for external wall insulation, this improvement is not likely to be cost-effective on energy saving grounds alone.

Insulation can either be fixed to battens and covered with plaster board, or incorporated in a composite board of insulation and plasterboard. Dry lining techniques are used to fix the boards to the wall. It is important to incorporate a vapour control layer on the warm side of the insulation to avoid interstitial condensation. Thermal bridging should be avoided, particularly around window reveals.

When considering either external or internal wall insulation, a careful assessment of cost-effectiveness will be required.

Other points to consider when installing internal insulation are:

- the need to minimise service penetrations of the internal lining
- the need to provide supports for heavy items such as radiators.

R Insulating timber framed walls

If external timber cladding needs to be replaced, there is the opportunity to insulate the wall at the same time. When the existing cladding is removed, insulation can be placed between timber studs, or rigid insulation board can be fixed to the outside of the frame, before recladding.

If internal refurbishment is to be carried out, an alternative to adding insulation between the studs is to use a composite board of insulated plasterboard fixed to the internal surface, instead of standard plasterboard.

A vapour control layer must be placed on the warm side of the insulation to prevent condensation within the construction. It may also be beneficial to ventilate the cold side of the insulation. Ventilation behind cladding is essential if the cladding is impervious to water vapour.

A M Reflective foil behind radiators

Foil can be installed behind radiators at any time, but is most easily applied as part of redecoration. Typical costs are about £10 per radiator. The foil surface reflects heat back into the room that would otherwise be lost through the wall. As well as reducing heating energy consumption, warm up periods are reduced and better heat distribution can be achieved. This measure is especially effective in intermittently heated areas with uninsulated solid walls.

A Blocking up chimneys

Old, unused, open chimneys can be blocked up when redecorating. This reduces uncontrolled ventilation losses and draughts. Ensure that sufficient controllable ventilation is provided after blocking the chimney.

FLOORS

A R Suspended timber ground floors

Where there is access to the underside of suspended timber floors, adding insulation between the joists is a cost-effective measure at any time. In areas where there is no access to the underside, insulating between the joists can only be carried out from above. To do this the flooring must be lifted, so it is only worthwhile if the floor requires renewal as part of a general refurbishment. Either mineral wool or rigid foam insulation can be used.

- Seal gaps at the skirting to avoid air infiltration.
- Maintain ventilation below the subfloor.
- Place electrical cables sheathed in PVC in conduit, or protect from direct contact with expanded polystyrene insulation.
- Heating pipes should not be placed below the insulation. If this cannot be avoided the pipes should be insulated.

R Solid ground floors

Where the existing floor finish needs to be renewed, there is an opportunity to add insulation. The insulation used should have adequate compressive strength for the intended loading and any timber products used should be moisture resistant.

Where a screed is not required, a convenient way of insulating solid ground floors is to resurface the floor using composite panels of insulation and chipboard or plywood flooring. These are laid loose over the slab, and the tongue and groove joints glued. The surface of the slab should be smooth with no bumps which can cause the insulation to 'rock'. A 10 mm expansion gap should be left at the edge of the floor. When floors wider than 10 m are covered, a gap of 2 mm per metre is recommended. If the insulation and flooring panels are laid separately, a vapour control layer should be laid between them.

FABRIC MEASURES

Where a screed finish is laid above the insulation the screed should be at least 75 mm thick. If there is no damp proof finish above the slab, a vapour control layer should be placed above the insulation before the screed is laid.

M Exposed floors

Where the underside of upper floors is exposed to outside air, look for an opportunity to add insulation.

Suspended timber floors can be easily insulated by lifting a few floor boards and insulating between joists with mineral fibre quilt or blown insulation. This is a fairly cheap and cost-effective measure.

Insulating solid floors is not as easy. Composite insulating boards can be fixed to the underside of flat concrete slabs. An insulation thickness of 50 mm to 75 mm is recommended. To avoid thermal bridging, any projecting downstand beams should also be fully insulated. An alternative that is particularly applicable to complex soffits, such as waffle slabs, is to use sprayed mineral fibre. This requires a protective coating.

WINDOWS

R Replacement windows

Where window frames are in poor condition and need replacing, consider installing double glazing.

For a typical window, the marginal extra cost of double glazing is around £17 per m^2. The U-value of standard double glazed PVC-U or timber windows is about 3.3 W/m^{2}K, compared to 5.7 W/m^{2}K for a timber single glazed window.

- The wider the gap between the two panes of glass, the better the insulation value. A minimum of 12 mm is recommended, provided the frame can accommodate this thickness.
- Installing double glazing with a low emissivity coating, known as low-e glass, improves the U-value still further. Low-e double glazing with a 12 mm air space in a timber framed window has a U-value of about 2.4 W/m^{2}K. The low-e coating reflects heat back into the building, raising the internal surface temperature of the glass. This greatly improves the comfort conditions close to the glazing compared with standard double or single glazing.

R Reducing areas of low level glazing

Many post-war schools were designed with large areas of single glazing which can lead to high heat losses in winter and poor thermal comfort in the summer due to high solar gain. A solution to this is to replace some of the low level glazing with insulated infill panels. Even modest levels of insulation in such panels can improve the thermal performance of the wall dramatically. For example, replacing a single glazed panel with one containing 25 mm of polyurethane will reduce the U-value from around 5.7 W/m^{2}K to around 0.8 W/m^{2}K. Increasing the insulation thickness to 50 mm would achieve a U-value better than 0.45 W/m^{2}K which compares with the DN17[2] recommended value of 0.40 W/m^{2}K.

R Solar shading devices

Where control of solar gain is required, the installation of shading devices can be considered. There are many forms of shading device using either louvres or blinds, which can be installed either internally or externally. The following points should be considered.

- External shading devices are more expensive than internal ones but are more effective.
- Fixed external shading devices will reduce the level of daylight entering the building.
- Where windows provide natural ventilation, roller blinds are not recommended.

M Solar control films

Where high solar gain is a problem, a useful short-term measure is to apply a solar-control film to existing glazing. However, it will also reduce daylight levels and effect the colour rendering of the remaining daylight. It is important therefore to ensure that this measure does not lead to excessive increase in artificial light requirements and that any resulting colour changes are acceptable.

As well as reducing summer heat gains, some films can reduce winter heat loss through the glazing. Some manufactures claim reductions of up 35%.

- Skill is required to apply these films correctly, so installation should be carried out by a specialist.
- Most films are easily scratched, so only non-abrasive cleaning materials should be used.

M Draughtstripping

Windows that can be opened, and are generally in good condition, should be draughtstripped. This reduces cold draughts and ventilation heat loss. In naturally ventilated areas, controllable trickle ventilators should be fitted to ensure minimum quantities of fresh air can be provided after draughtstripping. It is important to ensure good quality materials are specified and correctly fitted.

DOORS

R Draught lobbies

Providing a draught lobby at frequently used entrances to a building can make a significant contribution to reducing ventilation heat loss. It is important to ensure that lobbies are not only sized to provide unrestricted access, but also have sufficient space to enable one set of doors to be closed before the other is opened. Where possible, the two sets of doors should have automatic control.

M Draughtseals

The draughtstripping of external doors is very cost-effective and can be carried out at any time.

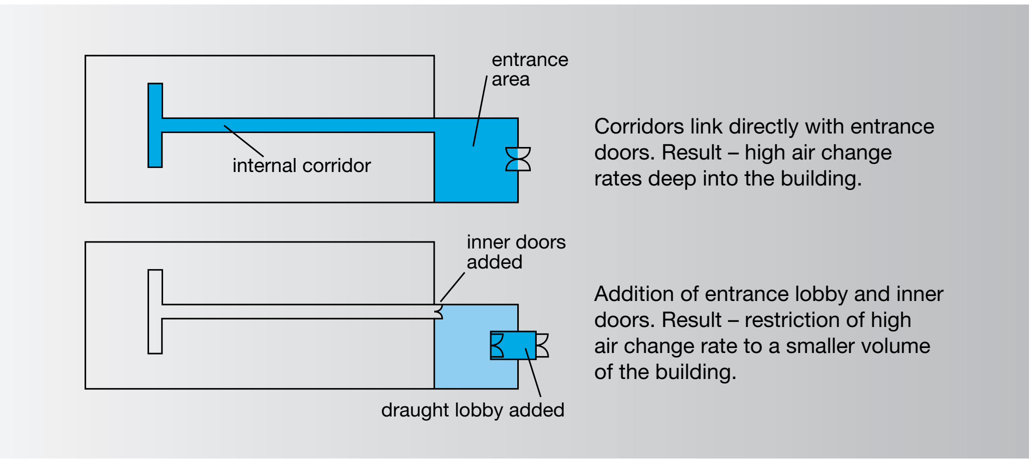


Figure 4 Using draught lobbies and inner doors to reduce heat loss

4 ELECTRICAL SERVICES

WHERE ELECTRICITY IS USED

While fossil fuel consumption within schools has been reduced in recent years, there has been an increase in electrical consumption. Electricity costs now represent over 50% of the total expenditure on energy. The greatest use of electricity within schools is for lighting, typically representing between 40% and 60% of the total consumption. The relatively high unit price of electricity means that any reductions in consumption that can be achieved provide good cost savings.

LIGHTING

As lighting is the major consumer of electricity in schools, measures to reduce lighting energy consumption can be readily justified either during regular maintenance or as part of a general refurbishment.

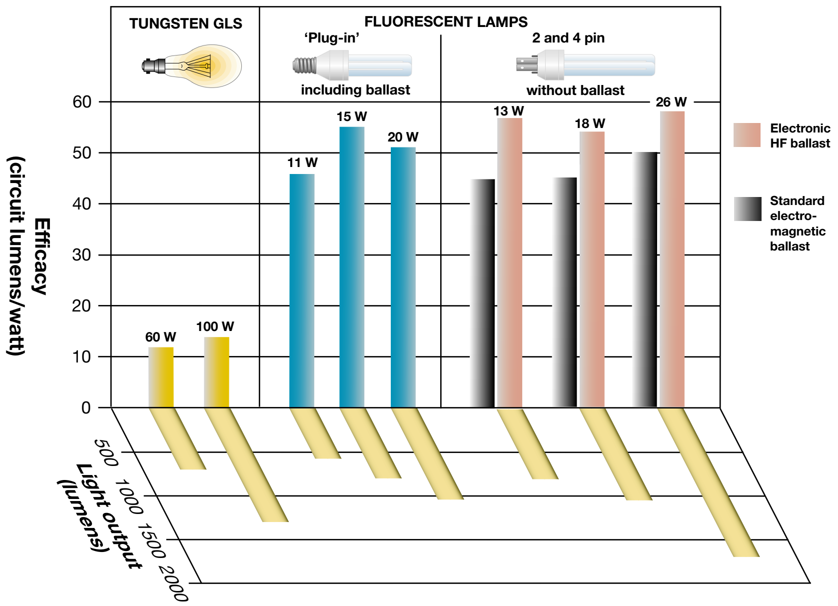


Figure 5 Typical efficacies for tungsten and compact fluorescent lamps

There are two areas where the energy efficiency of lighting can be improved:

- by replacing existing components with more efficient alternatives
- by reducing the number of hours when lights are switched on.

M Replacing tungsten lamps

A measure that can easily be carried out as part of routine maintenance is the replacement of tungsten (GLS) lamps with compact fluorescent lamps. Energy savings of 75% are possible, giving a simple payback of 1 to 3 years.

- The replacement compact fluorescent lamp must provide at least the same level of illuminance as the GLS being replaced.
- Where large numbers of compact fluorescent lamps are used, the need for power factor correction should be checked.
- The longer lamp life of compact fluorescent lamps (8-10 000 hours) compared with GLS lamps (1000 hours) will also dramatically reduce maintenance.

Compact fluorescent lamps can have a different light distribution to GLS lamps. Check that the replacement compact fluorescent lamp is appropriate for the luminaire.

M Replacing fluorescent lamps

Where tubular fluorescent lamps are already in use, 38 mm fluorescent tubes (T12) should be replaced with newer 26 mm tubes (T8) as part of routine maintenance. For fittings with switch starter circuits, the 26 mm tubes can be used as a direct replacement for the 38 mm ones. The 26 mm tubes cost no more than 38 mm tubes, so energy savings of about 10% can be achieved at no additional capital cost.

ELECTRICAL SERVICES

R Installing high-frequency ballasts

An even more efficient option is to use high-frequency (HF) electronic ballasts for fluorescent lamps. These use less power than the conventional electromagnetic ballasts and improve the efficiency of the lamp. HF ballasts operate at 28 000 Hz instead of 50 Hz, eliminating any flicker associated with fluorescent lamps, and extending the lamp life. HF ballasts are particularly appropriate in areas containing fast moving machinery, such as slicing machines in kitchens or circular saws in workshops, because the high frequency avoids the possibility of the machinery appearing to be stationary (stroboscopic effect).

Installing HF ballasts can provide energy savings of 15% to 20%. Their relatively high cost (£35 to £40 per luminaire) means they are most cost-effective in areas where lights are on for most of the day.

The modern T8 tubes should be used with HF ballasts. Special dimming electrical ballasts are also available to enable fluorescent lamps to be dimmed.

Compact fluorescent lamps (CFLs)

There are two types of CFL:

- those that include a ballast and can therefore be a direct plug-in substitute for incandescent GLS lamps
- those that require a separate ballast, which needs to be housed within the luminaire.

CFLs are more efficient than GLS lamps, with luminous efficacies of 50 to 70 lumens/watt compared with 12 to 16 for GLS lamps.

Although CFLs cost more than GLS lamps, the typical lamp life is around 8 times as long (around 8000 hours). The extended lamp life and the much lower power consumption makes the replacement of GLS lamps with compact fluorescent lamps a very cost-effective measure.

Tubular fluorescent lamps

Early fluorescent lamps were argon-filled, with a diameter of 38 mm. They are still used with starterless circuits and are often referred to as T12 lamps. The modern range of krypton-filled triphosphor lamps have a diameter of 26 mm (except for the 2400 mm long, which are 38 mm wide) and are known as T8 lamps. The 26 mm T8 lamps are the preferred choice for switched start and electronic circuits. They have luminous efficacies some 10% higher than the 38 mm lamps.

Recently, even smaller diameter fluorescent lamps have been introduced: 16 mm diameter T5. These have efficacies 5% higher than the T8 lamps. These lamps have good colour rendering and are approved for high-frequency control gear. T5 lamps cannot be used as direct replacements for T12 or T8 lamps and require high-frequency control gear.

Sodium and metal halide

For rooms with high ceilings, or for external lighting applications such as sports facilities and car parks, metal halide or high pressure sodium (SON) lamps are suitable. The higher efficacies and lamp ratings mean that fewer luminaires are required for a given area and this reduces the cost of installation. These lamps have distinctive colour rendering, so care must be taken when choosing which to use. SON lamps have higher efficacies, a long lamp life (typically 16 000-24 000 hours) and are the preferred option on energy grounds, but they have a distinctive golden light that may not always be acceptable. Metal halide lamps have a crisp white light and good colour rendering qualities, but a shorter lamp life (typically 6000 hours). The efficacy of metal halide lamps is lower than SON lamps, but is comparable with tubular fluorescent lamps.

These lamps have a relatively long ‘strike’ and ‘warm-up’ time that must be taken into account when assessing their suitability for any proposed application.

ELECTRICAL SERVICES

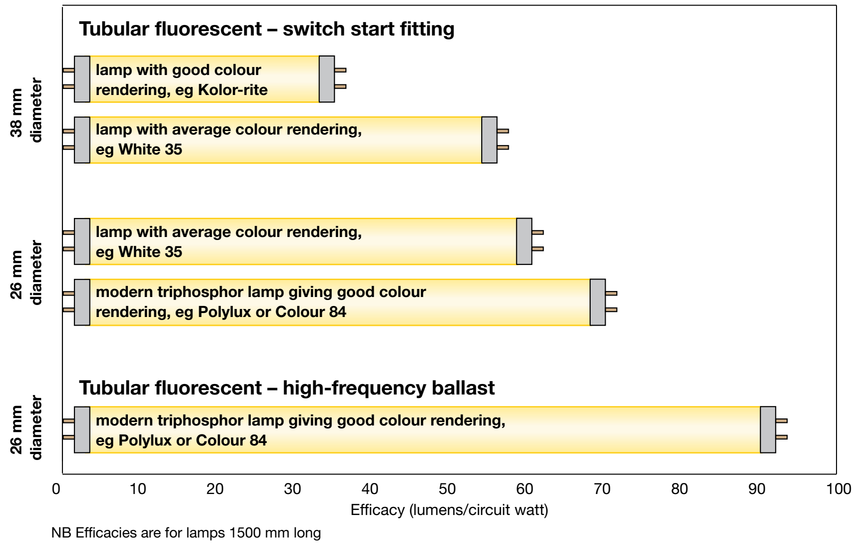


Figure 6 Typical efficacies for tubular fluorescent lighting

M R Replacing fittings

The replacement of luminaires or reflectors can be carried out as part of a planned maintenance programme or as part of a complete refurbishment.

Fitting high-efficiency reflectors can lead to a reduction in the number of lamps required to provide a given illuminance, but the new light distribution that results needs to be checked to ensure it is appropriate for the application.

The relatively high cost of these reflectors can be justified for areas where lighting is required for extended periods.

Some existing luminaires are suitable for HF ballast, although others need to be completely replaced.

Where luminaires are to be replaced, consideration should be given to installing a type suitable for the new 16 mm diameter (T5) lamps. These have higher efficacies than the T8 lamps.

M Lighting controls

The number of hours lights are on can be reduced by good controls that allow the maximum use of daylight. This may simply mean encouraging manual switching or dimming of lights, or the use of automatic sensors and controls to maintain a constant lighting level.

In some areas, particularly those used infrequently (for example, storerooms), occupancy sensors may be used to control lights. Preferably, a run-on timer should be installed to avoid switching too frequently.

Even where automatic control is undesirable manual switching can achieve good control. By correctly grouping lights on control circuits and locating switches appropriately, energy use can be reduced. For example, lights can be switched off near windows when daylight levels allow, or when areas are unoccupied.

Introducing changes to lighting controls should be considered during general internal refurbishment work. The cost of automatic controls will depend on the options chosen. However, typical simple payback periods are in the order of 2 to 5 years.

MOTORS

Motors are widely used in buildings with pumps, fans, compressors, and lifts. There is a potential for energy saving because motors are usually oversized.

- Speed and/or voltage adjustment has only recently become economic for all motor sizes.
- High-efficiency motors have only recently been developed (see page 15).

A Low-cost opportunities

The simplest way of achieving savings is to ‘switch off’ motors when they are not required. A number of devices are available to stop motors automatically. The majority of these employ load sensors which stop the motor when it runs in an unloaded state for a pre-set time. A typical application is for pumps left running against closed valves.

R Variable load applications

Two speed motors offer improvements in efficiency for applications such as ventilation fans where a set back flow rate is required during hours of reduced occupancy. It may not be worth installing

ELECTRICAL SERVICES

a new motor on energy efficiency grounds alone, but should be considered when carrying out a replacement for other reasons.

Applications requiring variable torque are suitable for variable speed drive (VSD) systems. Pumps and fans present the greatest potential for energy savings because the power requirement is proportional to the cube of the speed (Cubed law). Thus a 20% reduction in speed would produce a near 50% reduction in energy consumption.

The two main requirements for good energy saving VSD applications are a wide variation in load and high annual operating hours at less than full load.

When installing VSDs, care must be taken to ensure problems do not arise with harmonics or low power factors.

Low power factor can occur when motors operate at low speeds. This can be avoided by sizing the new motor more closely to the size of the load.

LIFTS

A Improved controls

Lift generator sets are often run continuously even when the demand for lifts is reduced. Energy savings can be achieved by installing run-on timers to all lifts to shut down the motor generators after a pre-set period. When setting the run-on time, consideration must be given to the number of starts per hour that can be tolerated by the motors.

There are a number of ways to reduce the energy consumption of motor installations without loss of performance.

High-efficiency motors

High-efficiency motors are designed to minimise inherent losses of the motor. Tests have shown that an increase of up to 6% in efficiency can be achieved. However, improvements vary with load and motor size. As well as being more efficient than standard motors, high-efficiency motors usually have a high power factor.

Motor controllers

These are used where motors are required to run at light loads for extended periods. The voltage of the supply is regulated to provide just enough magnetising force to meet the driven load demand so that motor losses are reduced. Motor controllers absorb power, and at high loads this may lead to an operating cost penalty. The duty cycle must therefore be taken into account when carrying out a cost/benefit analysis.

Electronic variable speed drives (VSDs)

These are electronic 'black boxes' which are a substitute for conventional electromechanical motor starters. Generally located adjacent to the motors they can be physically larger than the starters they replace, but are usually easy to retrofit. There must be feedback from a measured parameter into the VSD control circuit for the VSD facility to function. For example, VSDs may be controlled from pressure, temperature, speed, volumetric flow or power, or a combination of these.

Variable speed motors

Two speed ac motors are the simplest form of variable speed motor. Performance at both speeds is the same as for a single-speed motor operating at that speed.

Other types of variable speed motors include:

- ac three-phase commutator motors
- 'latest technology' ac switched reluctance motors and drive systems
- dc motor and drive systems.

5 MECHANICAL SERVICES

HEATING

Heating in schools is predominantly provided by low pressure hot water (LPHW) radiators or convectors. Many heating systems will be supplied by central boiler plant via a distribution system using LPHW. Larger sites may use medium pressure hot water (MPHW) with calorifiers converting heat from the central distribution system to LPHW for local use within individual buildings and departments.

The measures covered in this Guide can be applied when refurbishing a single building or department, but not when making major changes to central boiler plant and distribution systems.

Overall heating system efficiency is dependent on the efficiency of the heat source, the distribution system and the control of heat emitters.

HEAT SOURCES

Conventional boilers

Boiler plant is sized (often too generously) for mid-winter requirements, giving it considerable over-capacity for the rest of the year. Efficiency drops rapidly as the load falls, and averages some 65% over the heating season for traditional designs, and even less for over-sized and poorly controlled systems. Recently introduced legislation[3] has set minimum efficiencies for new boilers with a capacity of between 4 kW and 400 kW. Full load efficiencies are required to be 85% or better, depending on the size of the plant. Modern conventional boilers achieve these high efficiencies by minimising casing and sensible flue losses.

The time spent running at part load can be reduced by using multiple smaller boilers instead of a single large one. An extension of this principle is to use a number of small boiler units linked together as modular boilers.

Condensing boilers

Condensing boilers improve on the performance of high-efficiency boilers by using a second heat exchanger to extract more sensible, and some latent heat, from the exhaust gases. Full load efficiencies are required to be 92% or better, depending on the size of the plant. Within the limits of the boiler, the lower the return water temperature the more latent heat can be extracted, giving better performance. This can lead to higher efficiencies at part load than at full load.

In multi-boiler installations which include a condensing boiler, the condensing boiler should always be the lead boiler. This will ensure that the boiler with the highest efficiency runs for the longest number of hours and that full advantage is taken of the condensing facility of these boilers during part load.

Condensing boilers are ideal for use with weather compensated heating circuits and underfloor heating. Other potential uses include domestic hot water, where there is a high load, or swimming pools.

Combined heat and power (CHP)

CHP is the generation of thermal and electrical energy in a single process, optimising the energy available from the fuel. Efficiencies of CHP plant are typically between 80 and 90%. The higher installation costs of CHP units mean that they need to be operated at full load for a substantial proportion of the year to be economically viable.

MECHANICAL SERVICES

HEAT SOURCES

P Central boiler plant

Where the whole site is supplied from central boiler plant that still has a useful life, the options for refurbishment are limited. If the existing plant is near the end of its useful life or in bad repair it should be replaced. As with any replacement, all options should be considered.

Where central boiler plant is to continue to supply a refurbished department or building, it is important to ensure that any calorifiers are in good repair and correctly insulated. Most new calorifiers will be supplied with suitable insulation, but some older vessels may require additional insulation.

R Decentralisation

If the building or department being refurbished is a long way from the central boiler plant, or has a significantly different heat demand profile from the rest of the site, decentralisation may be appropriate. Care must be taken to ensure that the load on the central boiler plant does not drop below an acceptable level, causing inefficient heat supply to the rest of the site. Where central plant consists of more than one boiler, the opportunity to shut down one or more boilers should be considered prior to full decentralisation.

R Local systems

Local boilers in individual buildings are usually fired by natural gas. Electrical heating should only be used where it is not possible or practical to supply gas or heat from a central system, eg in temporary or remote buildings.

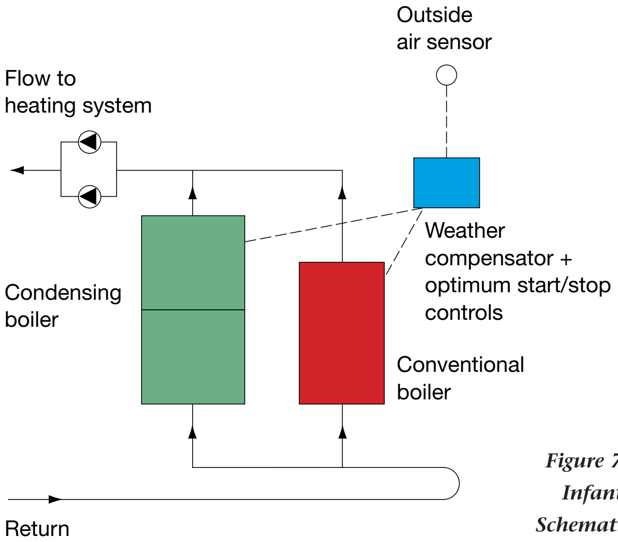


Figure 7 Vicarage Infant's School. Schematic heating system

M P Improvements to boiler plant

- ***Weather compensation*** – At the beginning and end of the heating season, it may be possible to reduce the temperature of the heating medium while still providing sufficient heat to the occupied space. This results in conventional boilers firing for fewer hours or condensing boilers running at higher efficiencies.
- ***Isolation*** – Where multiple boilers are used for load scheduling it is important to ensure that any that are switched off are isolated by control valves. If water passes through unused boilers unnecessary heat losses will occur, reducing the efficiency of the system. It is important to ensure that those boilers which are running can deal with the flow rate, or that a bypass is provided.

MECHANICAL SERVICES

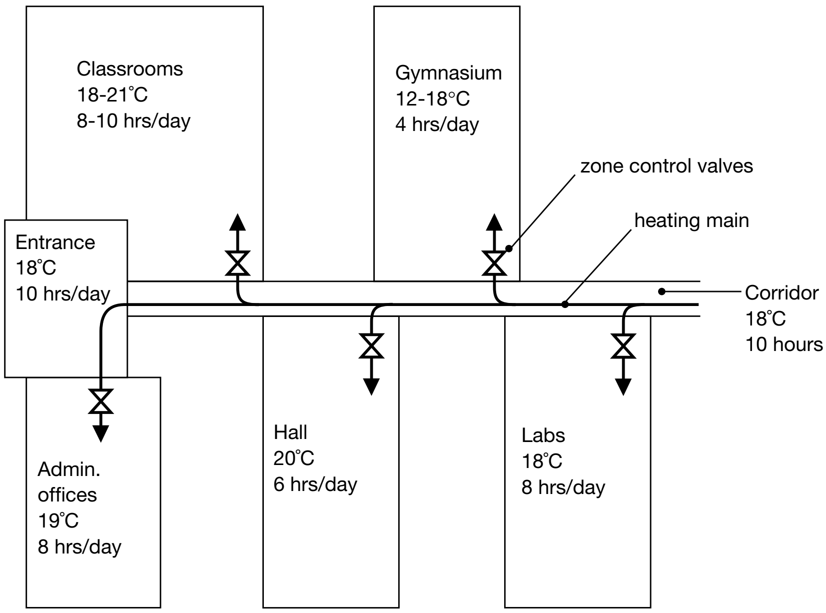


Figure 8 Example showing the use of zone controls to supply the specific heating needs of each department

HEATING DISTRIBUTION

M P Upgrading controls

Ensuring that the correct environmental conditions are provided is an important part of energy management. As well as providing adequate heating, the system must not cause underheating or overheating. Controls to improve energy efficiency can usually be installed at any time during the summer when the heating system is off. Where a building energy management system (BEMS) has been installed, it is beneficial to extend the functions of the system to include environmental monitoring and control. It is recommended that, as far as possible, controls are made tamper proof. Adjustments should be provided through the maintenance staff or caretaker, or via a computerised energy management system.

BUILDING ENERGY MANAGEMENT SYSTEMS (BEMS)

BEMS are designed to fully automate and link together the control of a building and its plant. The primary functions of a BEMS include:

- environmental control – temperature, humidity and lighting
- plant control and switching – zone control, optimum start/stop, weather compensation etc
- data collection – temperatures, fuel use etc
- monitoring and targeting – analysing performance.

While a BEMS can offer a wide range of facilities, the best performance will only be achieved if the staff understand its operation. Training should be provided for operating staff when a BEMS is installed.

Zoning

Where different parts of a building have different heating requirements, the building should be split into zones that can be controlled independently. If a building or department is to be refurbished, the addition of control valves and thermostats is worth considering.

- ***Time switches***
  Where buildings or departments are occupied intermittently, some form of time control should be provided. It should be set to provide a warm-up period so that the building is at the required temperature by the time occupants start to arrive.

- ***Optimum start/stop***
  The time taken to reach the required temperature will vary depending on the external conditions. Energy usage can be reduced if the warm-up period can be varied to suit the external temperature. This is called optimum start. In a similar way, optimum stop switches the heating off before the end of the occupied period. This relies on the thermal inertia of the building to maintain the required conditions until the building is unoccupied.

- ***Thermostatic radiator valves (TRVs)***
  Some systems may be suitable for installing TRVs. These can automatically adjust the output of each radiator to maintain the required temperature. However, at least one route through the distribution system must be left open in the event of all the valves closing down.

M Insulating pipework

Heating pipework is often unlagged within the heated building. Lagging any part of the distribution system that runs either outside the building or through unheated areas is a cost-effective measure which can be carried out as part of routine maintenance. Flanges, valves and so on should be lagged as well as the pipework. Special jackets are available for pipework fittings; the type chosen should be easily removed for pipe inspection. BS 5422 provides tables of economic insulation thicknesses for hot water pipes.

MECHANICAL SERVICES

As well as insulating unlagged pipework and fittings, it is important to ensure that any existing lagging is replaced when temporarily removed for inspection or maintenance.

M R Isolating redundant pipework

Any redundant pipework should be either isolated or removed. This work can be carried out during refurbishment or as part of an annual maintenance.

P Pumping

Where distribution flow rates vary with load, multi-stage or variable speed pumps should be considered.

Replacing large pumps with two or more smaller units with sequencing control can reduce pumping costs substantially, but is only worth considering where pumps require replacement.

If existing pumps are in good repair, it is worthwhile fitting variable speed drives.

M P Metering

Where different areas of a building or site represent different cost centres, such as kitchens or infant and junior schools both fed by the same boiler plant, sub-metering may be introduced to aid energy management. Linking such meters to a BEMS can automate data gathering.

It is difficult to quantify the cost benefits of metering. An individual analysis of each case is necessary to ensure that the cost of installing sub-metering can be recovered by the department for which it is intended.

DOMESTIC HOT WATER (DHW)

Where central boiler plant provides both heating and domestic hot water, summertime operation for DHW can be very inefficient. Boilers that are sized to deal with the winter heating load have low efficiencies when operating at low loads to provide DHW only. Also, at low outputs the distribution losses increase as a proportion of the total heat demand.

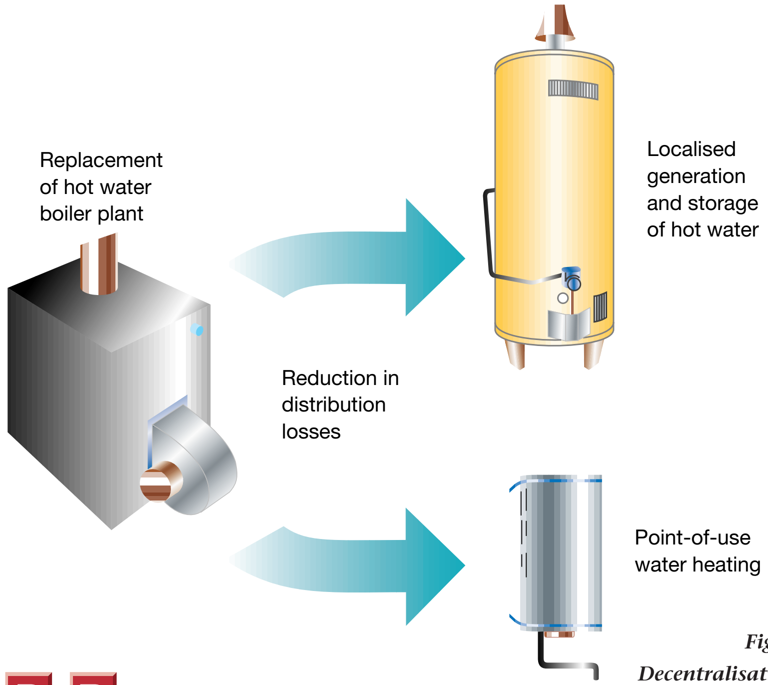


Figure 9 Decentralisation of hot water services

P R Decentralised boilers

To improve efficiency, the installation of dedicated local DHW boilers should be considered. These boilers will operate efficiently all year with minimal distribution pipework and associated losses. Where the requirement for hot water is small and isolated, it may be worth installing instantaneous point-of-use water heaters, avoiding heat loss from pipework and storage cylinders. Gas is the preferred fuel for both types of boiler on cost and environmental grounds.

P R Hot water storage

Heat will be lost from storage vessels even when they are insulated. The greater the volume, the higher the heat loss. Hot water storage, whether supplied from central or local boiler, should therefore be kept to the minimum acceptable for the demand. If DHW storage vessels require replacement, an investigation should be made into DHW demand as a check on the volume required.

M Insulation

Both distribution pipework and storage vessels should be insulated to current economic standards as part of routine maintenance.

LEGIONELLA

When considering energy saving measures for domestic hot water, it is essential that requirements for the control of Legionella (by maintaining sufficiently high temperatures) are not compromised. Full guidance on this is given in CIBSE Technical Memorandum 13[4].

MECHANICAL SERVICES

R REDUCING WATER CONSUMPTION

A simple way of reducing energy consumption is to reduce hot water consumption. Existing fittings can be replaced with more efficient devices such as:

- energy efficient shower units
- percussive self-closing taps
- spray taps.

It is only worthwhile installing these devices if existing fittings need to be replaced, or as part of a general refurbishment.

Reducing water consumption in the school leads to cost savings in its own right. The following ideas could be considered:

A Urinal cistern controls

Urinal cisterns are often set to flush at regular intervals, whether or not they are in use. To minimise waste, fit valves to pipework supplying the urinal cistern. Only when these detect a change in water pressure from hand-washing do they allow water to fill the supply cistern. Alternatively, fit micro-switches to washroom doors that allow flushing only after the washroom area has been entered a pre-set number of times. Both of these options have the minor disadvantage that if washrooms are used for hand washing only, the urinals still flush. Presence detectors allow urinal flushing after a pre-set number of people have been detected. Detectors can operate across a bank of urinals, or individual detectors can control the flushing if each urinal has its own cistern.

A WC cisterns

Water bye-laws now require all new WC cisterns to have a capacity of not more than 7.5 litres. Cisterns are available with a capacity as low as 6 litres. In existing cisterns, a plastic dam can retain some of the water lost during flushing.

MECHANICAL VENTILATION

Mechanical ventilation should not normally be required in schools. However, there may be some circumstances in which mechanical ventilation is required to supplement natural ventilation. Examples include areas where air-flow rates of more than 8 litres per second are required to maintain air temperatures such as kitchens, home economics rooms and laboratories, or toilets and changing rooms that cannot be ventilated to 6 air changes per hour (ach) naturally.

M P CONTROLLING VENTILATION RATES

Where departments are only occupied intermittently or for part of the day, ventilation can be switched off during unoccupied periods. Automatic occupancy sensors and run-on timers, with manual override, can be used to control ventilation rates in such cases. Linking such systems to a BEMS can ensure that departments are not left on at full flow after the manual override has been used.

Other opportunities include the use of variable speed drives for fans where a single air handling unit serves a number of areas and therefore has a variable load throughout the day.

R HEAT RECOVERY

Heat picked up from gains in mechanically ventilated spaces will be lost unless heat recovered from extract air can be used to heat the supply air.

There are a number of heat recovery devices available for ventilation plant. However, the choice of device will depend upon the distance between the extract and supply ductwork, and any risk of cross-contamination such as cooking smells or laboratory fumes. Most devices require the supply and extract ductwork to be close together. Where this is not the case, the choice of device is often limited to run-around coils or air-to-water/air-to-air heat pumps.

Before installing such a device, it is important to check that the cost of the heating energy saved is greater than the cost of the electrical energy required to drive the heat recovery unit.

ENVIRONMENTAL ISSUES

There are a number of methods of assessing the environmental impact of a new school building. While it may not be possible to rigorously follow all advice on environmental issues with refurbishment, environmentally friendly solutions should be adopted whenever possible.

The DfEE's publication 'Schools' Environmental Assessment Method'[5] covers the environmental issues that relate to school design. The aims of this document are:

- to raise awareness of the dominant role that buildings play in global warming through the greenhouse effect, and their role in the production of acid rain and depletion of the ozone layer
- to provide an improved environment for users, including better indoor air quality; and to ensure that products used in the construction are of an environmentally friendly nature, and do not lead to the depletion of non-renewable resources, destruction of the tropical rain forest, or waste resources
- to encourage better use of school grounds and resources for ecology teaching, recreation and recycling.

Wherever possible strategies to minimise the energy intensity of a school building should be adopted. However, the choice of materials must be evaluated against their life expectancy and function.

CONCLUSION

CONCLUSION

LMS has placed energy cost management under the control of school governing bodies. This has provided an incentive for reducing energy consumption and hence costs. By reducing spending on energy, funds can be released to provide other services.

Refurbishment offers an excellent opportunity to incorporate a variety of energy saving measures at little or no extra cost, while the consequent reduction in fuel consumption has a beneficial effect on revenue expenditure.

Whenever refurbishment is being considered, whether a total 'makeover' or something more modest, such as renewing a boiler or fitting replacement windows, the opportunity should be taken to adopt the most energy efficient systems available. For example, if windows are being replaced, the additional cost of specifying double rather than single glazing is marginal, and the pay-back period for the extra cost can be very short. Other improvements, such as switching to more energy efficient lighting, may be undertaken at any time, and do not have to wait for refurbishment works to commence.

The case for energy efficiency is now widely accepted, and the benefits – financial, social and ecological – are well documented. Improving the efficiency of energy consumption in schools can make a major contribution to balancing budgets.

REFERENCES AND FURTHER READING

REFERENCES

[1] Energy efficient design of new buildings and extensions – for schools and colleges, Good Practice Guide 173, DETR, 1997

[2] Guidelines for environmental design and fuel conservation in education buildings, Design Note 17, DfEE, 1997

[3] The Boiler (Efficiency) Regulations 1993, HMSO, 1993

[4] Minimising the risk of legionnaires disease, Technical Memorandum TM13, Chartered Institution of Building Services Engineers, 1991

[5] Schools' Environmental Assessment Method (SEAM), Building Bulletin 83, DfEE, 1996

DETR ENERGY EFFICIENCY BEST PRACTICE PUBLICATIONS

These publications, and others from the Department of Environment, Transport and the Regions' Energy Efficiency Best Practice programme, are available from BRECSU Enquiries Bureau (contact details are on the back cover).

Good Practice Guide

56 Saving energy in school swimming pools. A guide to refurbishment and new pool design for headteachers, governors and local authorities
159 Converting to compact fluorescent lighting – a refurbishment guide
176 Small-scale combined heat and power for buildings

Good Practice Case Studies

38 Energy efficiency in schools: condensing gas boilers
73 Energy efficiency in schools: potential benefits of boiler replacement
94 Energy efficiency in schools. Building Energy Management Systems
95 Energy efficiency in schools. Local controls for heating and lighting
185 'Out-of-hours' use of schools

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1 Building energy efficiency in schools

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Lighting controls and daylight use

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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting etc.