Energy Saving Measures

for

Municipal and other Office Buildings

Mary E. Ince

SLC Energy Group

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A Research Report

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Mary Ince
July 1980.

1 Introduction & Summary

This research report aims to explore the possibilities for energy saving in municipal office buildings. It is based on a study carried out for one London borough in mid-1980. One specific building complex, comprising two adjoining buildings was taken as an example. These buildings were intended to receive some refurbishment works and this was therefore seen as an appropriate time to investigate energy saving possibilities. However, costs given here do not assume any saving for associated work already being carried out. (For instance, although the heating system was to be drained down for maintenance work, the costs given for fitting thermostatic radiator valves do include the cost of draining down the system).

The two buildings considered will be referred to as buildings A and B. The fuel use figures apply to both buildings together as they share the same boiler plant but the detailed heat loss calculations apply to building A only and were extrapolated where required to give estimated figures for the two buildings together.

The report indicates the scale of potential savings along with the capital costs and simple payback periods for each measure considered. Three example 'packages' of measures are given on the next two pages. It should be remembered however that these apply directly to one particular building complex and although giving a good indication of the possibilities the costs and savings would vary with the individual characteristics of other buildings. It would therefore be well worthwhile to compile similar tables for each building for which energy saving measures are being considered. To assist with this an indication of the likely order of priority for the various measures follows the packages.

Whatever measures it is intended to implement, serious consideration should be given to employing specialist contractors for the work, for two reasons: firstly, their prices are likely to be more competitive because their speciality is their only business and secondly, they have the relevant experience and expertise and frequently give long term guarantees. It is probable that, as many energy conservation measures are of a similar nature, one specialist contractor would be able to carry out a number of different measures - for instance, draught stripping of doors and windows plus roof insulation for both flat and pitched roofs.

Package 1

Capital Cost	**£22,617**
Simple Payback Period	**2.1 years**
Yearly saving	**£10,757**
% Energy saving	**50%**
Net saving over 10 years	**£84,953**

Measures		capital cost	simple payback period	net saving over ten years
6.1.1	ventilation control	£5,210	2.4 yrs	£16,440
6.2(i)	curtains with reflective lining	£3,785	4.1 yrs	£5,405
6.3(a)(ii)	'plus-roof' for flat roofs	£4,654	2.8 yrs	£12,046
6.3(b)(ii)	160mm insul. quilt - pitched roof	£3,400	1.8 yrs	£15,270
6.6	change remaining tungsten lamps to fluorescent	£600	1.6 yrs	£3,070
6.7(a)(i)	programmers for d.h.w. boilers	£50	0.9 yrs	£480
6.7(a)(ii) 6.7(b)(ii)	reduction in temperature	nil	nil	£1,320
6.7(a)(iii)	insulation of pipework	£280	3.5 yrs	£510
6.7(b)(i)	time clocks	£150	2.8 yrs	£380
6.9(a)(i)	optimum start controllers	£1,750	2.7 yrs	£4,850
6.9(a)(ii)	anti condensation stat	£100	0.8 yrs	£1,220
6.9(a)(iii)	reduce temperature 19°C to 18°C	nil	nil	£6,600
6.9(b)(ii)	motorised valves for zoning	£2,638	1.3 yrs	£17,362
	TOTALS	£22,617	2.1 yrs	£84,953

Since the capital cost of £22,617 is spread over the payback period of 2.1 years almost half the capital cost is recouped in the first year. Consequently the *net* capital investment is only £11,860.

All figures quoted relate to July 1980 prices.

Package 2

Capital Cost	£2,938 recoverable within the financial year
Simple payback period	0.9 years
Yearly saving	£3,323
% Energy saving	14,5%
Net saving over 10 years	£30,292

Measures		capital cost	simple payback period	net saving over ten years
.1(d)	draught strip skylights	£150	0.50 yrs	£3,310
6.7(a)(i)	programmer	£50	0.90 yrs	£480
6.7(a)lii)	reduction in h.w. temperature	nil	nil	£1,320
6.9(a)(ii)	anti - condensation stat	£100	0.78 yrs	£1,220
6.9(a)(iii)	reduce heating temperature	nil	nil	£6,600
6.9(b)(ii)	motorized valves for zoning	£2,638	1.32 yrs	£17,362
	TOTALS	£2,938	0.90 yrs	£30,292

Package 3

Capital Cost	Nil
Simple Payback Period	Nil
Yearly saving	£792
% Energy saving	3.5%
Net saving over 10 years	£7,920

Measures		capital cost	simple payback period	net saving over ten years
6.7(a)(i)	reduction in hot water temperature	nil	nil	£1,320
6.9(a)(i)	reduction in heating temperature	nil	nil	£6,600
	TOTALS	nil	nil	£7,920

MEASURES IN ORDER OF PRIORITY FOR COST EFFECTIVENESS

This table lists the measures in order of cost effectiveness so that this can be balanced against the practicalities of implementing the measures. All figures quoted relate to July 1980 prices.

	Measures	capital cost	simple payback period	net saving over ten years
1	reduce set temperature for hot water from 65°C to 45°C	nil	nil	£1,320
2	reduce set temperature for space heating from 19°C to 18°C	nil	nil	£6,600
3	Draught strip skylights, trapdoors, letterbox lids and keyholes	£193	0.5 yrs	£3,667
4	Change 'frost-stat' to 'anti-condensation stat	£100	0.8 yrs	£1,220
5	Install programmers for the hot water boilers	£50	0.9 yrs	£480
6	Install motorised valves for zoning of space heating	£2,638	1.3 yrs	£17,362
7	Draught strip internal doors to ventilated areas	£260	1.5 yrs	£1,470
8	Replace remaining tungsten lights by fluorescent	£600	1.6 yrs	£3,070
9	Draught strip external doors	£400	1.8 yrs	£1,770
10	insulate lofts with 160mm quilt	£3,400	1.8 yrs	£15,270
11	Install optimum start controllers to all space heating plants	£1,750	2.7 yrs	£4,850
12	Insulate flat roof with 'Plus roof'	£4,654	2.8 yrs	£12,046
13	Install timeclocks to electric water heaters	£150	2.8 yrs	£380
14	Draught strip all windows	£2,880	3.0 yrs	£6,650
15	Install draught lobbies	£1,500	3.5 yrs	£2,830
16	Insulate all hot water distribution pipework	£280	3.5 yrs	£510
17	Provide curtains with reflective ('Milium') lining	£3,785	4.1 yrs	£5,405

RATIONALE

Current work [1, 2] by the SLC Energy Group on both new and existing housing indicates that is is possible to achieve significant energy savings at little or no additional cost. The scale of costs of energy saving measures in houses is naturally related to the amount and type of work already being carried out. It is feasible to expect that similar possibilities exist in the case of public buildings such as offices, schools and libraries although it is probable that the patterns of usage/occupancy of these buildings will play a significant role in determining the type of measures which will be most beneficial. It is worth remembering that, although reduction in energy costs is of great and increasing value to those who have to pay the energy bills, the additional reason for reducing energy consumption is to conserve the supplies of fuels.

The known reserves of fossil fuels are rapidly becoming exhausted [17] and it is necessary to ensure they last as long as possible so that time is gained for the discovery of new methods for producing fuels, the development of more efficient ways of utilising the renewable forms of energy such as solar, wind, wave, tide, geothermal power and even perhaps, discovery of new reserves of fossil fuels. It is appropriate that Central and Local Government should give a lead, by example as well as exhortation, by doing all in their power to conserve energy within their own sphere. Together they own a large proportion of the building stock of the UK [10]. Figure 1 shows that Central and Local Government buildings (domestic buildings excepted) account for some 2% of the total energy use of the UK.

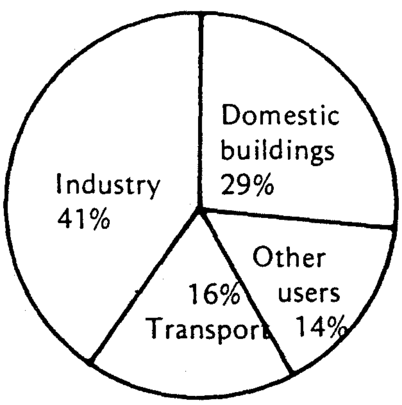


Figure 1a Gross Energy Use - Final users

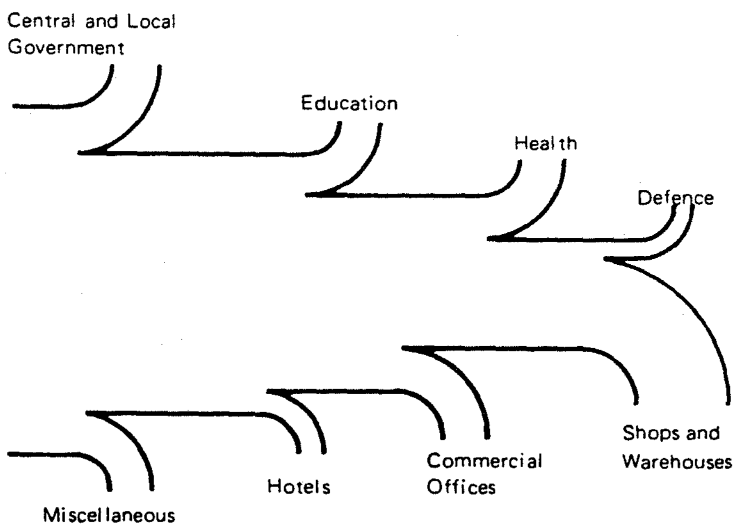


Figure 1b 'Other users' category split to show relative use

Although this may seem small in comparison to the 41% for Industry, nevertheless, the amount is significant (equivalent to 49,000 million kilowatt hours (electricity) or 1,700 million therms (gas) and the fact that large numbers of separate buildings are within the ownership of a single authority can simplify the organisation of energy saving measures.

Two reports [3,4] by LAMSAC* indicate that a number of local authorities have achieved worthwhile energy savings in the public buildings within their jurisdiction. In the majority of cases the expenditure on energy saving measures in any one year has been covered by the savings in energy costs for the same period. As the majority of the exercises involved have been carried out only over the last one or two years it would be premature to place complete faith in the absolute accuracy (in the long term) of the quoted figures but there are clear indications not only that considerable quantities of energy are being saved, but that many of the measures have actually paid for themselves several times over.

In a number of authorities, for instance, the Wirral MBC [4] and Nottinghamshire C.C. [28] a percentage of the proven savings are returned to the department (in these cases, the school) concerned to be spent as the department desires on improving working conditions. This can act as a valuable incentive to all occupants of the building to maintain those energy savings which can be achieved by 'good housekeeping' those measures which are in the hands of the building user such as switching off machinery and shutting windows and doors - which can save (typically) up to 10-15% of energy costs.

However, it has been found that, when ('Save It' and similar) campaigns have been launched they tend to lose their impact after a while. There are a number of related reasons why this occurs but two major ways of counteracting this are:

- to provide regular feedback of information on the savings being achieved.

- primary energy saving measures related to the building fabric and services are implemented where necessary.

Thus, the application of energy saving techniques to the building fabric, heating system, lighting and so on, can have a bonus effect. They not only save energy directly but also indirectly by increasing the awareness and enthusiasm of the building users for energy saving.

*Local Authorities Management Services & Computer Committee.

3 Potential for Energy Saving

POTENTIAL FOR ENERGY SAVING IN THE EXAMPLE BUILDINGS

It has been possible to identify the total fuel costs for the two buildings for the past three years and in detail for 1979/80. For this purpose the two buildings are treated as one unit as the boiler plant supplies the space heating to both. The costs are shown in Table 1.

Table 1 Fuel Costs

Table 1a Annual fuel costs 1977 - 1980

Year	Oil	Gas	Electricity	Total
1977/78	£9,450	£325	£8,729	£18,504
1978/79	£11,042	£414	£8,694	£20,150
1979/80		£13,174	£10,706	£23,880

Table 1b Fuel costs - for 1979/80 - detail

GAS	Cost	Therms	Kilowatt hour equivalent
1st quarter 2nd quarter	£6,194	34,315	1,004,165
3rd quarter 4th quarter	£6,980	29,164	853,339
Totals	£13,174	63,479	1,857,504

ELECTRICITY	Cost	Kilowatt hours
1st quarter	£2,582	70,407
2nd quarter	£2,447	70,132
3rd quarter	£2,555	70,580
4th quarter	£3,122	70,509
Totals	£10,706	281,628

Figure 2 shows the ratio of gas to electricity in terms of cost and of delivered energy and also indicates the various services supplied by each type of fuel.

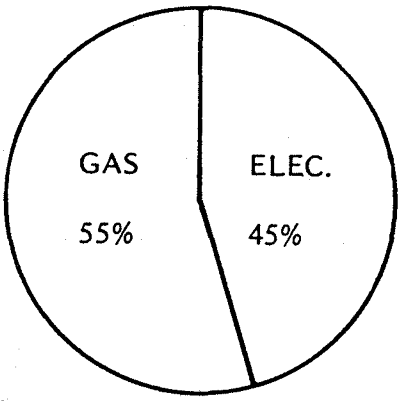


Figure 2a
Ratio - Gas : Electricity - Costs

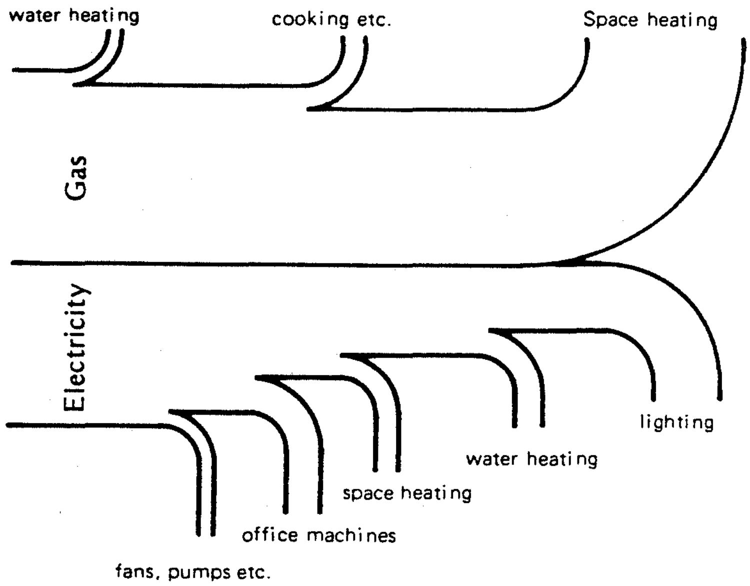


Figure 2b Gas and Electricity costs - by end use

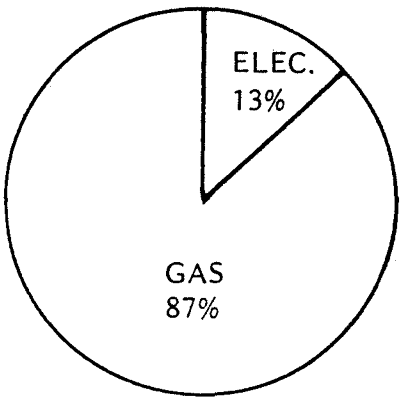


Figure 2c
Ratio - Gas : Electricity - Delivered Energy

With the current rate of fuel price increases, the total 1980/81 fuel cost for these two buildings could be in the region of £30,330. Table 2 shows the savings that would accrue from various percentage energy savings, for 1980/81 and for the five year period 1980/85. (The rate of fuel cost increase has been taken as 10% p.a. although it is likely to be considerably higher)

* or higher, as the costs for several buildings have not yet been identified.

Table 2 Fuel cost savings for a range of percentage energy savings

energy saving %	fuel cost saving 1980/81	1980 - 85
5%	£1,517	£9,258
20%	£6,066	£37,032
40%	£12,132	£74,064

POTENTIAL RANGE OF ENERGY SAVING MEASURES.

There are a number of different measures which can be taken to achieve a reduction in energy consumption. The combination of measures which it will be appropriate to apply to a specific building will vary considerably according to the individual characteristics of the building. (An indication of the merits and demerits of the various measures as they relate to the two buildings studied can be found in Sections 5 and 6).

The main areas where measures could be taken to reduce the use of energy include:

- ventilation and draughts

- heat loss through the building fabric - roof, floor, walls, windows and doors.

- heating system - plant, pipework, radiators

- water heating

- lighting and miscellaneous power usage

- recovery of waste heat

Additionally, 'Good Housekeeping' practices, publicity, tariff checks and metering of energy consumption can be considered (see Section 7) and these may be implemented at any convenient time, not necessarily at the same time as physical improvements although in order to gain maximum benefit it is probably useful to relate them to the physical measures if possible.

THERMAL COMFORT.

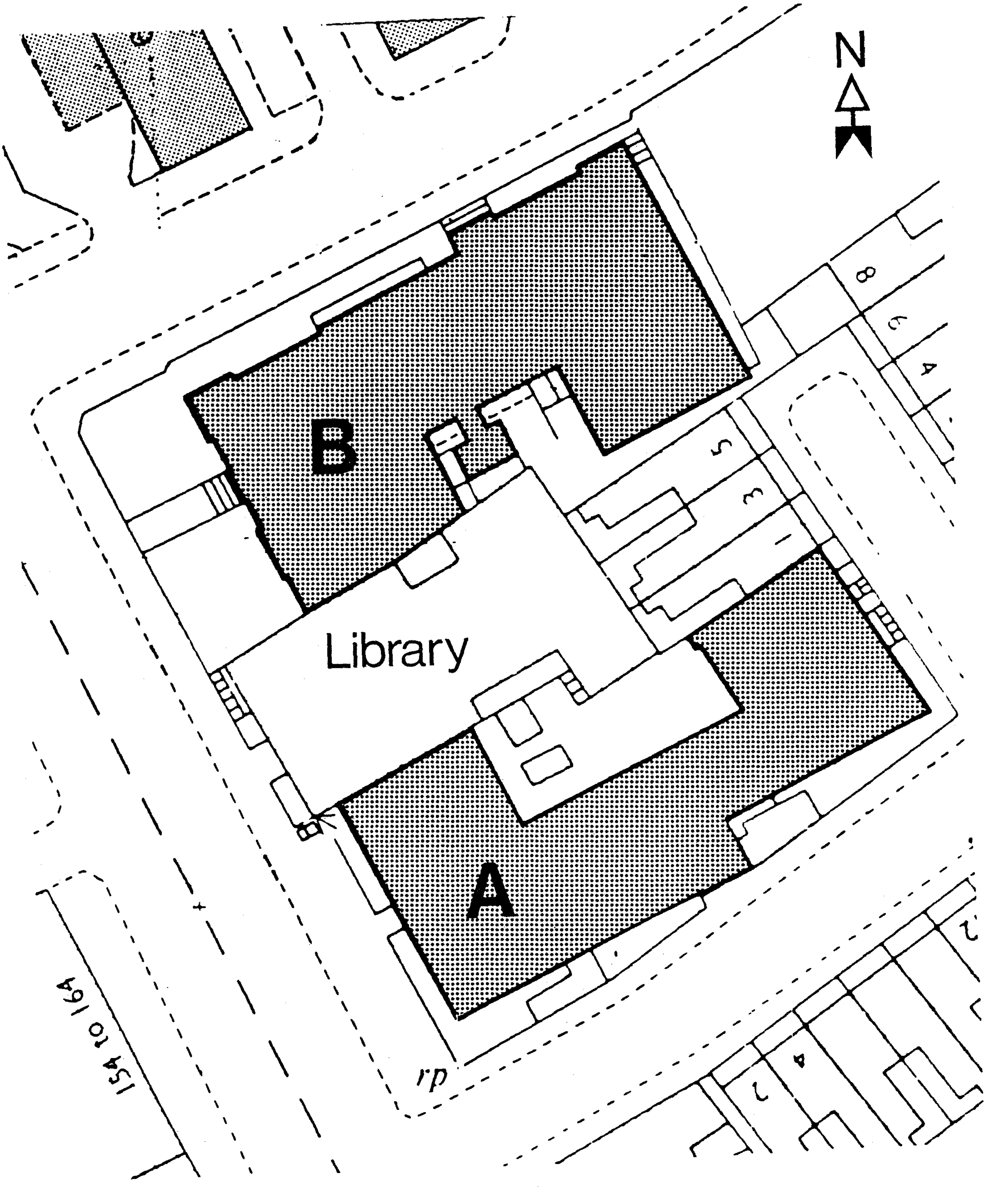
Although Queen Victoria would probably not agree, it is generally believed nowadays that people will work better and more efficiently if their working environment is physically (and psychologically) 'comfortable'. This usage of the word 'comfort' implies a steady state of the body in that it is not subjected to extremes of heat, cold, humidity, air movement or direct (cold or hot) radiation. It is not intended to imply the state of having 'forty winks' in an armchair in front of the fire or television!

Although most energy saving measures will increase thermal comfort levels, and indeed, this is a bonus in that efficiency should increase likewise, it is vital to ensure that no measures will have an adverse effect on the comfort of the building users, for instance, the ventilation rate must not be reduced to such an extent that the atmosphere created causes feelings of stuffiness.

Naturally, there are individual variations in the perception of comfort levels, and indeed, these may be quite wide. It is possible however to achieve conditions where only a small percentage of people are likely to be 'dissatisfied'(21). providing that the assumptions made about the level of activity and type of clothing worn in a particular space are correct. This does however mean that if the comfort conditions for an area are designed to suit, for instance, a particular type of activity and then the use of that area is changed considerably it is probable that a very much larger percentage of people will then be dissatisfied.

HEALTH & SAFETY

It is also necessary to ensure that the measures taken do not interfere with the statutory requirements regarding 'Health and Safety'. For although it would certainly save energy to reduce the temperature of the building by several degrees, it must be kept above the statutory minimum of 16°C (62°F). Likewise, despite the fact that the greatest heat loss is through ventilation, sufficient air changes must be maintained to comply with Health requirements. A great many of these aspects will also be covered by comfort requirements.



N
B
Library
A
154 to 164
rp

4 THE BUILDINGS

These two buildings were constructed at different times. Building B around 1870 and Building A around 1930. The style and construction are consequently also different. Building B is brick, based on a structure of cast iron pillars and beams, with timber windows and a pitched slate roof. Building A is of load bearing brick with concrete floors (with timber parquet finish), steel windows and a flat roof. There are a number of skylights, mainly in Building B - most of which are single glazed. As can be seen from the plan opposite, Building B is on the North side and Building A on the South side of a light well, the West side of which is formed by a Library building, The well is partially filled by a double storey building. The East side of the well is bounded by a short row of terraced houses.

SPACE HEATING AND HOT WATER SUPPLY

The two buildings share the same heating system, for which the boiler plant is located in the basement of Building A. (At one time the Library buildings were also heated by the same system but now have their own separate boiler plant.) The previous oil - fired boilers were replaced, approximately eighteen months ago, by ten gas - fired boilers, feeding the radiators throughout the two buildings. The radiators are a mixture of various ages and styles, the latest ones having been fitted with thermostatic radiator valves and some have also had foil fixed to the wall behind them - two energy saving measures already being implemented.

As far as can be ascertained, automatic controls for heating system basically comprise, a programmer to turn the heating on and off a pre - determined times, a thermostat in the boiler room and a 'frost stat' outside (this turns the heating on whenever the outside temperature drops to a level where there could be a danger of condensation in the building or damage to the heating system itself). In addition it is possible for the engineer on duty to control zones of the building through the use of manual valves located at various points throughout the system. As far as could be seen none of the distribution pipework is insulated (exceptions are in the boiler room itself and in the print room) and a large proportion of it runs against the external walls.

Heating of water for washing facilities is by individual, mainly electric, water heaters in Building A while Building B has its own gas - fired boiler for this purpose. Again, distribution pipework does not appear to be insulated.

From the information currently available, it is clear that consideration has already been given to the incorporation of certain energy saving measures during the refurbishment works, as described below. However, as the details of each area of work are to be finalised in stages as the work progresses, it should be practicable to incorporate further measures where cost comparisons show that this is viable, as each area is detailed. This is an advantage as it means that each item can be designed and cost and energy saving comparisons made at intervals throughout the next seven or eight months so allowing the energy saving measures to be fully integrated.

As it is not clear, at this stage, precisely to what extent energy saving measures are currently intended to be included the following sections (5 and 6) aim to provide, first of all, a consideration of the whole spectrum of energy saving measures which could be applied to this type of building and then to suggest which of these may be specifically suited to these two buildings. Section 6 will attempt to provide an indication of priorities in value for money terms.

Energy Saving Measures

The heat loss from a building is attributable to the various elements in different proportions for each individual building but generally the order of magnitude remains the same, with the *heat lost through ventilation being by far the greatest proportion - often equal to, or exceeding, the total of all the other losses.*[18] Each element is discussed below, in order of rate of heat loss, as calculated for Building A. Detailed calculations are given in the Appendix.

Table 3a Seasonal* heat loss, by element - Building A

Element	seasonal heat loss (GJ)
Windows	376.58
Flat roof	333.53
External walls	238.14
External doors	41.54
Basement floor	35.09
Total Fabric Heat loss	**1,024.88**

Ventilation Heat losses:	
1 airchange per hour	461.72
1½ airchanges per hour	692.77
2 airchanges per hour	923.44
2¼ airchanges per hour	1,038.86
3 air changes per hour	1,385.15

Table 3b Seasonal heat loss per square metre, per element - Building A

element	total area (m^2)	seasonal heat loss (GJ/m^2)
Windows	504.66	0.75
External doors	68.45	0.61
Flat roof	716.19	0.47
External walls	1,434.55	0.17
Basement floor	716.19	0.05

*heating season =33 weeks

* 1GJ (gigajoule) = 278 kilowatt hours

5.1 VENTILATION

Table 3 indicates the scale of seasonal heat loss from the various elements for the Building A*. Assuming a ventilation rate of 2 airchanges per hour, it can be seen that the seasonal heat loss due to ventilation (923GJ) is nearly half (47%) of the total heat loss for the building (1,948GJ).

If the *actual* airchange rate is *three* per hour, as seems probable considering the age of the building, gaps around windows and doors and the number of doors kept permanently open, then the heat loss due to ventilation would be 1,385GJ. (A comparison of the calculated figures with the actual figures for fuel used supports this view.)

If the ventilation rate could be reduced by just 25% (to 2¼ airchanges per hour) the overall saving in heat loss would be 14.4%. The consequent minimum financial saving would therefore be in the order of £2,165 p.a. for the two buildings.

An additional benefit, not directly quantifiable, of a reduction in the rate of airchange, is an improvement in thermal comfort. A high rate of air change in a building is perceived by the occupants as draughts and translated into a requirement for increased heat. Therefore, if the draughts can be reduced, then comfort levels can be achieved at lower temperatures, which in turn saves energy. A 1°C reduction in temperature will give savings of between 5% and 10%.(16)

It follows therefore, that a 25% reduction in airchange rate, by also reducing draughts, can result in a total saving of between 19% and 24%.

There are a number of ways of reducing the ventilation rate:

a. Draught proofing of windows

The majority of windows admit a considerable amount of air through the small spaces which remain around the opening lights even when they are shut.(22) Although these spaces seem very small, for a typical window in this building a gap of only 1mm around the opening portion adds up to 5,200mm^2 - equivalent to a 72mm by 72mm (3 ins by 3 ins) hole in the wall! The timber windows in the other building probably present a much worse case, due to warping of the timber, broken sash cords and so on, although the timber frame itself is a far better insulator than the steel frame. It is comparatively simple operation to apply draught stripping to the windows and the resultant energy savings will justify the moderate cost.

For metal windows, such as the steel windows in Building A, a silicone sealant type of draught stripping is likely to be most effective. The sealant retains its elasticity and is resistant to attack by water,

* See Appendix 2 for detailed calculations.

chemicals and ultra-violet light. Some manufacturers will install the sealant, guarantee the workmanship for a year or longer and the material for twenty or thirty years. The sealant can be obtained in a (limited) variety of colours.

For timber windows and particularly vertical sash windows such as those in the Building B, brush type draught strips are probably the most suitable. These generally have a guaranteed life of twenty years and should preferably be fixed by specialists. The curved heads of many of the windows may need to be treated separately - possibly with the silicone sealant mentioned earlier.

It is probable that there are a large number of offices in both buildings where:

(i) the openable window area exceeds the statutory minimum

AND (ii) all or some of the windows are never opened.

Where these criteria are met it would be beneficial to seal completely those portions of openable window which are redundant. This can be done by filling the gaps with a mastic sealant and painting over. Any operating gear, handles, stays etc., should be removed from those windows which are sealed in this way.

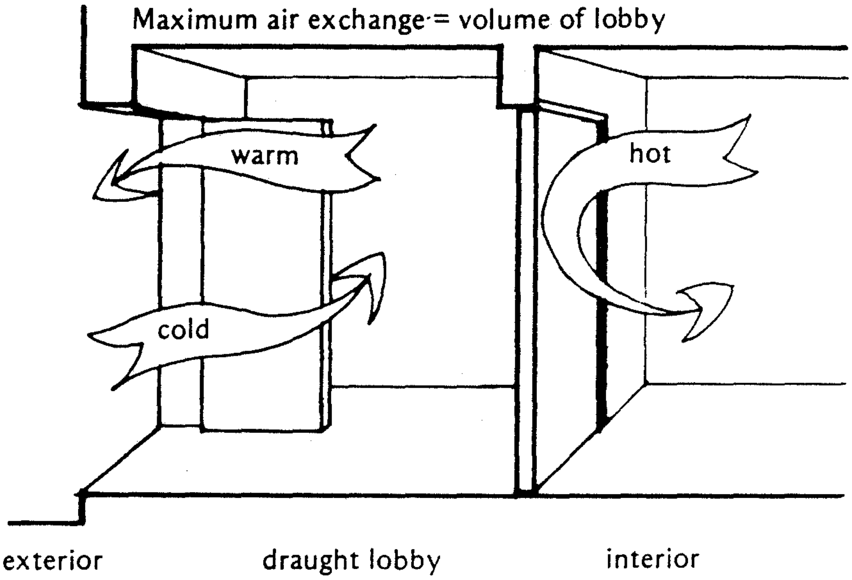
b. Draught proofing of doors

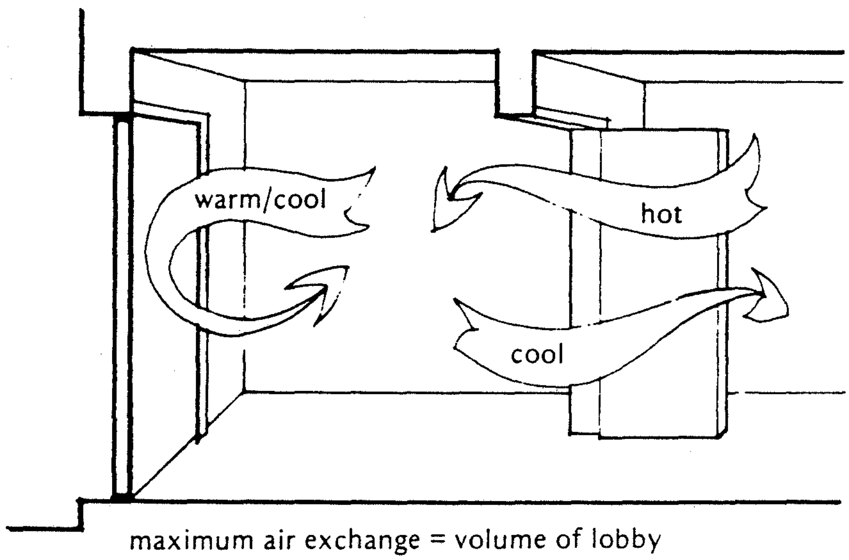
In both the buildings under consideration by far the greatest heat loss through ventilation is due to the external doors and this is an area which will amply repay attention. Whenever an external door is opened there is the tendency for the heated air from the area adjacent to the door to be exchanged with the colder external air. However large the adjacent internal space may be, if the door is opened often enough or for long enough, *all* the heated air will be replaced by cold air. The rate of exchange will vary according to the difference in temperature, wind direction and wind speed.

An effective way of overcoming this problem is the provision of 'draught lobbies' so that, when the outside door is opened only a small amount of air can be exchanged as the remainder is contained by the inner door. (see Figure 3 - next page) It is, of course, vital that both sets of doors are draughtproofed.

In many cases a draught lobby can be created simply by installing an additional door, or pair of doors, part way up a corridor. Care must be taken to ensure adequate space within the lobby to manoeuvre prams, wheelchairs and so on and to allow for closing one door (or pair of doors) before opening the other. Subject to this however, the lobby should be the minimum size possible.

Figure 3
Draught Lobby





Where space is at a premium, as at the main entrance to Building A, and alternative provision for prams and wheelchairs can be made, the revolving type of door may be found to be the solution as the nature of these doors ensures that they are, effectively, shut at all times and only one quadrant of air will be exchanged each time the door is used. In addition, they are usually well draught stripped although this should be checked and extra provision made if necessary. However, they do tend to be very costly so that it may be difficult to justify their installation.

The doors themselves can be draughtproofed in a similar way to the windows - with the brush type strip probably being the most effective at a reasonable cost. The bottom of the door, where it meets the threshold, requires careful treatment to ensure a satisfactory seal while not impeding the action of the door.

Openings within the door itself should also be draughtproofed. This includes letterboxes, keyholes and holes formed for such things as door knockers, bell wires and so on. These can be easily filled with a mastic sealant.

It is also advisable to check for gaps between door (and window) frames and the wall, as over a period of years quite wide gaps can develop here. Again these are easily filled with a mastic sealant.

c. Draught proofing of Skylights

There are a number of skylights in the buildings - mainly at the tops of stairwells. As the skylights are therefore at the highest points it is to them that all the heated air in the buildings will tend to flow. If, as is generally the case, the skylights incorporate openable sections, which are not fully shut, nor draughtproofed and where there is no secondary glazing or other means of reducing the heat loss, it is probable that all the heat stored in the building during the day would be lost, through these alone, during the night. Therefore it would be desirable to seal the openable areas and provide secondary glazing below the skylights, although it will be necessary to allow for some ventilation to the airspace between the two sets of glazing to reduce the risk of condensation. Consideration may also be given to the installation of horizontal blinds to be used at night to reduce the heat loss further.

There is one specific situation where the problem is most severe - the secondary staircase in the Building B where the heat from the canteen kitchen can actually be felt rising up the stairs! In this situation it is obviously desirable that some ventilation be maintained but it would be most effective if located at the source - i.e. in the kitchen, where a direct extract could remove vapour, odours and excess heat at once. There could also be possibilities for reclaiming the excess heat thus extracted, which could then be used, for instance, for keeping food warm or for heating the washing up water.

d. Draught proofing of some internal doors

There are a number of areas within the building which require rather more ventilation than the rest - mainly the toilet facilities, kitchen

Table 4 Effects of various window treatments on energy use:

a typical steel window - (Building A) (area 2.98m^2)

		single glazing	single glazing, curtained at night	single glazing + solar control film	single glazing + insulating solar control film	single glazing + secondary glazing	single glazing + vertical insulating venetian blinds
		a	b	c	d	e	f
(i)	seasonal heat loss (GJ)	2.942	1.786	2.784	2.049	1.460	0.947
	seasonal heat gain (GJ)						
(ii)	North	0.71	0.71	0.291	0.185	0.638	0.71
(iii)	East and West	1.19	1.19	0.485	0.309	1.063	1.19
(iv)	South	1.99	1.99	0.813	0.517	1.781	1.99
	net heat balance for heating season (GJ)						
(v)	North (i - ii)	-2.232	-1.076	-2.493	-1.864	-0.822	-0.237
(vi)	East and West (i - iii)	-1.751	-0.596	-2.299	-1.740	-0.397	+0.143
(vii)	South (i - iv)	-0.952	+0.204	-1.971	-1.532	+0.321	+0.943
	% reduction in seasonal heat loss						
(viii)	North		52%	-12%*	16%	63%	89%
(ix)	East and West		66%	-31%*	0.6%	77%	92%
(x)	South		121%	-307%*	-61%*	134%	199%

* minus figures indicate *increase* in heat loss

The ratio of the windows on the four sides of the building is approximately 2:2:2.66 (N:S:(E+W). Therefore the relative total net heat balance for each measure is:-

Orientation	a	b	c	d	e	f
North	-4.464	-2.152	-4.986	-3.728	-1.644	-0.474
East + West	-4.658	-1.585	-6.115	-4.628	-1.056	+0.380
South	-1.904	+0.408	-3.942	-3.064	+0.642	+1.886
Total	-11.026	-3.329	-15.043	-11.420	-2.058	+1.792*
∴ seasonal heat loss { % reduction / % increase		70%	36%	3.6%	81%	116%*

* i.e. a net heat *gain* from the windows

and print room. Where this is the case, heat loss from the rest of the building to these areas will be reduced if the connecting doors are draughtstripped in the same way as the external doors.

5.2 HEAT LOSS THROUGH WINDOWS

The next greatest area of heat loss in this building is through the windows. This is due to three factors; the high window to wall ratio (of 4:11), the steel frames and, most importantly, the fact that the windows are unprotected at night.

There is little that can be done about the first factor, short of 'bricking in' some of the windows, the steel frames *could* be insulated but this would be a very labour intensive activity and therefore expensive, but it would be feasible and most worthwhile, to take steps to reduce the night heat loss. It is possible that the same measures could also serve to reduce excess solar gain through the windows in Summer. These two aspects, particularly for South facing windows, are inextricably linked and a balance has to be reached between the need to cut out solar gain in Summer and the need to conserve heat and, indeed, benefit from solar gain, during the heating season.

There are a number of measures which can be used for solar control and a number for insulation of windows. Unfortunately, those which work best for the one purpose are generally much less useful for the other. [16] For instance, the most effective method of solar control is external shading[24] - either by projections of the building itself or by angled blinds or louvres, but these have little effect on the heat loss from the windows. Insulated shutters, preferably external, are the most efficaceous for insulation, but are of little use for solar control where the aim is to control solar heat gain whilst maintaining daylighting and an unobstructed view.

The most obvious form of solar control is to use special tinted glass or the solar control films which can be applied to existing glazing. Consideration might also be given to using the latest form of these films which, it is claimed, also reduce the heat loss through the windows. However, the figures given (by the manufacturers) show that the heat gain is reduced by considerably more than the heat loss. Table 4 (opposite) shows consequentially that the application of solar control film (case [c]) will *increase* the net seasonal heat requirement and that the application of 'insulating' film (case [d]) will also *increase* the net seasonal heat requirement for South facing rooms by 61%, although the net requirement for East and West facing rooms would be *slightly* reduced (by 0.6%) and for the North orientation would be reduced by 13.6%. Overall, therefore, there would be a need for more heat to be supplied to the building than b before. It is also interesting to note that it is unlikely that the use of such films would be permitted on Listed buildings which applies to a large number of Municipal Offices.

Solar control films also reduce the daylight entering the the building by some 75% and tend to give an overall colour cast (usually grey or brown) to the interior. Either of these factors is liable to result in a significant increase in the use of artificial lighting.

On the other hand, the provision of curtains which are drawn at night during the heating season would result in a considerable reduction in the net seasonal heat requirement for *all* orientations. (Table 4, case [b]) This method would in fact result in a net heat *gain* on the South side. The heat requirement for the North orientation would be reduced by 52% and for the East and West by 66%. Figure 4 illustrates this [10]

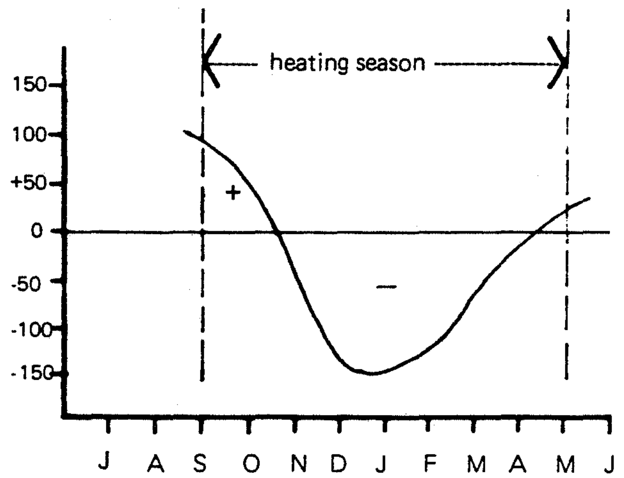


Figure 4a Net heat balance for $1m^2$
South-facing glazing
Not curtained at night

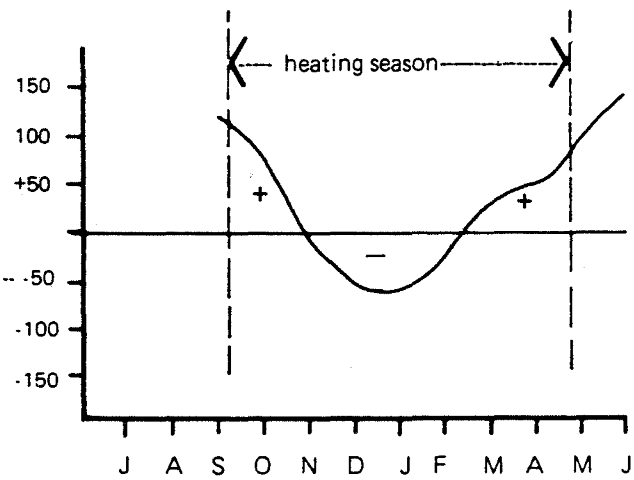


Figure 4b Net heat balance for $1m^2$
South-facing glazing
Curtained at night

Consideration needs to be given to whether curtains can also be used to give adequate protection from solar gain during Summer whilst not reducing daylighting levels or restricting the view to an unacceptable extent. It is probable that, because curtains are familiar in the domestic situation and because their use could be controlled by the building occupants, they would be felt to be adequate for this purpose.

Alternatively, it is possible that the use of horizontal or vertical venetian blinds, particularly those with insulated and/or reflective louvres, might be more appropriate [24] although they are somewhat more expensive.

It must be remembered, however, that any form of internal screening, whilst cutting out the direct radiation from the sun, will itself become heated and then transmit a sizeable proportion of that heat into the room.[16] From this point of view some form of insulation or reflectivity should be built into the screening. (In the case of curtains, this can be provided by incorporating a reflective lining.)

Double glazing has both advantages and disadvantages in this context. It will reduce the heat losses by about 50% but also reduce the solar gain by 10% - 11%. (Table 4, case [e]) The result is that the seasonal heat requirement will be reduced by 63% for the North side and by 77% on East and West sides. There will still be a small net gain on the South side. Thus, double glazing is slightly more effective than the use of curtains at night. However, because the reduction in solar gain is comparatively small, double glazing is not effective for eliminating excess solar gain in Summer. It may be considered that double glazing is appropriate for reasons other than reducing heat loss, such as sound insulation. The design criteria for double glazing for noise reduction are, however, different to those for thermal insulation. The thermal insulation value of double glazing is reduced as the air gap between the two sheets of glass is increased beyond 19mm (¾") because heat is dissipated by the convection currents set up in the air space.[24] Acoustic double glazing, on the other hand, requires an air gap of at least 200mm (8") to be effective.

Double glazing can have a useful side effect in that it considerably reduces the cold radiation and down draughts experienced with single glazing. This will increase thermal comfort levels, resulting in comfort levels being achieved at lower temperatures.

Because double glazing is expensive, it may be that in some situations one of the alternative solutions would be preferable, although there are cases where double glazing will be the best solution.

Whatever method is used for the reduction of heat loss through the windows, maintenance and cleaning costs need to be considered in addition to the capital cost. These must be balanced against the probable energy savings. Also, if curtains or blinds are to be used for reducing night heat loss, then consideration needs to be given as to how to ensure that they are put in place at the appropriate time. It may be that it is feasible to expect the occupants of the offices to deal with this when leaving at the end of the day, or sooner if they so wish, or, it may be considered more appropriate to make this the province of one or more persons, perhaps the cleaners or the porter, in which case there would be some payment involved for this task.

It was noted, on visiting Building A that most of the windows have had roller blinds at some time - either externally or between the double glazing where this exists. Consideration could be given to using existing fittings such as these as this could then prove to be a cost effective solution.

5.3 HEAT LOSS THROUGH THE ROOF

The heat lost through the flat roof is next, in order of magnitude, for this building. (see Table 3) The heat loss through the main roof and the portion over the front two-storey section together accounting for approximately 14% of the total heat loss. This represents 33% (1/3) of the heat lost through the building fabric (i.e. excluding the heat lost through ventilation).

There are a number of methods which may be used to insulate an existing flat roof but these can be split into two basic categories:

a) Insulation placed on underside of ceiling

and

b) Insulation placed on top of the roof - either above or below the waterproof surfacing.

The first option would initially appear to be the better solution as the insulation would be internal to the structure, giving a shorter warm-up period when the heating is switched on which is important for buildings which are heated intermittently. Likewise, the 'cold radiation' from the ceiling would be reduced. In addition, if the insulation was fixed above a suspended ceiling there would be a small additional gain by virtue of the fact that the room heights were diminished. However, the costs and disruption to work involved in that it would be unlikely to show a reasonable return in energy cost savings[19].

This leaves the option of putting the insulation on top of the roof structure. The two alternative ways of doing this both have disadvantages; If the insulation (eg. 50mm rigid glass fibre) is placed on top of the roof structure and then covered by the waterproofing layer (roofing felt or asphalt) then the insulation will normally be kept dry and therefore keep its insulating properties. However, there are two ways in which water can become trapped in the insulation, so reducing the insulation value - firstly by water being trapped during installation before the waterproof covering is laid and secondly, when the waterproof covering becomes damaged-due to impact, thermal-stress, degradation of the material itself (due to long term exposure to ultra- violet light) or condensation on the underside of the waterproof membrane, One way of partially overcoming the second cause is illustrated in Figure 5 - where the rigid insulation is placed on the roof structure, covered by a waterproof membrane, which is then protected by, for instance, a 50mm(2") concrete screed. Some provision for ventilation of the insulation would still be required, which in turn detracts to some extent from the insulating value.

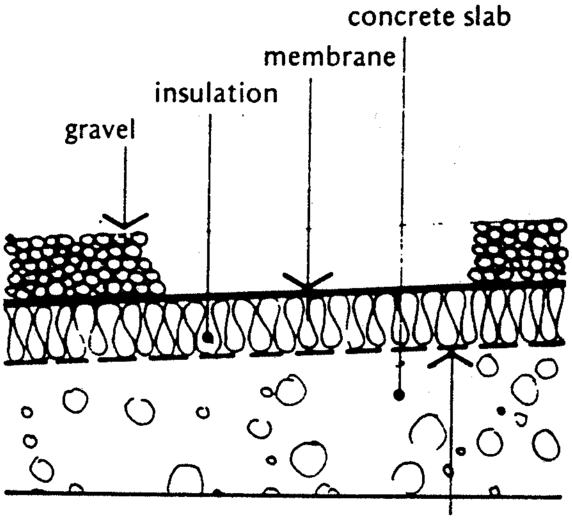


Figure 5 Flat roof insulation Conventional

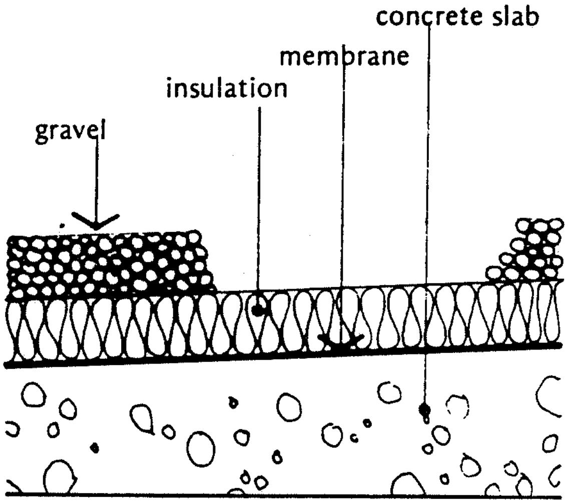


Figure 6 Flat roof insulation 'Plus Roof' concept

Another alternative is the system outlined in Figure 6 - the 'inverted' roof - where the insulation is laid on top of the waterproof membrane and weighted down by loose gravel or, for areas subject to frequent foot traffic, paving slabs. For this method, the insulation used must be such that the water absorption is very small. An example would be closed cell expanded polystyrene foam where the water absorption is around 0.1% by volume. With this type of roof, rainfall drains through the gravel layer, through the insulation and runs off, to drainage points, on top of the waterproof membrane. Obviously, the water will take some heat with it as it runs off, but if the insulation thickness is increased by 20% this will adequately compensate for this factor.

The main advantage of this system is that the waterproof membrane is protected from damage by impact and by thermal stress and will therefore not need to be renewed as often as is the case where the membrane is also the surface covering. [19] Because the insulation is able to drain freely there will not be the problem of reduction in insulation value due to moisture being trapped in the material. The other major advantages of this method are that it is relatively quick to install, can be easily lifted for inspection/maintenance of the waterproof membrane and can be installed comparatively cheaply with no disruption to the building users.

There is however, one disadvantage, which is that, although extruded polystyrene can be treated with a flame retardant additive it is combustible and can burn. Once in place, on top of concrete and covered by gravel or paving slabs, this problem is minimised and may not be felt to be a hazard.

A third alternative method of insulating above the roof structure is the application of foamed polyurethane or polycyanurate, the latter giving better fire protection [29] although both will burn and should therefore be generally used only on the outside of buildings. An advantage of sprayed foam is that it is very light and can therefore be used on roofs which could not support heavy loading.

Polyurethane foam has the lowest K-value (thermal conductivity) of all insulation materials (0.0l7w/moC to 0.023w/moC) and therefore a thinner layer is required to achieve the required level of insulation. It appears to be possible to obtain isocyanurate foams with Class I (BS476 part 7) Flame Resistance and they can be coated with a surface finish to give a seamless weatherproof covering, thus taking the place of the usual felt or asphalt covering. A special coating can be applied to increase the fire resistance to conform with Building Regulations.

It is obviously most important that all the properties of a proposed insulation method should be fully investigated.

Table 5 gives an indication of the improvement of U values for the flat roof treated in the various ways described above.

Table 5

Effects of various roof treatments on heat losses - Flat roof, Building 'A'

Description	'U' value w/m²/°C	seasonal heat loss GJ	reduction in seasonal heat loss %
Existing flat roof construction	3.3	333.53	0
With suspended ceiling + 50mm insulation	1.16	117.40	64.8%
50mm rigid insulation on roof deck + waterproofing	0.852	86.38	74.1%
50mm loose laid polystyrene slabs over roof surface + gravel layer	0.65	65.71	80.3%
Sprayed insulating foam on roof deck + waterproofing	0.65	65.71	80.3%

5.31 HEAT LOSS THROUGH PITCHED ROOF.

Although detailed calculations have not been carried out for Building B (as they have for Building A) it is certain that a large proportion of the heat loss from this building also is through the roof structure. The proportion is likely to be less than for the flat roof and to be around 20-25% of the fabric heat losses. (10% of total heat loss).

It would be a comparatively simple operation to lay insulating quilt over the ceiling joists to the desired thickness. The most cost effective thickness is probably between 100mm and 160mm.[2].

Several points must be borne in mind when insulating the roof in this way:-

a) The roof space above the insulating must be ventilated to remove the risk of condensation.

b) Any tanks or pipes in the roof must be insulated - in the case of tanks the top and sides of the tank should be insulated, but insulation should not be placed underneath a tank which is resting on the joists. (Thus allowing some warmth from below to reach the tank).

c) Any hatches or other entrances to the roof space should have insulation applied to their roofside surface and *should be draught - proofed.*

The installation of 160mm insulation is likely to reduce the heat loss through the pitched roof by about 89%.

The installation of 100mm insulation is likely to reduce the heat loss through the pitched roof by about 83%.

5.4 HEAT LOSS THROUGH THE EXTERNAL WALLS.

The heat loss through the external walls of Building A accounts for approximately 23% of the total fabric heat loss (10% of total heat loss).

It is doubtful whether general insulation of the walls, which are of solid brickwork, would be cost effective unless, perhaps, it was necessary to replaster them totally in any case.

However there are two ways of improving the overall performance of the walls. One of the contributory factors to heat loss from external walls is the effect of water on the external surface. Water on the surface (from rain, leaking gutters, rainwater pipes etc), takes heat away from the wall both as it runs down the wall and as it evaporates from the wall. The latter is probably of greater significance because water that has penetrated into cracks, joints or the bricks themselves can continue evaporating for long periods and can also freeze within the spaces, creating further or larger cracks for water to penetrate.

In order to cut this effect as far as possible it is essential to ensure that all leaks in pipe overflows and gutters are repaired promptly and that the mortar joints between brickwork are repointed when necessary. It may also be worthwhile to consider the application of a transparent (silicon-based) waterproofing liquid to the wall surface - especially on sides of the building exposed to the greatest percentage of driving rain. However, it is unlikely that the cost of this could generally be justified in energy saving terms at present. and it is not suitable for all types of brickwork.

The areas of greatest heat loss from external walls are located behind and above radiators as shown in Figure 7. British Gas (27) have researched this subject and consider that some 6.1% of the heat output from a radiator is transmitted directly through the wall behind the radiator. A further 5.6% is transmitted through the wall just above the radiator so that, effectively, only about 88% of the radiator output is available to heat the room.

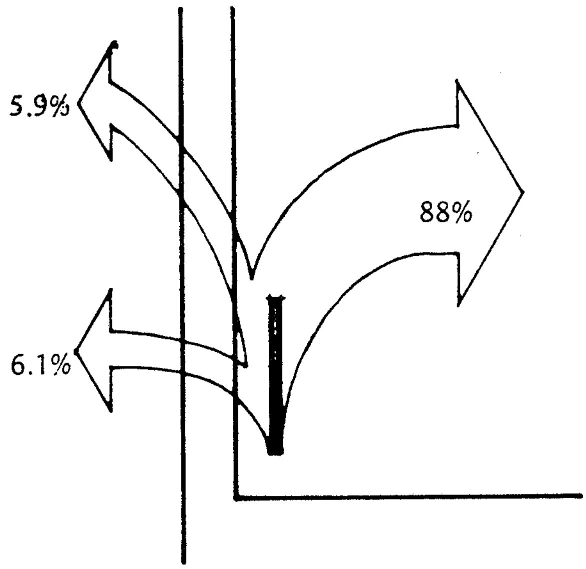


Figure 7 Heat loss through wall, behind and above radiator

There are two steps which can be taken to reduce these heat losses. The first is to fix a reflective material, such as aluminium foil, to the wall behind the radiator. This deflects some of the heat back towards the radiator and to the room. The second step is to fix a shelf above the radiator to deflect the heat rising by convection back into the room. Figure 8 illustrates this.

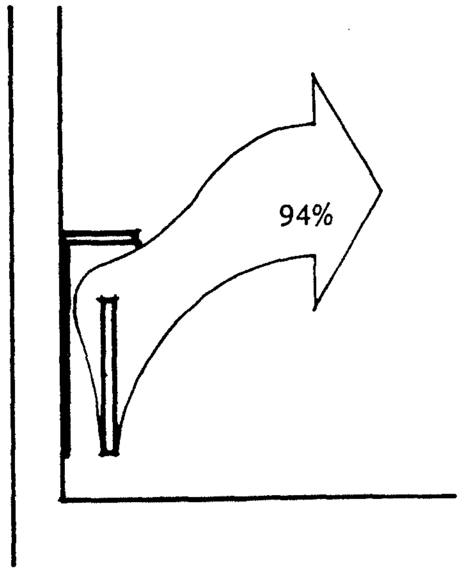


Figure 8 Reduced heat loss due to foil and shelves

These two measures, particularly the shelf, also increase thermal comfort by deflecting the heat across the room rather than it being allowed to immediately rise towards the ceiling. The use of reflective foil behind and shelves over all radiators which are situated on external walls will save some 4% (£422 p.a. for both buildings), of the energy used for heating (assuming 80% of radiators are situated on external walls and the saving per radiator to be 5%). Similarly, the use of foil alone would save around 2.4% (£253 p.a).

5.41 EFFECT OF WALL SURFACES ON THERMAL COMFORT AND HEAT REQUIREMENTS.

The texture and tone of wall (and floor and ceiling) surfaces can have a significant effect on the thermal comfort of the building occupants, which in turn, as mentioned before (5.1, p.16) can result in an increase or decrease of the temperature demanded from the heating system. The illustration of an example room (Figure 9) indicates the likely effects of the application of the two basic categories of surface treatment which are:

a. Reflective - smooth textured surfaces, light in colour and bright; such as white gloss paint, pale coloured metallic sheen wallpapers or vinyl flooring. These surfaces reflect considerably more heat (and light) than they absorb.

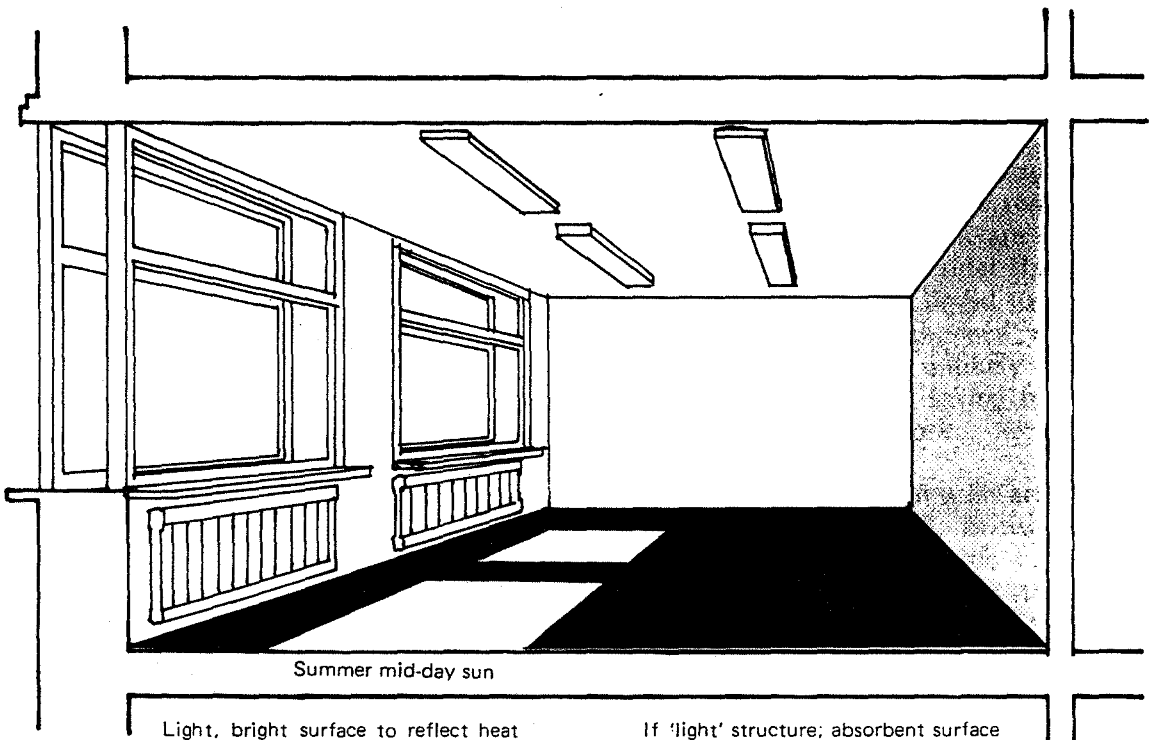
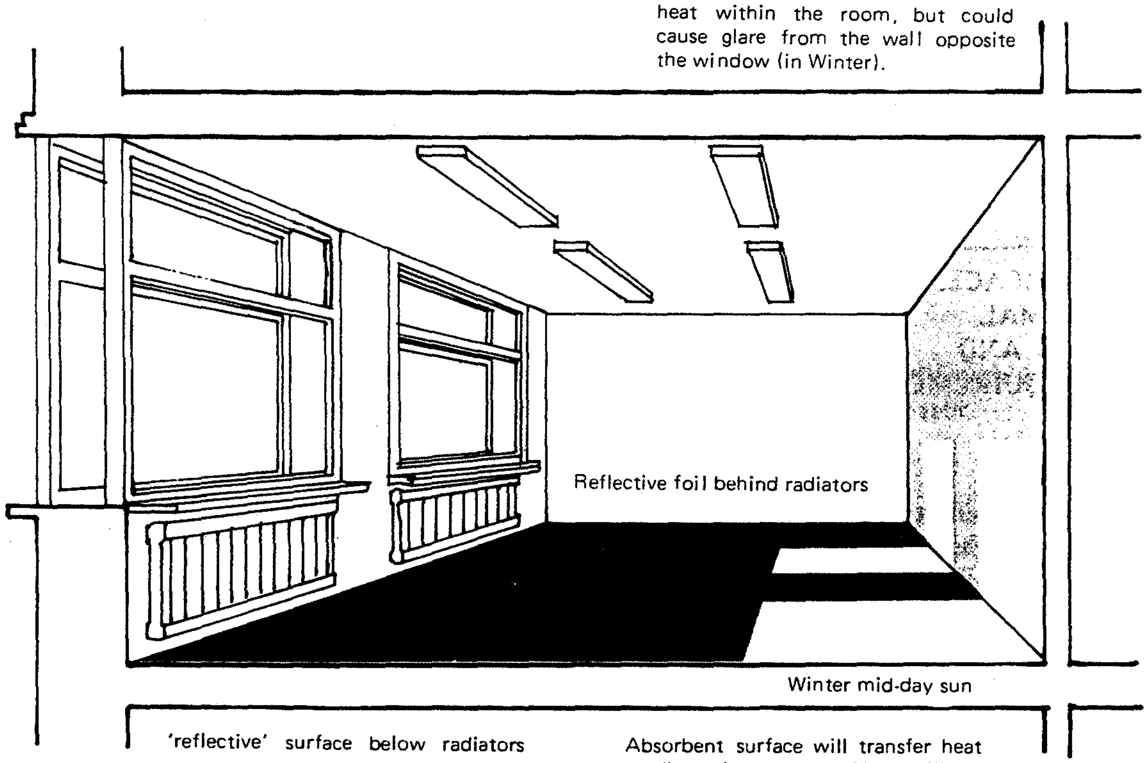


Figure 9 Effect of surface treatments on thermal comfort levels



b. Absorbtive- rough textured surfaces, dark in colour and dull, such as hessian wall covering, carpet, cork tiles, dark coloured textured paint. These surfaces will absorb more heat (and light) than they reflect and will then emit an equivalent amount of heat - either almost immediately if the structure behind is lightweight (eg plaster board on timber framing) or, after a time lag if the structure is heavyweight (eg brick or blockwork).

It could be beneficial to bear these points in mind when considering redecoration.

5.5 HEAT LOSS THROUGH THE FLOOR.

Heat losses through intermediate floors are of little consequence (except as indicated in 5.41) as the heat is merely transferred to the next storey.

The floor of the basement or ground floor however, may be worth separate consideration. There is a heat loss through this floor to the ground below representing 3.4% of the fabric heat loss (or 0.02% of the total heat loss.) This is small in comparison with the other elements. (eg. 1/10 of losses through the flat roof) and therefore unlikely to repay any stringent measures. If however, it was intended, for instance, to resurface the floor using a sand and cement screed, it could be worthwhile to lay the screed over a layer of insulation, or, if a new floor covering was required, to lay carpet, or cork tiles, in preference to a vinyl or tiled surface. The latter would, again improve thermal comfort, as well as reducing the energy loss slightly, thereby contributing to a reduction in required temperatures and therefore a saving in energy use.

5.6 ARTIFICIAL LIGHTING.

There are two main categories in which the use of artificial lighting can contribute to excess energy usage:

1. Inefficient luminaires.

2. Lack of control of lighting.

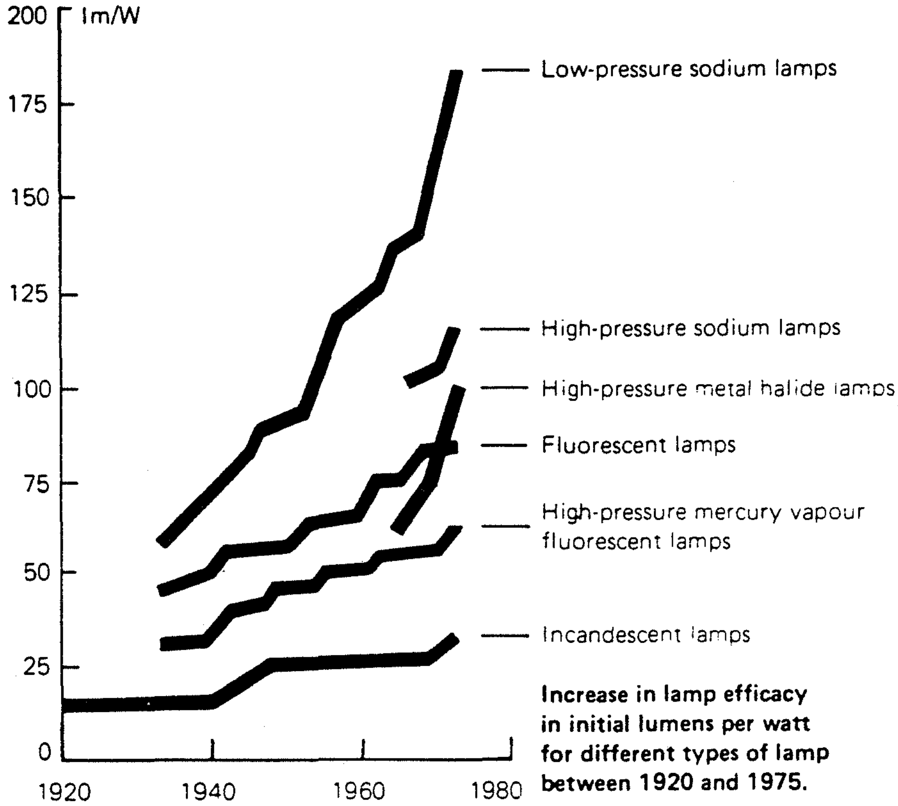
Efficiency of luminaires.

Although most areas of the buildings concerned are now fitted with fluorescent lamps, which have an efficiency* of up to five times that of ordinary (incandescent/tungsten) lamps,[5] consideration should be given to replacing any of the latter which still exist by fluorescent lamps. Care should, of course be taken to ensure an acceptable quality of light.

The most efficient lamp currently available is the low-pressure sodium lamp (see figure 10) as used for much street lighting.

*ie. amount of light (in lumens) per watt of energy consumed.

Figure 10 Efficiency of lamps



Increase in lamp efficacy in initial lumens per watt for different types of lamp between 1920 and 1975.

However, the colour rendering of these lamps is so poor that it is unlikely that their use anywhere in buildings would be acceptable, although there *might* be a role for them in 'security' lighting of stairways and external spaces.

The relatively new high-pressure sodium lamps and high-pressure metal halide lamps combine high efficiency with good colour rendering. Their disadvantage however is that they require a long 'start-up' period - sometimes up to 20 minutes - and they are therefore unsuitable for use in the office situation where a fast response is necessary. They may, however, be of use in circulation areas.

The light output of any lamp decreases with age and a lighting maintenance programme is therefore valuable in that lamps may be replaced before the end of their quoted 'useful' life. For fluorescent lamps this is normally the period over which the light output drops to 80% of its initial value (after 9-11,000 hours use). If the effect of soiling of the luminaire is also taken into account this will reduce the light output by up to 30% over 12 months. If the luminaires are cleaned at 6-month intervals and re-lamped after two-thirds of the 'useful' life have passed then the loss in light output will be considerably reduced.[25] The advantage of this in energy conservation terms is that there will be less necessity to turn on additional lamps to compensate for loss of efficiency. Care must be taken to ensure that replacement lamps are of the same type, colour and wattage as the originals.

The choice of light fittings (luminaires) is most important as some will restrict the light to such an extent that the efficiency of the lamps is unreasonably reduced. Where diffusers are required with fluorescent lamps the prismatic type should be specified and care should be taken to ensure that the diffuser material is such that it will not discolour with age.

2. Control of lighting.

The excessive use of lighting is generally due to failure to switch lights off when they are not required rather than to switching them on unnecessarily. However, lights *will* be switched on unnecessarily where too large a number of luminaires are controlled by one switch. [6,7]

Manual Control - The simplest method of dealing with this problem is to increase the degree of manual control available by providing separate switching, either for rows or banks of lights or for individual lights. For instance, in rooms where there are two or more rows of luminaires running parallel to the window wall each row should have its own switch as the row(s) nearer to the window will need to be switched on far less frequently than those deeper into the room. Individual switching (possibly by pull switches) can sometimes be effective, depending on the arrangement of the work spaces in relation to the lighting fitments. Where it is desired to increase the lighting levels, it may be beneficial to install 'task' lighting, ie. lights fitted to individual work stations, independently controlled. It is generally found that users are more likely to switch off these 'local' lights when not required [7] and may even consequently become more aware of the need to switch off the ambient lighting also. Care and maintenance of the 'local' fittings must be taken into account. However, manual switching still relies on the building users remaining aware of the need to switch off those lights which are not required.

Automatic on-off control - Provided that patterns of building or zone occupancy can be clearly established and/or manual over-ride of the controls provided with subsequent automatic switch off, the provision of on-off time controls can be a significant step in saving energy use. However, care needs to be taken to ensure that this form of control does not result in lighting being on automatically when it is not required and that allowance is made for lighting for cleaners and for security.

Photo-electric control of individual, or groups of, luminaires. - This is especially advantageous when used to control lighting close to windows which will generally be required for much shorter periods in a day than that which is lighting areas more deeply set into the building. Frequently lighting is switched on, say, first thing in the morning when daylight is inadequate but as daylight increases and would provide the desired illuminance by itself, the artificial lighting remains on, thus wasting energy.

Photo-electric control can be used to switch rows of luminaires on or off according to the levels of day lighting reaching to different depths of a room. However, with the possible exception of the row nearest to the window, the frequent sudden changes in illuminance which will result from this form of control are likely to be disturbing to the occupants and therefore the form of photoelectric control which also incorporates a 'top-up' control would be more acceptable and also save further energy.[5] With this system the level of artificial lighting is automatically increased and decreased so that the total illuminance provided by the combin-ation of the available daylight and the artificial lighting remains constant. Further savings can be made if the occupants have to positively switch *on* the controller as this action is unlikely to be performed until daylighting levels have dropped consid-erably.

Analysis of cost effectiveness has shown the following order: [5]

simple automatic on-off control
mixture of task and ambient lighting
replacement of tungsten by fluorescent lamps
photo-electric on-off and 'top-up' controls.

It is likely that the incorporation of some or all of these measures would result in energy savings of between 4% and 35% [6] of the lighting bill and could also increase lighting efficiency.

Photo-electric control is likely to be cost effective only where total rewiring is being undertaken in any case. If rewiring is being done but there are no plans for automatic control as yet, the installation of an extra conductor wire to each luminaire will cost very little but allow for installation of automatic control at a later date.

Although artificial lighting will contribute useful heat to the building during the heating season, in the summer the converse is true - the artificial lighting contributes excess heat. Any reduction in the use of lighting in summer will therefore aid comfort levels and, if incorporated as one of a number of measures, the loss of winter heat will be balanced by the reduction of heat losses in other areas.

5.7 WATER HEATING.

The two buildings under consideration use different methods for water heating. Building B has a gasfired boiler from which hot water is distributed to the usage points - kitchen, toilet facilities etc. Several measures can be taken to reduce energy consumption in this system. It should be ensured that the boiler itself has a programme control so that it can switch on for as few hours per day and days per week as possible. It should also be possible to reduce the temperature to which the water is heated. With the possible exception of kitchen use the maximum temperature at the point of use needs to be no higher than 45^{o}C.

As far as can be ascertained, very little of the distribution pipework is insulated at present and as it most frequently runs along external walls there is a very large heat loss direct to the outside air. Although some of the heat lost from the pipes will be a useful gain to the building in winter, hot water is in use all the year round all and losses from pipework in the summer are total losses and may even be counter productive in that they may contribute to overheating. Therefore adequate insulation of the pipework will save a significant amount of energy.

Another measure is to reduce hot water wastage by, for instance, installing single spray mixer taps for hand washing. With these, the ratio of hot to cold water is increased according to how far they are turned on.

In Building A water is heated by individual electric storage heaters at the points of use. As these are very well insulated it may appear that little heat is lost from them. However, although the rate of heat loss is reduced it does still occur. Therefore it would be beneficial to operate these heaters with time switches so that only enough water for the days usage is heated. Again, the temperature at the tap does not need to exceed 45^{o} C (higher is uncomfortable in any case) and the heaters should be adjusted accordingly. As before, the use of single spray mixer taps would be appropriate. The pipe runs are generally short so the benefit of insulation is likely to be insignificant except where one heater serves two or more basins situated some distance apart.

5.8 OTHER ELECTRICAL EQUIPMENT.

Apart from lighting and water heating there are a number of various other electrical appliances in use, including electric fires, photocopiers, printers, typewriters, refrigerator, fume extractors and extractor fans. Consideration should be given to all these on an individual basis. For instance, it could be sensible to replace extractor fans in toilets by permanent ventilation wherever possible provided that the doors between toilets and other areas of the building are draught-proofed and care is taken that these areas are still heated. Or, an alternative form of direct heating for the areas where electric fires are found to be necessary might be found.

With respect to office machines there may be no immediate scope for savings beyond regular maintenance and general care. However, when machines are due for renewal there may well be scope for installing machines with lower energy consumption. Photo copiers are an interesting case where one machine may consume several times as much power as another which does the same job or better and may even have a lower capital cost. It should be remembered that all electrical energy used is finally converted to heat which may itself be causing problems of overheating which would then be reduced at the same time.

5.9 SPACE HEATING.

The space heating system offers wide scope for energy saving measures. The system is split into three sections; boiler plant, distribution and emitters (radiators).

Boiler Plant.

The gas fired boilers have been recently installed (around eighteen months ago). Their operation is controlled by a timeclock, a boiler room thermostat and a 'frost-stat'. The disadvantage of timeclock operation is that the boilers will be fired and switched off at preset times regardless of other conditions, particularly climatic conditions. An 'Optimum Start' controller will operate the boilers in relation to weather conditions, having been pre-programmed with such information as the 'warm-up' time for the building fabric [25,12] (This will of course be different for a Monday morning after the heating has been off over the weekend, than for other mornings). Although these controllers have been fairly expensive to install they are now becoming cheaper with improvements in 'chip' technology. There is obviously a need for protecting the building fabric from condensation during periods when the heating is off, but the 'frost-stat' can cause the heating to come on when the outside temperature is low but the temperature inside the building may still be sufficiently high. Therefore an 'anti-condensation' theremostat would be more appropriate. This would switch on the heating if the *inside* temperature falls below, say, 5^{o}C - 10^{o} C.

Another measure which could prove effective, if not already implemented, is the installation of flue-sealing dampers which close off the boiler flues when the boilers are not running, thus preventing cold air from entering and cooling the boiler heat exchangers. [19]

The overall temperature for the building should also be reduced. The statutory minimum for offices is 16°C. The statutory maximum temperature has just been reduced from 20°C to 19°C.* If other measures are taken to reduce draughts and generally increase thermal comfort it may well be possible to decrease the overall temperature by at least a further 1°C - ie to 18°C - without any compromises having to be made by the occupants. As mentioned earlier, each degree centigrade reduction in temperature represents between 5% and 10% reduction in consumption.

ibution.

The space heating water is distributed from the boiler room (in the basement of Building A) to radiators in both buildings. Much of the distribution is through larger diameter pipes (4") none of which (with the exception of those in the boiler room and the print room) are insulated. As the major proportion of these pipes run along external walls there is a large heat loss direct to the outside air. The heat lost through the pipework accounts for a substantial portion of the heat supplied by the boilers. Many of the pipes also run at ceiling level so there is therefore little useful gain to the general space heating as the heat will remain at high level. A high standard of insulation of the pipework could therefore result in significant savings.

Another area for consideration is the zoning of the heating system. At present various zones can be isolated by means of manual valves located through the building but it is doubtful if these are utilised fully. There are some specific areas of the building which are used out of normal office hours. Therefore, ensuring that these areas are distinct zones on the heating system, governed by automatic devices, will save the full building being heated unnecessarily. One way in which this could be done is fitting motorised valves, in place of the manual ones, connected to a control panel in the boiler room. This method could also be used to control other zones, for instance where one side of the building may sometimes become overheated due to solar gain. The valves could be linked with thermostats and/or time clocks.

*Michael Heseltine MP Secretary of State for the Environment - 23rd July 1980 - announcement in House of Commons.

Emitters - radiators.

There is a great need for localised control of central heating systems due to a number of factors[20] such as:

building fabric cooling	individual preferences wind direction and speed effect of precipitation	vary according to time of day and year and weather conditions
building heating	solar gain lighting gain gain from occupants	

If radiators are not controllable, or can be only fully on or fully off, then when the heat is too great the only remedy is to open windows or doors, or install fans and other cooling devices so wasting valuable energy. If the radiators are fitted with thermostatic valves (TRV'S) then these will increase and decrease the heat flow through the radiator to compensate for the conditions mentioned above to keep the room at the desired temperature. (which can be easily varied by adjusting individual TRV's). A major improvement on the design of these valves is the remote sensing element which overcomes the problem of the TRV being unduly influenced by its proximity to the radiator. Care must be taken however, to locate these sensors (and any other thermostats) in a suitable position. They will not perform properly if they are placed immediately above the radiator or where they can be unduly influenced by any other localised heat source. This applies equally to those wall areas where sunshine may fall, or, in fact, to cold areas and those subject to draughts.

6 Energy Saving Measures - v - Costs

In this section the effect is shown of applying those measures discussed in section 5 to the particular buildings under consideration with an indication of the capital costs and energy savings for each measure. The rates given for both are reasonably accurate (being based on actual quotations wherever possible) although the totals for the whole building could alter slightly once the precise details of implementing the measures are worked through. No deductions have been made from the costs where two or more measures have overlapping overheads.

When decisions are finally taken as to which measures to implement it should be remembered that a number of measures taken together will save energy in excess of the arithmetic total [1] However, it is generally preferable to take one measure in full throughout a building rather than to implement many different measures in just one part of a building.

(Items in the following tables appear in the same order as they are discussed in section 5)

Notes to Tables on following pages.

(1) The annual energy cost for the two buildings is £23,896.

(2) Simple Payback Period is worked out as the ratio of the Capital Cost/Saving per annum without taking into account either interest on the capital or price rises for energy costs.

(3) Likewise no account is taken of either the interest or inflation in calculating the saving over 10 years. In practice the figures in Column 8 are likely to be much higher than indicated.

TABLE 6 ABSTRACT of MAJOR ENERGY SAVING MEASURES

All costs and savings are based on July 1980 prices.

Energy Saving Element/measure	Page no. in text.	Significance to Thermal Comfort Scale 1 to 5	Buildings A and B: Rate (July 1980)	Saving as % of Heat loss Through each Element	Capital Cost	Energy Cost Saving Per Annum	Simple payback Period (see note 2)	Net saving over 10 years (see note 3).
6.1 Ventilation 25% reduction in air-change rate by:-	16							
(a) Windows - draught stripping		1	£2/m	11.0%	£2,880	£953	3.0 yrs	£6,650
(b) External doors								
(i) draught stripping		3	£20/door	2.5%	£400	£217	1.8 yrs	£1,770
(ii) draught lobbies		3	£300 each	5.0%	£1,500	£433	3.5 yrs	£2,830
(iii) draught stripping of letter boxes & keyholes		3	£20(total)	0.5%	£20	£43	0.5 yrs	£ 410
(c) Internal doors - draught stripping		3	£20/door	2.0%	£260	£173	1.5 yrs	£1,470
(d) Skylights - draught stripping		5	£30 each	4.0%	150	£346	0.4 yrs	£3,310
6.1.1 Ventilation Control TOTALS				25.0%	£5,210	£2,165	2.4 yrs	16,440
6.2 Heat loss through Windows Reduction of night heat loss, plus solar shading for Summer (alternatives)								
(i) curtains with reflective lining	21	1	£7.50/m^2	39.0%	£3,785	£919	4.1 yrs	£5,405
(ii) insulated vertical venetian blinds		1	£45/m^2	68.0%	£22,710	£1,598	14.2 yrs	nil
(iii) double glazing		1	£55/m^2	50.0%	£27,720	£1,188	23.3 yrs	nil
(iv) roller blinds (between double glazing)		1	£13.50/m^2	39.0%	£6,813	£919	7.4 yrs	£2,377

TABLE 6 ABSTRACT of MAJOR ENERGY SAVING MEASURES

All costs and savings are based on July 1980 prices.

Energy Saving / Element/measure	Page no. in text.	Significance to Thermal Comfort Scale 1 to 5	Buildings A and B: Rate (July 1980)	Saving as % of Heat loss Through each Element	Capital Cost	Energy Cost Saving Per Annum	Simple payback Period (see note 2)	Net saving over 10 years (see note 3).
6.3 Heat loss through Roof	24							
(a) Flat roof (alternatives)								
(i) traditionally insulated		5	£13.50/m^2	74.0%	£9,666	£1,544	6.3 yrs	£5,774
(ii) 'Plus Roof' insulation		5	£6.50/m^2	80.0%	£4,654	£1,670	2.8 yrs	£12,046
(iii) Sprayed insulation		5	£13.50/m^2	80.0%	£9,666	£1,670	5.8 yrs	£7,034
(b) Pitched roof (alternatives)								
(i) 100mm insulating quilt		5	£2.75/m^2	83.0%	£2,200	£1,725	1.3 yrs	£15,050
(ii) 160mm insulating quilt		5	£4.25/m^2	89.0%	£3,400	£1,867	1.8 yrs	£15,270
6.4 External Walls	27							
(i) waterproofing		5	£2/m^2	10.0%	£6,080	£149	41.0 yrs	nil
(ii) foil behind radiators plus shelves over		3	£17/rad	4.0%	£5,100	£422	12.0 yrs	nil
6.6 Artificial Lighting	31							
Change remaining (40) tungsten lamps to fluorescent		3	£15 each	60.0%	£600	£367	1.6 yrs	3,070

TABLE 6 ABSTRACT of MAJOR ENERGY SAVING MEASURES

All costs and savings are based on July 1980 prices.

			Buildings A and B					
Energy Saving Element/measure	Page no. in text.	Significance to Thermal Comfort Scale 1 to 5	Rate (July 1980)	Saving as % of Heat loss Through each Element	Capital Cost	Energy Cost Saving Per Annum*	Simple payback Period (see note 2)	Net saving over 10 years (see note 3)
6.7 Water Heating	35							
(a) Walworth Road								
(i) programmer for boiler		5	£50	20.0%	£50	£53	0.9 yrs	£ 480
(ii) reduction in temp. from 65°C to 45°C		2	nil	25.0%	nil	£66	nil	£ 660
(iii) insulation of pipework		5	£2/m	30.0%	£280	£79	3.5 yrs	£ 510
(iv) spray mixer taps		2	£30 each	10.0%	£300	£26	11.5 yrs	nil
(b) Larcom Street								
(i) timeclocks		5	£30 each	20.0%	£150	453	2.8 yrs	£ 380
(ii) reduction in temp		2	nil	25.0%	nil	£66	nil	£ 660
(iii) spray taps		2	£30 each	10.0%	£300	£26	11.5 yrs	nil
6.9 Space Heating	36							
(a) Boiler Plant								
(i) Optimum Start Controller		5	£1,750 ea	5.0%	£1,750	£660	2.7 yrs	£4,850
(ii) change 'frost-stat' to 'anti-condensation stat.		5	£100 each	1.0%	£100	£132	0.76	£1,220
(iii) reduce temperature from 19°C to 18°C		4	nil	5.0%	nil	£660	nil	£6,600

TABLE 6 ABSTRACT of MAJOR ENERGY SAVING MEASURES

All costs and savings are based on July 1980 prices.

Energy/Saving — Element/measure	Page no. in text.	Significance to Thermal Comfort Scale 1 to 5	Buildings A and B: Rate (July 1980)	Saving as % of Heat loss Through each Element	Capital Cost	Energy Cost Saving Per Annum	Simple payback Period (see note 2)	Net saving over 10 years (see note 3).
6. Space Heating(contd.)								
(b) Distribution								
(i) insulate 4" diameter pipework		3	£5/m	10.0%	£11,500	£1,319	8.7 yrs	£1,690
(ii) motorised valves for zoning		5	£250 each	10.0%	£2,638	£2,000	1.3 yrs	£17,362
(c) Emitters								
Remote sensor thermostatic radiator valves		2	£25 each	5.0%	£7,500	£660	11.4 yrs	nil

7 Continuing Activity

This section covers a number of measures which could be effective in reducing energy costs but can be implemented at any time, not necessarily during major works. *Some of these can result in high enough savings to be paid out of running costs rather than capital.*

A number of on-going activities have been shown to be of value in reducing energy consumption. [4,11] One of the major areas is "**good housekeeping**" which encompasses all activities which can be carried out by the building users such as closing doors and windows, switching off lights, turning taps off fully. It is an accepted view that this can give maximum savings for minimum capital outlay for the publicity campaign. [4] However, the greatest difficulty is in sustaining the interest of the building users following the first (or subsequent) major publicity campaign. Therefore it is beneficial to initiate a publicity campaign for good housekeeping at the same time as physical improvements can be seen, to be in progress on the building fabric and services. It is desirable for all the building users to be fully informed of the measures which are being taken and the reasons for them. This initial stage can then be reinforced and the level of energy usage awareness kept high by, for instance, feedback of data on energy use and costs to the users, preferably compared to a 'target' consumption figure, plus continued persuasion, the form of which needs to be changed from time to time to re-engender interest.

The introduction of some form of consumption monitoring would be beneficial for several reasons; to assist good housekeeping, to check the efficacy of the energy saving measures, form a basis for tariff negotiations and also to show up deviations from the 'normal' pattern which may indicate, for instance, malfunction of a control. It would be preferable for the energy consumption to be monitored on a monthly or weekly basis, rather than relying on quarterly accounts (although even these can give some useful indicators). There may be a distinct advantage to be gained in appointing one (or more) member of staff per building as an Energy Officer - in much the same way as there are Health and Safety Officers, Incident Officers and so on. His/Her responsibilities could include regular readings of meters, persuasion to achieve good housekeeping practice, checking that maintenance is carried out on energy related items and so on. It is possible that the use of a computer, to compare monthly consumption figures; between buildings, with weather conditions and with previous years data, could be cost effective in the long term (particularly if a microcomputer is used). Indeed if previous local authority experience [4] is a guide then the 10% -20% savings possible from good housekeeping measure could cover the cost of this several times over, or alternatively be used to fund further measures.

An energy audit can be implemented in the first instance and at intervals thereafter; to help identify areas of possible savings and for comparison with other similar buildings and target consumption figures. [13, 14] Any recording/monitoring procedure should record units of energy, rather than only cost as, for instance, the costs per kWh for electricity are (at present) very much higher than for gas. These figures can later be used to check the accuracy of the quarterly bills. Where possible the end uses of energy supplied should be identified. For instance electricity may be being used for lighting, water heating, office machines and, possibly, air conditioning, extract fans or even some space heating and therefore it would be useful to be able to identify the relative consumptions.

Now that energy costs have a greater significance in relation to overall costs it would be worth considering the clear identification of these within each Department's Budget and careful comparison of the subsequent *actual* costs with the budget figures. As the cost of energy is one area where it is possible to make economies (by implementing energy saving measures), a clear picture of the costs can only be beneficial.

In a number of authorities it has been found useful to hold **'in house' seminars** at intervals to encourage energy awareness. Some authorities have also felt that the encouragement of energy studies in schools was appropriate, so influencing the energy users of the future. In Inner London, where the ILEA have the control of schools rather than the Borough, it might be appropriate to consider some (lesser) input of a similar sort through the Libraries and even at play centres and the like. The influence of children on their parents should not be underestimated - if children understand that, for instance, completely filling the kettle for just one cup of tea wastes energy they will quite probably point this out to their parents on every available occasion! This gradually increases the parents awareness also.

As was seen in section 5, the role of **planned maintenance**, is of great importance in ensuring that initital energy savings are continued. A study carried out elsewhere indicated that some 80% of controls were not working to their optimum efficiency due in part to lack of appreciation of the importance of maintenance of the control unit. Properly planned and executed maintenance, for instance on luminaires, can repay its cost, in energy savings, many times over.

There may be scope, in some buildings, for the incorporation of some **'alternative' energy sources**, such as solar water heating or waste heat recovery, but this should only be considered once the basic conservation measures have been taken. However, it should be noted that, in addition to the possibility of saving further (fossil fuel) energy directly, this type of development has an interesting side effect as, because it is something 'new', and frequently visible, it assists in increasing awareness of energy usage with a resultant effort to help reduce consumption.

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Appendix

SEASONAL HEAT LOSS CALCULATIONS - BUILDING A.

The 'degree day' method was used for the calculations.

Assumptions made were:
heating period of 13 hours per day, 6 days per week
(giving correction factors of 1.13 and 0.85)
No. of degree days = 2128
Design temperature difference = 21°C

(a) Hours of full rate of heat loss

$$= \frac{24 \times \text{degree days} \times \text{correction factors}}{\text{temp. difference}}$$

$$= 24 \times \frac{2128}{21} \times 1.13 \times 0.85$$

= 2,336 hours

(b) Maximum rate of heat loss (kWh)
(see following tables for detailed calculation)

Floor	(i) 1 airchange per hour	(ii) 2 airchanges per hour
Basement	40.2	55.7
Ground	52.0	72.0
First	44.4	62.1
Second	84.7	100.3
Total	221.3	290.1

(c) Net seasonal heat loss

$$= \frac{(a) \times (b)}{\text{conversion factor}}$$

(i) for 1 airchange per hour

$$= \frac{2{,}336 \times 221.3}{278} = 1{,}860 \text{ GJ}$$

(ii) for 2 airchanges per hour

$$= \frac{2{,}336 \times 290.1}{278} = 2{,}438 \text{ GJ}$$

Maximum rate of heat loss (W)

job title

BUILDING A ONLY BASEMENT

fabric heat loss

1 fabric construction	2 area (m^2)	3 U value (W/m^2 °C)	4 temperature difference (°C)	5 rate of fabric heat loss (2 x 3 x 4) (W)
External walls	288.07	1.12	21	6,775.4
External doors	11.93	4.3	21	1,077.3
s.g. windows	81.98	5.6	21	9,640.8
d.g. windows	29.88	2.78	21	1,744.4
Flat roof				
Skylights				
external walls*	5.84	2.5	21	306.6
Floor	777.00	0.32	21	5,221.0
			total	24,766.0 Watts

ventilation heat loss

ventilation location (having differing ventilation or temp difference)	number of poeple alternatively volume (m^3)	ventilation heat loss rate per m^3 or per person	temperature difference (°C)	rate of ventilation heat loss (2 x 3 x 4) (W)
case (i)	2168	0.34	21	15,480
case (ii)	2168	0.68	21	30,959

note the watt is a measure of heat flow rate:
eg one watt equals approx 3600 joules per hour

Total heat loss rate:

case (i) 40,245 W

case (ii) 55,725 W

Maximum rate of heat loss (W)				
job title BUILDING A ONLY GROUND FLOOR				
fabric heat loss 1 fabric construction	2 area (m^2)	3 U valve ($W/m^2\ ^oC$)	4 temperature difference (^oC)	5 rate of fabric heat loss (2 x 3 x 4) (W)
External walls	386.33	1.12	21	9086.5
External doors	29.42	4.3	21	2656.6
s.g. windows	123.83	5.6	21	14562.1
d.g. windows	18.59	2.78	21	1085.4
Flat roof	51.19	3.3	21	3547.7
Skylights	1.69	3.8	21	134.9
external walls*	17.91	2.5	21	940.3
Floor				
			total	32,013.5 W
ventilation heat loss ventilation location (having differing ventilation or temp difference)	number of poeple alternatively volume (m^3)	ventilation heat loss rate per m^3 or per person	temperature difference (^oC)	rate of ventilation heat loss (2 x 3 x 4) (W)
case (i)	2800	0.34	21	19,992
case (ii)	2800	0.68	21	39,984

note the watt is a measure of heat flow rate:
eg one watt equals approx 3600 joules per hour

Total heat loss rate:

case (i)	52,006 W
case (ii)	71,998 W

***walls enclosing main stair/lift well - treated as external.**

Maximum rate of heat loss (W)

job title

BUILDING A ONLY FIRST FLOOR

fabric heat loss

1 fabric construction	2 area (m^2)	3 U valve ($W/m^2\ ^oC$)	4 temperature difference (^oC)	5 rate of fabric heat loss (2 x 3 x 4) (W)
External walls	363.5	1.12	21	8,550
External doors	13.4	4.3	21	1,210
s.g. windows	135.0	5.6	21	15,876
d.g. windows	7.4	2.78	21	432
Flat roof				
Skylights				
external walls*	12.7	2.5	21	666.8
Floor				
			total	26,734 W

ventilation heat loss

ventilation location (having differing ventilation or temp difference)	number of poeple alternatively volume (m^3)	ventilation heat loss rate per m^3 or per person	temperature difference (^oC)	rate of ventilation heat loss (2 x 3 x 4) (W)
case (i)	2474	0.34	21	17,664
case (ii)	2474	0.68	21	35,329

note the watt is a measure of heat flow rate:
eg one watt equals approx 3600 joules per hour

Total heat loss rate:

case (i)	**44,339 W**
case (ii)	**62,063 W**

***walls enclosing main stair/lift well - treated as external.**

Maximum rate of heat loss (W)

job title

BUILDING A ONLY SECOND FLOOR

fabric heat loss

1 fabric construction	2 area (m^2)	3 U valve (W/m^2 °C)	4 temperature difference (°C)	5 rate of fabric heat loss (2 x 3 x 4) (W)
External walls	338.1	1.12	21	7,952
External doors	13.7	4.3	21	1,237
s.g. windows	107.98	5.6	21	12,698
d.g. windows				
Flat roof	665.0	3.3	21	46,085
Skylights				
external walls*	22.1	2.5	21	1,160.3
Floor				

ventilation heat loss

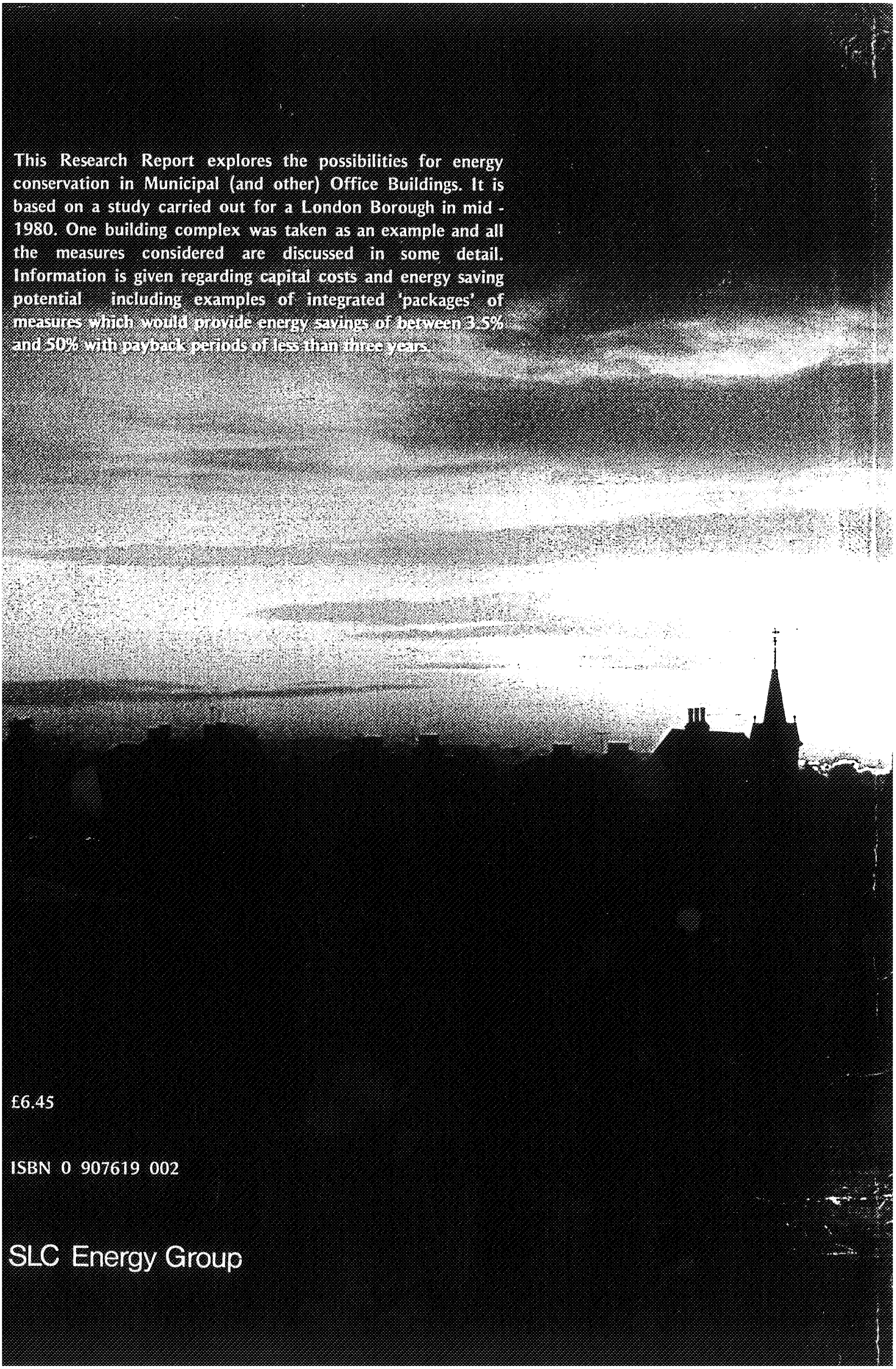
ventilation location (having differing ventilation or temp difference)	number of poeple alternatively volume (m^3)	ventilation heat loss rate per m^3 or per person	temperature difference (°C)	rate of ventilation heat loss (2 x 3 x 4) (W)
case (i)	2181	0.34	21	15,572
case (ii)	2181	0.68	21	31,145
			total heat loss rate (W)	

note the watt is a measure of heat flow rate:
eg one watt equals approx 3600 joules per hour

Total heat loss rate:

case (i)	**84,705 W**
case (ii)	**100,277 W**

***walls enclosing main stair/lift well - treated as external.**



This Research Report explores the possibilities for energy conservation in Municipal (and other) Office Buildings. It is based on a study carried out for a London Borough in mid - 1980. One building complex was taken as an example and all the measures considered are discussed in some detail. Information is given regarding capital costs and energy saving potential including examples of integrated 'packages' of measures which would provide energy savings of between 35% and 50% with payback periods of less than three years.

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