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Energy wastage in non-residential buildings – basic principles

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The realisation that any edifice is both a static and also a continuously dynamic entity, should lead to the acceptance of the need to apply the skills of a number of disciplines, although this basic concept is most certainly not generally realised or implemented.

These dynamic functions centre on the requirement to maintain the occupants of the building in a continuously comfortable situation, and the advanced state of the art prescribes that this is done with the employment both of minimum capital outlay and minimum annual running cost.

When one considers the importance of these monetary strictures, it is a continuous source of surprise and concern that prospective building owners and lessees do not more frequently ask three questions:

- What are the yearly energy costs?
- How could this figure be reduced?
- What are the maintenance costs?

These basic questions can only be answered by a most careful and competent survey of the total situation, and it is the purpose of this paper to present an overview of the main factors which should be examined.

A building is always affected by the hourly and seasonal changes in the weather, and also the external daylight levels, and accordingly it is in a continuous state of flux in terms of –

1. The requirement for artificial light in order to maintain an acceptable internal level of illumination.
2. The requirement for heating and cooling to be provided by the internal environment control equipment.

This control of the internal climate is further complicated by the ingress of outside air caused by both wind pressure and the prevailing thermal stack effect.

The variation in the number of occupants also has an impact on energy sources, as the building is having to cope with other important variables, such as lift usage and sanitary systems, but this paper will concentrate on the two aspects previously mentioned.

Requirement for artificial light

Only a careful analysis of the building's ability to admit natural light would provide an answer to the question how much the annual lighting bill will be (see Table 1).

Let us now examine the possibility of reducing the artificial lighting load. Most windows admit some daylight, but those at pavement level admit dramatically less than those at high level, if there are other buildings surrounding the structure under consideration.

Rooflights of equivalent glazed area admit very much more light than vertical windows (a fact which is not generally appreciated), and Figure 1 shows the relationship between light reflective sky areas and the window cases cited above.

Most city buildings have a widely varying natural light admittance when considering each floor, from pavement to roof level, and from facade to facade.

Once an evaluation has been made of the admittance potential of natural light through the windows, it is possible to assess the merits of a light switching system which allows the peripheral banks to be shut off, e.g. in three stages of depth, depending on the ability of the direct natural daylight to penetrate into the body of the space – see Figure 2.

It is now a standard function to computerise the natural light admittance and the artificial light requirement, taking into account the following –

1. Light occluding potential of surrounding buildings.
2. Overhanging reveals and related window position.
3. Diurnal and seasonal variation in the external light levels.
4. Light reflecting potential of the internal and external surfaces.
5. Probability of sun blinds being drawn.
6. Examination and reduction of glare problems.

Table 1
Behaviour of different glass types

Glass type			Coefficient of: Light transmittance	Solar radiant heat: reflectance	absorptance	transmittance direct	total
Clear glass	4 mm		0.89	0.07	0.11	0.82	0.85
Clear Float	6 mm		0.87	0.07	0.15	0.78	0.83
	10 mm		0.84	0.07	0.23	0.70	0.77
	12 mm		0.82	0.06	0.27	0.67	0.75
'Spectrafloat'	6 mm	51/65 (bronze)	0.51	0.10	0.36	0.54	0.65
	10 or 12 mm	51/62 (bronze)	0.51	0.09	0.42	0.49	0.62
'Antisun' Float	5 mm	78/65 (green)	0.78	0.05	0.43	0.52	0.65
	6 mm	75/61 (green)	0.75	0.05	0.49	0.46	0.61
	4 mm	54/68 (grey)	0.54	0.05	0.39	0.56	0.68
	6 mm	41/60 (grey)	0.41	0.05	0.51	0.44	0.60
	10 mm	24/48 (grey)	0.24	0.04	0.69	0.27	0.48
	12 mm	18/44 (grey)	0.18	0.04	0.75	0.21	0.44
	4 mm	61/68 (bronze)	0.61	0.05	0.39	0.56	0.68
	6 mm	50/60 (bronze)	0.50	0.05	0.51	0.44	0.60
	10 mm	33/48 (bronze)	0.33	0.04	0.69	0.27	0.48
	12 mm	27/44 (bronze)	0.27	0.04	0.75	0.21	0.44
Reflectafloat	6 mm	33/52 (silver)	0.33	0.28	0.29	0.43	0.52
'Solarshield'*		20/18 (deep gold)	0.20	0.57	0.36	0.07	0.18
		20/24 (gold)	0.20	0.47	0.42	0.11	0.24
		20/24 (bronze)	0.20	0.47	0.42	0.11	0.24
		38/38 (gold)	0.38	0.33	0.42	0.25	0.38
Coolray*		14/33 (silver blue)	0.14	0.27	0.58	0.15	0.33
		17/35 (grey)	0.17	0.24	0.59	0.17	0.35

Courtesy of Pilkington Brothers Ltd
* 'Solarshield' and Coolray are available in thicknesses 6.4 mm, 8.4 mm and 10.4 mm

Computer analyses

All these can be calculated by computer on an hourly basis, for an average day, for each month of the year, for each level of windows, on every separate facade.

The computation is relatively inexpensive and is the basis of any competent recommendation affecting the proposal to reduce the artificial lighting loads, and of course, the annual electricity bill.

Carpet and paint suppliers are now accustomed to supplying light reflective factors for their products, and the value of correct floor and ceiling reflectances in the successful manipulation of both natural and artificial light cannot be over-emphasised.

It can be easily demonstrated that the portion of the glass reaching from floor level to a height of 750 mm does not make a significant natural light contribution at the working plane. When assessing the optimum window areas, an energy balance must evaluate the winter heat losses against the year-round lighting potential.

Computerised energy studies on structures with vertical walls, and situated beside similar structures, show in the clearest possible terms the desirability of sizing windows, not only on a facade basis, but also a facade/floor-by-floor basis, in order to achieve true optimum energy saving for the building as a whole.

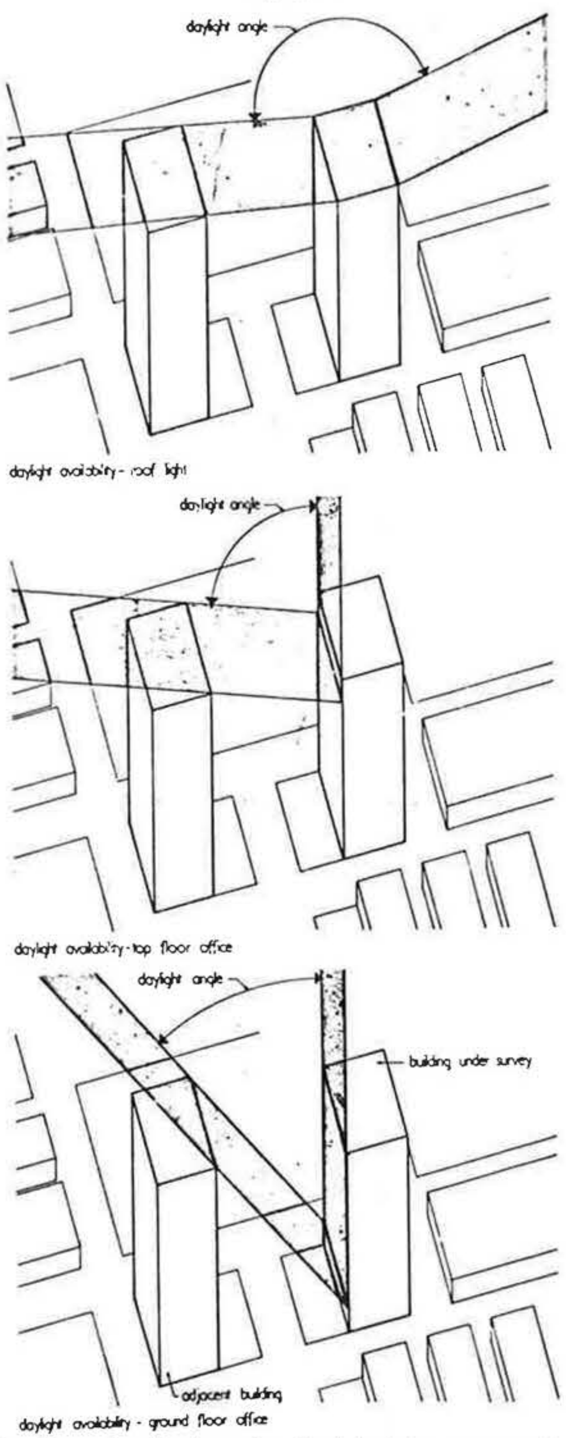
It is worth noting here that previous recommendations regarding the desirability of having small windows in order to conserve heat, have in the main, equated light energy directly to heating energy, and of course it should be realised that electrical (light) energy is supplied (and paid for by the consumer) at a pithead efficiency of 25 per cent, whilst an average in-house (heating) boiler operates at 75 per cent or more efficiency.

Also for air conditioned buildings, the extra electrical lighting load during the summer, when considering small windows, represents a load on the refrigeration plant in particular, and the system in general. Modern factory and office lighting systems should have the facility to reduce dramatically the lighting level when the only occupants are the cleaning staff.

It should be evident that a light meter is an essential part of the surveyor's equipment when investigating existing buildings, and even a general description of the natural light admittance might well be a deciding factor in any report, together with recommendations on the method of banking and switching the lights.

Should it be possible to reduce blanket switching-on of the lighting, it would follow that for those buildings which are air conditioned, there would also be a significant *reduction* in the refrigeration load, as less heat is being generated in the occupied areas.

Figure 1 Ratio of sky envelope reflecting natural daylight



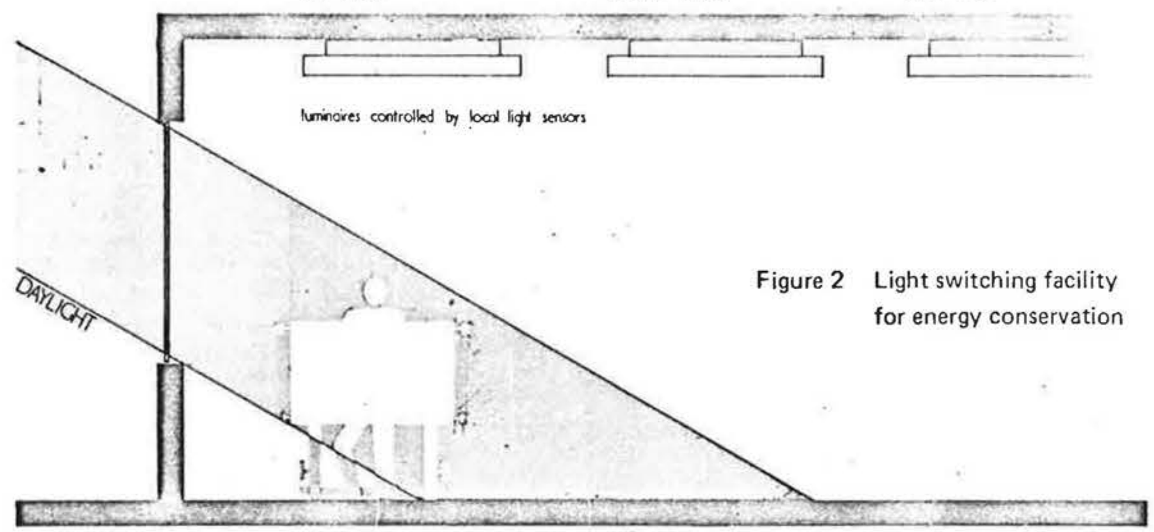


Figure 2 Light switching facility for energy conservation

Requirement for heating and cooling

All buildings are always in a constant state of thermal flux, with each of their facades responding to different internal and external stimuli, and with each facade having a varying sun-shadow pattern as the sun moves over the neighbouring buildings.

A cardinal design aspect to investigate when considering any heating or conditioning system is its ability to control efficiently the desirable internal temperature on a module basis.

A heating system should ideally control the room or module temperature, taking into account local instant heat gain conditions, for example whether the sun is projecting heat into the room, whether the lights are on or off, whether the sun blinds are drawn or not, and the number of occupants.

The heating systems typically encountered range from the simplest form which merely supplies constant temperature hot water, to uncontrolled radiators over the entire building. A more sophisticated concept would be the zoning of the building on a facade basis, with the reduction of the water supply temperatures in direct ratio to the sun heat and lighting load experienced at that time.

This can be achieved by measuring the water temperature returned from each zone, and reducing the flow water temperature accordingly, the object being to reduce the temperature levels. A further refinement would be the incorporation of thermostatic water throttling valves fitted to each radiator, which allows the sensing of the local temperatures and a commensurate reduction in the water passed into the radiator.

Some heating systems utilise fan convectors. Each small fan is switched on and off according to the dictates of a local thermostat, and the master control facility associated with these banks of convectors requires investigating, as does the electrical consumption of the fan motors.

All these measures tend to reduce the possibility of local over-heating, and to provide stable comfort conditions more economically than an unzoned, uncontrolled heating system. Should the building be equipped with an air conditioning system, the same cardinal question also should be asked – can the system efficiently control the correct internal temperature on a module basis?

Here it is worth drawing an analogy with the drawing of bath water. Hot and cold water are run into a bath in order to obtain the desired temperature; on the one hand there is cold water at tap temperature and on the other, the heated domestic water supply; the colder the tap water, the more hot water is required, alternatively the hot water needs to be even hotter.

Consider the situation if the cold water was refrigerated (as are the cooling systems of air conditioning plants). Here one would be using energy both to refrigerate and to supply more and/or hotter water – obviously a thermally inefficient procedure, although, and this is the underlying important point, the final bath water temperature is correct and acceptable.

Testing efficiency

Almost all air conditioning systems operate on this principle of mixing heating and cooling, and most also operate on a modular basis. The question is, how efficient is the system thermally?

The complete answer must rest with the mechanical services engineer. However, it is possible to outline some basic aspects to look for and report upon.

1. Is the air conditioning system designed to control the facades separately?
2. Are the terminal room units equipped to sense and control local temperatures?
3. Are the heating and cooling media programmed to vary their temperatures in sympathy with the thermal load?
4. Is any heat recovery equipment incorporated in the design?
5. Has the system been designed to reduce mass flow under low load or quiet hours conditions, and thus save on fan and motor electrical consumption?
6. Is the building equipped with solar reflecting blinds?

These questions are simple to enunciate; however, to formulate good quality answers requires considerable experience. Knowing the questions must be a good stride forward.

A great number of buildings are now equipped with sun absorbent or, in some cases, sun reflective glass; in all cases the cosmetic value to the building of these glasses must be evaluated *against* its particular daylight obscuring potential, and the factors reported.

Cost of maintenance

Before commencing the task of assessing the possible problems presented by the building, it is certainly most worth while to attempt to gauge the impact made by the existing or proposed buildings surrounding the site.

There are those aspects already discussed, e.g. natural daylight and sun penetration, but of course there are a number of other factors to evaluate; the most important include the following:

Additional solar load Should any of the surrounding buildings incorporate solar reflective glass, it is important to check that the reflected heat is not directed towards the building under consideration.

Short-circuiting of ventilation, heating and air conditioning plant Surrounding chimney exhaust stacks, cooling towers, and air extract systems from cafeteria and restaurants may all represent a pollution hazard to the building. On industrial sites one may encounter dust extract systems, or those handling offensive odours. It is necessary to assess whether or not the prevailing winds will tend to project chimney gases, cooling tower vapour and/or smells, into the intakes of the building under consideration.

Noise As more and more plant systems are incorporated, it is necessary to check the noise generated in the vicinity, and if one is considering houses or flats, then the nocturnal noise levels are of paramount importance. A typical case might well concern a block of flats positioned close to a supermarket whose refrigeration plant must be run 24 hours a day, throughout the week.

Turning now to the building itself, one is always presented with piping systems containing possibly various qualities of water, and expensive equipment ranging from new to very old. To a considerable extent the maintenance/replacement cost depends directly on the quality of the water treatment plant, and the upkeep of the log books relating to the water control.

In fact, many buildings never use water treatment, and the piping systems must be considered to be suspect. Should there be any doubt, it is worth while having short lengths of existing piping cut out for laboratory inspection. Systems should be tested for sludge, which accumulates at low points, and the facilities for draining out this material need surveying.

All systems should conform to the latest regulations in force, as, of course, a new tenant would inherit the legal requirements embodied in both the Health and Safety at Work Act and these regulations.

CIBS Energy Code – footnote

It is impossible to know at the design stage of a new building precisely how many occupants the building will house, exactly what they will be doing or how they will use the mechanical and electrical services – neither will the designer know the day to day weather conditions. Comparisons of design must therefore be based on standardised assumptions, but in the course of the design process the form of the building and its services will be fixed.

The building operator knows fully the properties of his building and the details of occupancy, use and climate which have been assumed by the designer. On the other hand the exact allocation of measured energy to the various causes of its use may be difficult to accomplish.

The designer then requires a standard method of calculation coupled with a set of standardised assumptions and guidance in their application. The operator requires methods for analysing his energy measurements, comparing those for one period with those of another and guidance on their allocation and interpretation.

Both will find target values of assistance for judging effectiveness. Consequently, a four-part Code was envisaged, consisting of (1) Design Guidance, (2) Design Calculation Method and Targets, (3) Operational Guidance and (4) Operational Comparative Method and Targets. Given their full titles, the Parts of the CIBS Building Energy Code are as follows:

- Part 1 – Guidance towards Energy Conserving Design of Buildings and Services
- Part 2 – Calculation of Energy Demands and Targets for the Design of New Buildings and Services
- Part 3 – Guidance towards Energy Conserving Operation of Buildings and Services
- Part 4 – Measurement of Energy Consumption and Comparison with Targets for Existing Buildings and Services.

Circumstances have necessitated the subdivision of Part 2 into two sections – Section (a) for heated and naturally ventilated buildings, and Section (b) dealing with mechanically ventilated and air conditioned buildings (in preparation).

Already the Property Services Agency is making full use of the procedures and targets outlined in the Code for the design of all future Government buildings. It is also likely that the provisions of the Code will be allied to future Building Regulations. The publication of the CIBS Building Energy Code has provided all professionals working with buildings, from conception to demolition, with a tool suitable for their use.

Part One

Parts 1 and 2 of the Code provide guidance at the design stage of new buildings, including alterations and extensions to existing buildings but excluding dwellings and premises with a large component of process heat, on means of achieving economic usage of primary energy whilst maintaining satisfactory levels of internal environmental conditions for the occupants.

The overall objective of this Code is to save *primary* energy and open the way for designers to plan for minimum primary energy usage by improving system efficiencies, exploiting techniques of heat recovery and the use of non-depleting energy sources etc.

Part 1 of the Code considers in detail the majority of the factors which control the usage of energy in buildings. Levels for the internal environmental conditions and the appropriate levels of performance and general design criteria for the building services etc on an individual basis are suggested, drawing on existing Codes of Practice etc, where possible.

Although the Code is aimed at buildings designed mainly for human occupation, many of the factors considered are applicable to other building types.

In the climate of the UK there is a general need that buildings be heated rather than air conditioned and it must be recognised that the latter use more energy than the former. However, air conditioning can be essential in certain circumstances such as: local urban pollution and noise that prevent windows being opened or high-rise constructions which do not permit windows to be opened for natural ventilation because of excessive wind speeds etc.

Part Two

The intention of Part 2 of the CIBS Building Energy Code is to help the designer of a proposed building and its services to *compare* the likely demands for thermal and electrical energy with quoted Targets, or standard values, for a similar type or class of building, both Targets and Demands being expressed as W/m^2 of floor area. It is not intended to forecast the future energy consumption of a new building.

The method of expression represents the mean annual heating and electrical powers likely if the recommendations given in Part 1 of the Code are followed. It is to be noted that section (a) of Part 2 of the Code refers only to buildings that are heated and naturally ventilated.

The method of calculating Demands for energy enables such calculations to be done manually, if desired, so that the consequences of changes in the assumptions made are readily appreciated; standard calculation sheets are available from the CIBS for this purpose.

It is anticipated that energy Demands will be calculated at progressive stages throughout the

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