March 1993

BEST PRACTICE PROGRAMME

General Information Leaflet

Energy Consumption Guide

ENERGY EFFICIENCY IN OFFICES

Energy efficiency and human performance: a guide for facilities and personnel managers

Purpose of this Guide

This Guide is intended for those who make decisions which directly affect office buildings and their day-to-day use, such as facilities and building managers, and those whose decisions indirectly affect long-term use, such as personnel managers or senior managers.

There is increasing evidence to show that organisations which have energy-efficient office buildings not only benefit from savings on energy costs for gas, electricity and oil, but also make further, much more substantial, indirect savings through higher staff productivity and other related qualitative benefits.

Many people think that energy efficiency is solely a technical matter for the building manager or services and maintenance engineer, but this is not so. It must also enter into long-term cost planning for the organisation as a whole for energy efficiency is also an indicator of management quality.

There is a long-surviving myth that buildings which are designed to be energy-efficient are somehow less comfortable for their occupants than "ordinary" buildings. On the contrary, energy efficiency and comfort go together and this is one of the reasons why energy efficiency and productivity are also connected.

Well-managed energy-efficient buildings tend to be more comfortable for their occupants, the people who use them are likely to feel healthier. They are less prone overall to complaints such as headaches and lethargy which arise in certain types of office building and disappear on leaving in the evening.

Energy efficiency, productivity, comfort and occupant health all go together in offices which have been designed with care and forethought and where managers and occupants understand how the building can be made to work to support their needs and activities. But this cluster of attributes is so far achieved only in an estimated ten per cent or less of British office buildings. This leaves great potential for improved performance, especially when managers understand more fully how these seemingly separate parts of their organisations' activities are, in fact, connected.

When the office (below) was converted from one-person offices to an open plan layout, little or no thought was given to how the controls for lighting and temperature would work in the new open plan arrangements. As a result, environmental conditions got worse and energy consumption rose by 17 per cent.

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Energy efficiency and comfort

Figure 1 shows the energy performance of six British office buildings over a period from December 1988 to September 1991. The carbon dioxide emissions from the fuels used to supply energy are proportional to their consumption, varying between different fuels. Thus a graph of carbon dioxide emissions broadly represents the relative costs of energy used by the buildings and also shows the contribution of the buildings to global greenhouse gas emissions. Carbon dioxide emission is shown as a proportion of the "treated" area (the floor area heated or air-conditioned).

There is a small upward trend in consumption over the three years, as well as three to fourfold differences in consumption levels between the buildings themselves. The upward trend comes mainly from increased electricity use for office equipment. The difference in consumption levels is partly because some of the buildings are naturally-ventilated and others air-conditioned with naturally-ventilated buildings in general producing much less CO_2 than air conditioned ones. A prestigious air-

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Energy Efficiency Office

DEPARTMENT OF ENVIRONMENT

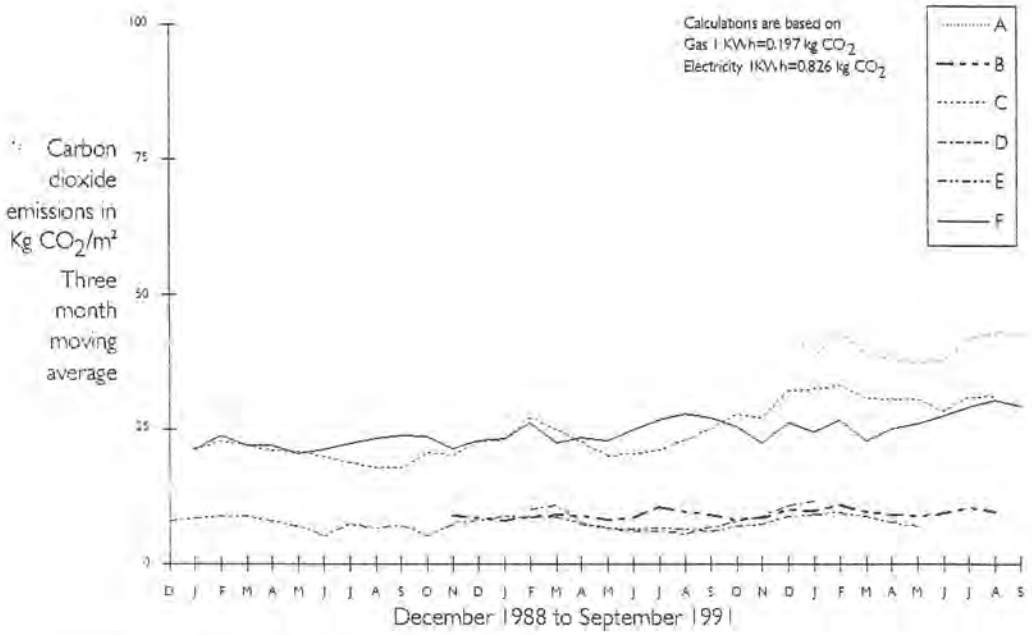

Figure 1Carbon dioxide emissions from six UK office buildings.

conditioned headquarters office, complete with restaurant and mainframe computer suite, would necessarily use more energy pro rata than a more modest office suite (For more information on these comparisons see *Consumption Guide 19*).

You would also expect the largest energy consumer - building A - to be prestigious air-conditioned; buildings C and F to be more modest air-conditioned; and buildings B, D and E to be naturally-ventilated. In fact, C is the most prestigious, and A and F nearly so. Building B is air-conditioned, not naturally ventilated.

Figure 2 shows how occupants rated comfort in the six buildings. Building B is exceptionally comfortable. Buildings C, D and F all are uncomfortable in one way or another. Building A is reasonable in all respects except temperature. Building E is comfortable all round, but not as good as building B.

The building rated by the occupants as the most comfortable is also the most energy efficient. The relationship between comfort and energy efficiency appears to hold across the other buildings as well, although less strongly than with the building B.

Buildings A and B are in many respects similar, but Building B uses nearly three times less energy and is much more comfortable. Why? The buildings are similar in age and have air-conditioning systems and similar occupants. Building A had more advanced energy-saving features than B including- a more advanced building management system and heat recovery system, for instance. However A is a speculative office operated by the landlord's management contractors who have been given no incentives to operate it economically. The fit-out ignored energy efficiency in lighting and local controls. The tenants do not have separate facilities to adjust time clocks or monitor energy operation and consumption in their own areas, the services systems run for much longer hours than necessary and are poorly controlled, if at all. Their costs are unnecessarily increased.

The landlord's areas of the building include the atrium which is lit and air-conditioned whether or not there are people in the building, increasing costs further. Overall, much energy goes to waste, especially in the lighting and air-conditioning systems.

Building B operates on different principles. Although rented, it was "pre-let" by the developer to the tenant well in advance of move-in, so that the tenant was able to have a role in the design and construction. Because the tenant organisation had a clear idea of what they required (influenced by a well-developed company mission) they were able to add these requirements to the building brief. Among them were an automatic lighting control system with local infra-red override controls for use by occupants and a building management system (BMS) with monitoring and control on a floor-by-floor basis. The tenant also appointed a building manager of the highest quality. Two design teams worked on the project: one on the developer's brief, the other on the working design itself. Building B achieves excellent levels of energy efficiency because it combines forethought in design (a well-developed brief with occupant's requirements included) with careful procurement (a well-managed briefing and design process) and high-quality day-to day management of the building in use.

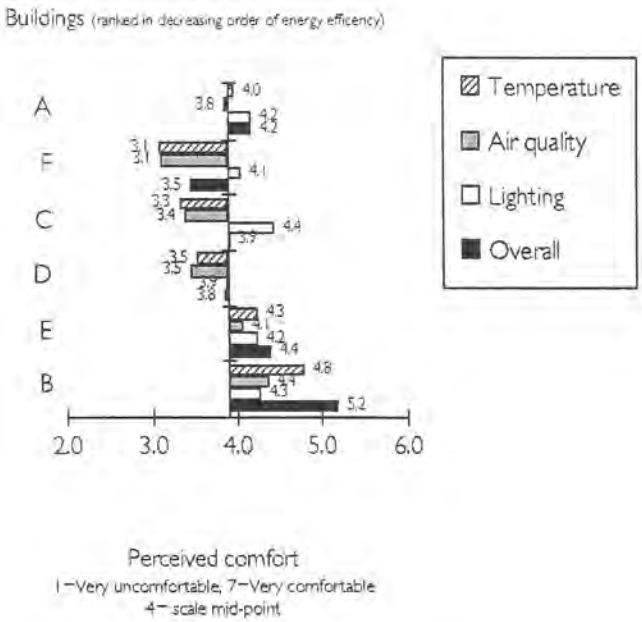

Figure 2 Perceived comfort of occupants in six office buildings

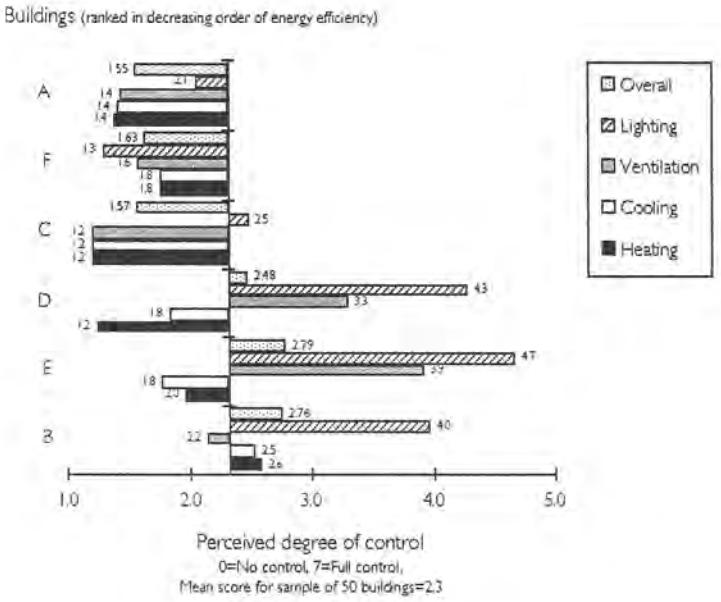

Figure 3 Perceived degree of control in six UK office buildings

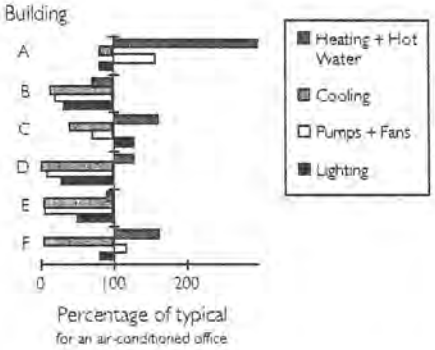

Figure 4 Energy consumption in six UK office buildings.

Interestingly, there was no explicit reference to energy efficiency in the brief. It was sufficient that the brief insisted that the systems were simple to operate and economical to manage.

Building B achieves comfort and energy efficiency through a well-managed briefing and procurement process in advance of occupancy and excellence in day-to-day management. The building management system, for instance, is used to monitor environmental conditions, so that temperature and ventilation are often adjusted in advance of any complaints from the users because the building manager knows what the occupants' preferred conditions are. When complaints occur, they are dealt with as fast as humanly possible.

The data-gathering systems used by the building manager are simple, but very clear and effective. Figure 1, for example, is based on the in-house method the manager uses to collect and present the energy consumption data for the building.

The monitoring, user feedback and rapid response systems, which combine the physical control systems and the day-to-day management systems, are very important in achieving user satisfaction, as will be explained in more detail shortly.

Although Building B is a particularly good case and demonstrates what can be achieved, Building A is more representative. While it is easy to blame the high levels of consumption on the management, the problem is more deep-rooted. Building A achieves reasonable comfort, but at the price of poor energy efficiency. As the controls have not been set up to suit the way the building is managed, they do not respond well when people become uncomfortable or when they make specific requests (such as wanting to use the building late in the evening). This lack of responsiveness, which is partly, but not solely, lack of controllability, is at the heart of many management and user problems in office buildings.

Control and productivity

Controls which are sensitive to occupants' needs are not just important for energy efficiency. They are also contribute towards health and productivity. Figure 5 shows why. The more control people perceive that they have over the temperature, ventilation and lighting, the more productive and healthy they seem to be. The more symptoms of ill-health that people experience, the less productive they say they are. Here, control over temperature seems to be the most important factor influencing productivity. People report higher levels of control over lighting (see Figure 3) but control over lighting is not as strongly related to productivity: it is more important for energy efficiency.

Some designers have reacted to findings such as these by adding controls into buildings in a gratuitous way: the more the merrier, they think. But evidence from buildings like D in Figures 1-4 is showing that, although the building may be relatively energy efficient, occupants' comfort has been sacrificed by control systems that do not work satisfactorily. "Nice to have" features are becoming more common, but people become impatient with controls that they do not understand or which do not function properly.

As Figure 3 shows, the more energy efficient buildings have higher perception levels of overall control and control over lighting and, in some instances, ventilation. Control is important, but not if devices do not work effectively, or if management is incapable of looking after the physical systems properly.

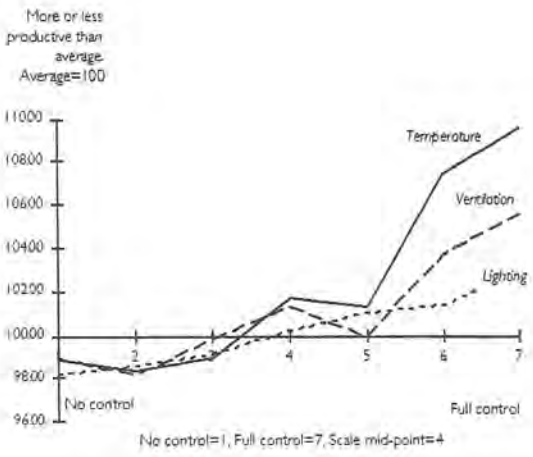

Figure 5 Control and Productivity

As people perceive an increase in control (bottom axis) over temperature, ventilation and lighting, so their assessments of their own productivity increase as well. Productivity is measured by polling self-assessments on a scale from plus 40 % to minus 40%, then taking each individual score away from the mean score for that particular building, to remove differences between buildings. The graph essentially shows that overall people report "negative" productivity (less than 100 on the productivity scale) when their perceptions of control fall below three on the control scale. Of the total sample of 5,000, relative few (less than 500) report high control (5 or more on the scale).

Rapid response

The essence of providing healthy, productive and energy efficient office buildings is rapid response. The best buildings, like Building B, not only keep people comfortable for most of the time, but respond very rapidly on the rare occasions when people do become uncomfortable as shown in Figure 6.

Where naturally-ventilated offices are preferred by their occupants to air-conditioned offices it is often not because the environmental conditions are any better (they may, in fact, be worse) but because the buildings, when they do become uncomfortable, are much more controllable. Greater controllability makes people more tolerant when things go wrong: they have, in other words, a higher dissatisfaction threshold in the buildings with more rapid response.

Rapid response can be designed into buildings through clearly understandable, easily-accessible, responsive controls like window blinds and light switches. Rapid response can also come from the management system, refined by facilities managers for suitable staff preferences. To some extent, excellent facilities management can make up for design deficiencies as well, but this is not always so.

Monitoring and feedback from occupants is an important feature of a successful management approach. Managers who have data about user's requirements and operating costs readily available, are also more likely to use this information for fault-finding and checking.

This all adds up to a "demand-led" approach to management, in which user requirements are treated systematically both at an everyday management level and in long term strategic planning. Understanding of everyday needs is eventually translated through the management system into new briefs and requirements for designers leading to buildings which are more appropriately designed for occupant's requirements.

Cost benefits

Office buildings with low energy consumption tend to have higher occupant satisfaction. Perceived comfort and control seems to come not solely from individual control devices but from the way systems - both physical and managerial - work together to react rapidly when people find that conditions are unsatisfactory. Greater controllability is also linked to higher staff productivity and better staff health.

A well-managed energy-efficient building can save 1-2 per cent of total operating costs, but this figure can become an estimated 10-15 per cent of operating costs, when staff productivity, satisfaction and health are taken into account as well.

As yet, there are no studies which have investigated all these associations in detail over large samples of buildings. The evidence used in this Guide comes from studies investigating ill-health and productivity in offices and from studies of energy efficiency (see box below). The links between the two have been established through the common link of control systems and control behaviours affecting both health and energy efficiency, but no studies have yet been carried out of the full cost implications to organisations.

Summary

- Office buildings often adversely affect the performance of staff, more so if staff perceive that they lack control over their environment.
- Lack of controllability is associated with ill-health problems, but it is also linked with poor energy performance.
- Buildings which respond rapidly when people become uncomfortable save energy by so doing, but they also make people more tolerant and happier with their conditions at work.
- Cost savings made through energy efficiency are also linked to cost-benefits gained from healthy, comfortable productive staff.

Management strategies

- The key for management is providing a "rapid response environment". This can be achieved by simple controls linked to local services zones which in turn respect patterns of work activities, and by management systems which monitor usage and react quickly.
- As long as this design and management approach is in place and people can perceive responsiveness when things go wrong, naturally-ventilated, air-conditioned or "mixed mode" (a combination of the two) can all work well.
- Complaints about comfort are more common when people are affected by the actions of others, especially those not within their immediate working groups. Keeping groups together, and ensuring that control actions by individuals do not conflict with the needs of others, is essential. This applies particularly to those sitting away from the windows in the middle of deep, open-plan floors who are often adversely affected by the behaviour of those in the window seats.
- Simple and comprehensible control is best, avoiding unnecessary complexity in the control device interfaces and in the technical features of the systems themselves. Do not be seduced by lists of technical features; concentrate instead on functions that work reliably.
- Devices should give clear indications that they are running properly, so that people know they are switched on or set. Often, people do not know that systems are running unnecessarily and would switch them off if they did.
- Try to create an environment where the standard default setting for lights and equipment is "Off". Once on, lights tend to remain on because it is often difficult or time-consuming for people to arrive at rational switch-off decisions.
- Monitor what is happening to energy consumption by fitting meters to buildings and/or sub-areas: read them regularly and plot the results.

You may find that energy-efficiency is the best measure of management excellence that you have!

People usually perceive discomfort and decide to do something to change the conditions only when a dissatisfaction threshold has been exceeded. Naturally-ventilated buildings often are controllable enough to bring conditions back below the threshold relatively quickly. Occupants like this, and may put up with often worse conditions in exchange for the added control and faster response times.

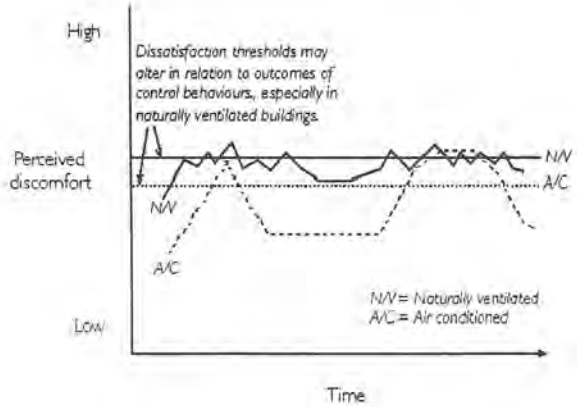

Figure 6 Response times and discomfort

This Guide has been written by Adrian Leaman of Building Use Studies. The information in it is drawn from two studies carried out by Building Use Studies: *The Office Environment Survey* (1985-87) and *User and Automated Controls and Management in Buildings* (1991-1993). Further details may be found in S. Wilson and A. Hedge, *The Office Environment Survey: A Study of Building Sickness*, Building Use Studies, London, (May 1987) and K. Bromley, W. Bordass and A. Leaman, *Improved Utilisation of Building Management and Control Systems*, CIB/IEA Symposium on Energy Efficient Buildings, Stuttgart (9-11 March 1993). Other useful sources are the Energy Management Guide, Brecsu Information Leaflet 12, January 1993 and Bordass W. and Field J., *Energy Utilisation, Audits and Management*, chapter 3 of the second edition of Building Maintenance and Preservation by E. Mills (ed), London, Butterworth, 1993.