OPTIMISING THE IRRELEVANT?
LESSONS FROM REAL BUILDINGS IN USE

Bill Bordass *

SYNOPSIS

Case studies and monitoring of completed low-energy commercial buildings frequently reveal that their overall energy consumption is too high. Common reasons for the shortfalls include:

> MISPLACED PRIORITIES, for example efforts to make marginal (and sometimes unrealised) savings in heating and cooling loads, without paying the same amount of attention to the HVAC installation and its control, and perhaps installing lighting which does not even meet rudimentary levels of efficiency.
>
> POOR INTEGRATION, and in particular the lack of a coherent approach to planning, construction, servicing, control and management.
>
> ACHILLES' HEELS, where lack of attention to critical (sometimes almost trivial) details can undermine otherwise sound proposals.
>
> OVER-COMPLEX BUILDINGS AND SYSTEMS, which prove difficult to understand, to manage, and to maintain.

The key to better buildings appears to be through good integrated practice: in briefing, design, installation and management. Critical areas requiring attention include:

- A better feel for where the energy is actually going and where avoidable waste can occur.

- A better understanding of the needs and requirements of building users, including the development of a briefing language which takes better account of how ongoing change in a building is managed.

- Understanding how to use technology to improve the functionality of a building, rather than to transfer problems from one place to another; and

- A more professional approach generally, including the members of the client, design and building teams working better together: the present climate of fee and design competition can get in the way of this, with principles established too hastily and details not fully resolved.

* Principal, William Bordass Associates, 10 Princess Road, London NW1 8JJ
Phone & fax +44 171 722 2630
email *Bordass@usablebuildings.co.uk*
website *www.usablebuildings.co.uk*

INTRODUCTION

Energy-efficiency is an essential attribute of a green building. Fuel-burning is a major source of pollution and over about five years a typical building consumes as much primary energy as was used to build it and to extract, make and transport everything that went into it (1).

This paper is largely on commercial buildings, and principally offices, which I have studied most over the past few years. It concentrates on how these buildings use energy, where waste occurs, and how performance and energy efficiency could be most easily improved. It does not deal with the wider issues of whether we have the right buildings in the right places to minimise the overall environmental burden.

Feedback of experience from buildings to the people who design and build them is often poor. Success is judged largely by the absence of complaint and if systems do not go badly wrong they are often thought to be working well. The success of building services is largely measured by occupant comfort and reliability: failure to achieve the expected energy performance is seldom noticed (and sometimes not measurable - even some recent energy-award winning buildings have not got their own meters!). Where problems are found, they are often regarded as anecdotal one-offs and blamed on mistakes, poor commissioning or on the incompetence of the user. But over a wider sample of buildings similar things recur.

A SENSE OF PERSPECTIVE

Nearly twenty years after the first oil crisis there is still a surprising level of ignorance about how non-domestic buildings use energy. We are not good at describing them, their occupancy and use, and their energy-consuming systems in a comparable manner; we are sloppy in defining important parameters such as floor area; and comparisons are often made in terms of total delivered energy when some energy supplies - and particularly electricity - have much higher primary energy use, cost and environmental impact than others.

Figure 5.1 compares delivered energy consumption, energy cost, and carbon dioxide emissions for a typical office: the messages you get from each are very different! In particular, heating fuel - which looks quite important in the delivered energy histogram - becomes much less significant, and in an office insulated to current building regulations heating could already be down to half these levels, or less. But even today too people still concentrate on reducing heating loads while much more costly electrical consumption is taken as a matter of course!

Ten years ago the London Energy Group developed a format for comparing information (2), but despite continued efforts, and a simplified version, it has not been widely used to date. But until we can talk systematically about such things, can we hope to set meaningful energy and environmental targets for buildings? With EC Directives looming, BRE is now investigating standard methodologies for assessment and reporting energy use data.

Without a clear language for comparing energy consumption, it is relatively easy for anyone to demonstrate that their proposed building will be energy-efficient. Undertake some theoretical calculations - with or without a computer model - and compare these with measured figures from existing buildings. The answer is likely to be considerably smaller, but this may be partly - or even largely - because some things have not been allowed for and systems are assumed to work perfectly in practice. This is illustrated graphically in Figure 5.2. The design looks good because of the assumptions used, but will these assumptions hold?

Designers, their institutions, and energy models often seem to put more stress on reducing theoretical energy demands than on minimising the sources of waste in practice. Sometimes the optimum solutions don't work, are too complex and impossible to manage, or are not tailored to meet the real needs of the users. Are we optimising the irrelevant? The gap between what we expect and what we get seems to be widening, but if it is not closed then credibility will be lost. We need to concentrate not only on improving a building's potential to be energy-efficient but on how this potential can be realised effectively in practice. In a word, we need to understand how to improve a building's *functionality*.

LESSONS FROM BRECSU OFFICE CASE STUDIES

Figures 5.3 and 5.4 from Energy Consumption Guide 19 (3) show typical annual energy consumption and cost for four different types of office:

- Type 1 — Simple, naturally ventilated cellular.
- Type 2 — Naturally-ventilated open-planned.
- Type 3 — Fully air-conditioned speculative.
- Type 4 — Air conditioned head office, with restaurant, computer suite etc.

The increase in energy consumption and cost with type is not only a function of the HVAC system. More complex and up-market buildings tend to have a whole variety of higher-energy attributes, for example an air-conditioned building also tends to be deeper, make use of artificial light, and have more IT in it.

The BRECSU Office Case Studies sought buildings which performed better than average for their type in most, if not all respects. They took into account all the building's energy consumption - not just the good bits! In 1988 it wasn't very easy to find suitable buildings, and a current quest for more Case Studies is having similar difficulties.

Why were good buildings so hard to find, even among those which claimed to be energy-efficient?
Using tried and tested techniques, it should be relatively easy to attain good practice levels shown in figure 5.5, at least for the building services components of the energy consumptions. Some reasons for the shortfalls are outlined below.

1 THE CLIENT HADN'T ASKED FOR ENERGY EFFICIENCY

One can hardly expect design teams to respond actively to things their clients don't seem to value. Something needs to be in the brief, even if it is just that energy-efficiency is important and it mustn't cost any more! A shared concern for energy helps the team pull together and a problem addressed is well on the way to being solved.

2 DESIGNERS DIDN'T OFFER ENERGY EFFICIENCY

Of course nobody in this audience would write or accept a brief which didn't include energy efficiency. However, if your fees have been cut to the bone, the architect has been selected on the basis of price and perhaps drawings prepared for nothing for planning consent; the consultant team has not been appointed until afterwards and may never have worked together before (or want to again); why make extra rods for your own backs?

3 DESIGN APPROACHES NOT INTEGRATED

Hardly surprising in the light of 1 and 2 above! If client isn't very interested, colleagues aren't being paid, and the brief says nothing about it, it is not easy to make energy a central part of the design agenda. Fee competition and litigation also seem to have forced individual professionals back into their corners, with areas of joint collaboration, inquiry, innovation and attention to detail consequently being neglected. In energy-efficiency professional skills really can add value: designing-out as well as designing-in, and fee agreements need to recognise this. With a high-energy approach, in principle one can put in more plant and burn more energy to create the internal environment one wants. But designing-out can be labour intensive: integrated, energy-efficient designs are delicate: a series of small steps, all leading towards the final objective. However, too often one finds that there have been two steps forward, one step back.

4 UNEVEN PERFORMANCE

Excessive preoccupation with heat loss has already been mentioned, and even a number of energy-award winning buildings are only good in one or two respects; usually heating and lighting. Similarly, in air-conditioned buildings cooling load reduction, chiller efficiency and heat recovery tend to receive more attention than minimising fan power, which is frequently the higher energy user, and controlling systems energy-efficiently at low loads. In some buildings, the money being wasted by inefficient computer room air-conditioning systems would be enough to pay the whole building's heating bill.

5 TOO MUCH FAITH IN TECHNOLOGY

Energy technologies are a means to an end and not an end in themselves. Machinery, however efficient, has a habit of consuming energy and can run away with quite a lot if left to its own devices. It also needs maintenance and management. Inappropriately applied, it can also alienate end-users. The design ambition should be to have no more technology than necessary to do the job, and for that necessary to be as efficient, uncomplicated and reliable as possible.

6 ENERGY EFFICIENCY NOT AFFORDABLE

With energy costs more-or-less back at 1960s levels in real terms, added capital costs can be difficult to justify, particularly for those who sell-on and/or let their buildings to people who do not regard long-term running costs as significant. This is a severe obstacle if energy efficiency is seen as an add-on extra-cost item. However, often what looks expensive may be affordable as part of an integrated concept. For example high-frequency lights, good reflectors and automatic lighting controls look expensive and indeed in the *One Bridewell Street* Case Study 21 (4) the developer asked the tenant to bear their additional cost. But in the end there was no added cost: fewer fittings were required, the air-conditioning had less heat to take out, and wiring-up and fitting out (not to mention later alteration) was much easier and quicker with no switch drops to contend with.

7 UNSURE ABOUT THE BENEFITS

The lack of good and consistent information about where energy goes and where one can reasonably save can make it difficult to know exactly what one should be doing and how to achieve the objectives.

8 DIFFICULT TO MAINTAIN

Often people are seduced by the technologies and start adding-on features before the essentials are as efficient as possible. This adds to the complexity of the system and to its control and maintenance requirements. "Add-on" features also tend to be the first to fall off, particularly if systems continue to work without them . It is better to build-in efficiency, for example by using condensing boilers than to have a less-efficient ones plus heat recovery.

9 DIFFICULT TO OPERATE

Often it takes a lot of effort to get building services and environmental control systems to work properly and energy-efficiently. Designers often blame poor management for this, but conversely one can claim that many buildings are more complex, inappropriately controlled, and more difficult to manage than they deserve to be. Adrian Leaman of Building Use Studies is at present attempting to relate the complexity of a building and its services to the amount of management required to look after them and the related human aspects. The relationship could well be an S-curve (figure 5.6), which rises rapidly in the central section. If management does not appreciate this and tailor its effort accordingly, problems are likely to appear as symptoms of this unmanaged complexity, often in the form of staff dissatisfaction. People who move into technologically more complex buildings without appreciating the management implications - and designers who encourage them to think that technology, flexibility and automation is the answer to all their problems - may be in for a shock. The solution may be better management, but could it alternatively be simpler buildings?

10 USER SATISFACTION PROBLEMS

In terms of comfort, performance, management, maintenance and user-friendliness. Energy efficiency is a reward for a good job well done: anyone can save energy by making people miserable!

11 NO MONITORING OF ENERGY CONSUMPTION AND COST

Most offices lack even the most elementary methods of reviewing overall energy consumption and expenditure, even though these can often be sensitive indicators of hidden problems. Sub-metering of energy supplies to different parts of the building and systems in it is often non-existent and - where it exists - seldom used, at least other than for landlords billing tenants (and they often prefer to apportion on a floor area basis).

12 INSUFFICIENT ATTENTION TO DETAIL

Often the principles are fine but the design has one or more Achilles' heels. Energy-saving controls often don't work properly because their ergonomics have not been thought-through and people don't use them in the anticipated manner. For example, people may object to automatic lighting controls which cannot take account of the fact that the blinds are down in their particular room. Systems can also come apart when operated under conditions which the designer has not properly foreseen. The most common if these is the "tail wags the dog" effect, where a large system operates uneconomically to satisfy a very small load - or sometimes even no load - at the end of it. Common examples are the use of central heating boilers to provide hot tap water in summer, and the use of large chilled water systems out of normal working hours to cool a few internal rooms which may have year-round cooling requirements and machine rooms with 24-hour loads.

13 CLAIMS NOT RELIABLE

Information on building area is often wrong and claimed energy savings based on design studies may not have materialised in practice. Sometimes some energy uses or human frailty and control problems had been ignored in the calculations, or energy consumption was transferred from one area to another - as when small windows to save heat increase the cost of electric lighting by an even greater amount. At a more high-tech level, heat recovery systems are often justified only in terms of the heat "saved", while the extra electrical costs of running the associated fans, pumps and refrigeration systems are underestimated or even ignored.

The more successful buildings demonstrate good design, good execution, good management and appropriate technology, at normal levels of capital cost. There is evidence of a virtuous circle: with energy efficiency just one of the symptoms of a well-designed and well-managed building. Nevertheless, none of the case study buildings is without scope for improvement, often quite substantial: avoidable waste still remains. In some of the buildings not chosen for case studies, some of which were designed to be low-energy, the avoidable waste can be tremendous.

SOME DETAILED PROBLEMS

It is not enough to get the principles right: the ideas actually have to work in practice. In existing buildings, both energy-efficient and otherwise, too many measures lack functionality. Here are a few examples.

1 NATURAL VENTILATION

Effective natural ventilation does not come automatically with opening windows: they have to be designed for the job. In many recent offices they fall short, unable to supply sufficient fine control for winter use, good draught-free cross-ventilation for heat removal, and adequate air movement on still days. Often the root cause is the attempt to use a single opening element to do a job which was previously done by two or three.

Some "green" offices aim to use thermal capacity and night ventilation to avoid air conditioning, but in practice windows are often shut tight to keep rain or burglars out, locking-in heat from the previous day. Even when windows are left open they may not work very well unless there are intelligent security guards who will close them if it starts to get too cold. Perhaps some automation is required (5).

2 MECHANICAL VENTILATION

Some low-energy buildings supplement natural ventilation with mechanical systems, to solve the night security problem, provide controlled wintertime ventilation (sometimes with heat recovery) and to give additional summertime air movement.

However, recent monitoring indicates often disappointing performance:

i Energy use by the fans is often disregarded, but some systems use more energy for night ventilation in summer than would have been necessary for daytime comfort cooling to lower temperatures by refrigeration!

ii Night cooling is often less effective than the designers predicted, owing to fan heat gains, poorly-located air intakes, recirculation of warm air through partially-open dampers, heat recovery devices not properly by-passed, poor or poorly-maintained controls, and lower heat transfer rates between air and fabric than anticipated, particularly in floor voids.

iii Wintertime heat recovery is not entirely free: not only is electricity used by the fans, but the additional controls, heater batteries etc. introduce their own parasitic losses, as was found at the BRE Low-Energy office (6). The mechanical ventilation rates may also be higher than those found acceptable naturally, causing additional - and possibly unnecessary - heat losses.

This is not to say that some systems are not effective: merely that automatic success should not be assumed - a lot of care and thought is necessary to get systems which are both effective and low-energy.

3 NATURAL LIGHTING

Good natural light is difficult to achieve, particularly in open-planned areas where people have restricted choice over their furniture layout and seating position. Windows can often end up as sources of glare, so the lights stay on anyway, either because the blinds are down or in order to reduce contrasts. Good window design plus effective provision of glare control devices are essential.

4 ARTIFICIAL LIGHTING

Buildings, even low-energy ones, are often uneconomically lit. Criteria for efficient lighting - for example the 3 W/m^2 per 100 lux used as an entry criterion by EMILAS - do not seem to be widely used, particularly in office fit-outs. Many offices seem to be over-lit, often perhaps through conservative application of recommended standards: ideally such standards should be seen as the starting point for a dialogue with the client.

Lighting in corridors, reception areas, restaurants, WCs etc. can also be uneconomical and often seems to have escaped scrutiny. In one building where great care had been taken to ensure good daylight and efficient, well-controlled artificial lighting in the offices, the lighting of circulation and common areas was so inefficient by comparison that its energy use exceeded that in the working areas!

5 LIGHTING CONTROLS

Often lighting is poorly-controlled, even by the standards of BRE Digest 272 (7), which itself was not developed for offices with VDUs. Often controls are of the wrong kind and in the wrong place, and difficult to manage, and so lights stay on unnecessarily. Energy consumption by high-intensity discharge lights - often used in uplighters - can be high because their prolonged run-up and restrike times causes them to be left on "just in case".

6 CONTROLS GENERALLY

An ongoing study of controls in buildings is revealing major mismatches between the ways in which controls are configured and operate and the most energy-efficient mode of operation. One common problem is a lack of appreciation of the role of the user in the control loop. For instance, multi-tenanted buildings have sophisticated controls which can potentially switch on and off systems in each tenant's premises. However, these are not used fully because there is no information system to tell the operators what the tenants want. Nor is there the incentive to set such a system up, since the tenants are obliged to pay for the landlord's energy via their service charge in any event. Often the systems are operated according to the rules of "supply-side" economics, where energy is consumed regardless of whether there is a demand, with the default state of many systems being ON, not OFF. It would not have been difficult in principle to configure the systems to respond to tenant demand instead, but they seldom are.

SOME RULES

1 THE CLIENT BODY NEEDS TO ORGANISE THEMSELVES

Clients should know what they want and set up - or be helped to set up - mechanisms to allow them to have creative discussions with their designers and to make good decisions.

2 THE RIGHT DESIGN TEAM

It needs to be selected to tackle the energy and environmental issues, be given the right responsibilities, and be appointed and paid appropriately.

3 A WELL-INTEGRATED DESIGN

The team must to work together and to explore passive methods to reduce the building's dependence on active ones which need energy, manpower and maintenance to work effectively. Decisions on costs etc. should be made in the interests of the whole project.

4 AVOID UNNECESSARY TECHNOLOGY

Energy-efficiency technologies should be concentrated on what consumes the most energy or where energy costs are most easily reduced. Make sure what you have got is efficient before adding something else. So before adding heat recovery, make sure you have got a good boiler, and before adding lighting controls, make sure the lights are efficient!

5 REVIEW STANDARDS

Designers will often be conservative and design to meet the worst case. The client may be happy to aim for a lower level or provision and treat worst cases as a management problem. For instance, a low-energy lighting scheme might fall short of recommended illuminance standards, but nevertheless be acceptable if good daylight is available and there is a policy to give supplementary lighting to those who ask for it.

6 THINK ABOUT ADAPTABILITY

Don't let special cases rule the design. Be suspicious about highly-flexible solutions: they may contain features unlikely ever to be used and which may get in the way of other things.

7 CONSIDER HOW THE BUILDING WILL BE USED

Frequently designers envisage a god-like figure sitting at the control panel or computer console and running the building. Very few organisations have paragons like this, who both understand the plant and the needs of the people in the building. One can easily get the wrong control facilities in the wrong place, so make sure you are always asking *"how would one actually go about using this?"*. If possible, make sure that the people who are going to run the building are identified early on and are able to comment on the design, and make sure the building is compatible with the time and the expertise available to run it.

8 INSTALL MONITORING DEVICES

Make sure that information is available so one can tell how the building is performing. BEMS can also give valuable diagnostic information but seldom seem to be programmed to do so. For instance, we have not yet found a building with night mechanical ventilation which alerts the operator if the supply air temperature is significantly above outdoor air temperature: this could be a useful warning of problems such as damper failure. Indicators, sub-meters and hours run recorders also cost very little but the information they give is invaluable, at least when anybody bothers to think about it! I would certainly recommend metering major plant items, catering kitchens and computer rooms and their air-conditioning.

9 HAVE AN ENERGY BRIEF FOR FIT-OUTS

Office fitting-out is often done in a hurry, and too often by space planners and interior designers for whom energy efficiency - and frequently even building services and their controls - do not seem to be a high priority, and sometimes not even on the agenda. Make sure that they are. Lighting is often the main culprit: the fittings may be decorative but they can often be wasteful and poorly-controlled.

CONCLUSIONS

Green buildings seem to have caught the imagination, but people may not have fully appreciated the effort and attention to detail necessary to make them work properly in comfort and energy terms. In particular more work needs doing on simple, efficient, reliable systems, with more effective combinations of natural and mechanical systems and more user-friendly controls. If we do not address these issues vigorously now, we risk a backlash from disappointed clients.

Fortunately, however, the cloud may have a silver lining. If a building is humane, people seem to be more likely to forgive minor shortcomings. For instance, in the buildings with thermal capacity and night cooling monitored last summer, problems of design, control and management made them warmer than they should have been, but nobody seemed to mind very much (more systematic user surveys are planned for this summer). As Humphries' work showed in the sixties, people are more tolerant of high temperatures in "free-running" buildings, and his diagram (8) is still incorporated in the CIBSE Guide. Perhaps the key to a green building is putting people first: and if this is evident to occupants, they may respond accordingly.

On the other hand highly-engineered, non-intuitive, environments may sharpen peoples' sensitivities to problems, and this should make us cautious about the more high-tech approaches to green buildings. For example, natural ventilation which does not come through the window in the usual way may be perceived as some rather ineffective form of air-conditioning! In engineering environments for the future, perhaps we need to move away from what is precisely measurable and design for the subjective as well. After all, that is what comfort is all about!

REFERENCES

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2 Energy Reporting Format, London Energy Group (1982).

3 Energy Efficiency in Offices: A Technical Guide for Owners and Single Tenants, Best Practice Programme Energy Consumption Guide 19 (Energy Efficiency Office, Oct 1991).

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5 A H C van Paassen & P J Lute, Natural Ventilation and Automation with Manual Overriding are Healthy Solutions, Symposium on Healthy Buildings in relation to Building Services, Utrecht (17-20 February 1992)

6 R W John & A C Salvidge, The BRE Low-Energy Office - Five Years On, Building Services Engineering Research & Technology 7(4) 121-128 (1986).

7 Lighting Controls and Daylight Use, BRE Digest 272 (April 1983).

8 CIBSE Guide Section A1, Environmental Criteria for Design, figure A1.2 (1986).

26-Mar-92

1	Blank	
2	EE in buildings	*5 years!*
3	Lessons from CSs	
4	Energy statistics	*Not primary energy!*
5	Need for more clarity	
6	BSRIA histograms	
7	Type classification	
8	Type 1	
9	Type 2	
10	Munters	
11	Type 3	
12	Type 4	
13	Typical vs good practice cost histos	
14	Landlord/tenant	
	CSs aimed to be better than average in all respects	
15	CS cost histos	*Point out fridge, fans+pumps*
16	Energy priorities	
	Some of the good performers were rather surprising	
17	Hempstead House	
18	Hempstead interior	
19	Hempstead lights	
20	Bridewell exterior	
21	Bridewell interior	
22	SSWC exterior	
	New search is having a hard time finding anything better	
	The league table	
23	Histograms incl MM	*Discuss HH and 1BS here too*
24	SSWC light shelves ext	
25	SSWC slight shelves int	
26	SSWC unbrellas	
27	NFU low angle	
28	Features of EE bldgs	

	Where do they trip over: they could do far better	
29	Attention to detail	
30	Quadrant House	*NB: was a gas-guzzler*
31	Stockley atrium	*Discuss crimes of atria*
32	Laing corridor	*Discuss W/m2 too*
33	Arab Bank junked outstation	
34	Refuge lights	
35	Mendip lights	
36	Telford window	
37	Telford window opener	
38	William Ellis window	*Draughts and glare*
39	Stukeley window	*Conflicting strategies*
	Not just knocking copy: this is the state of the art	
40	Common horror stories: design	*Discuss integration + multi-steps*
41	Common horror stories:management	*NB: no meters!*
42	Leaman S-curve	*Design for manageability*
	Will you do any better?	
43	OPTIMISING THE IRRELEVANT?	*NB: functionality*
44	Actual and theortical energy costs	
45	Trying too hard	
46	Design for usability	
	Where next	
47	ENERGY EFFICIENCY NEEDS	
48	BS the solution, not the problem	
49	Simple control diagram	*The operator doesn't only twiddle*
50	More modern concept	*Who sits at the control panel: God?*
51	What should controls be doing?	
52	Individuals are the best judges	
53	Remember the people!	*Green buildings are people-centred*
54	BLANK	*Sort it out, or risk the backlash*

OHPS

Discuss controls	
Discuss summertime temps	*Remember light load!*