ENERGY EFFICIENCY BEST PRACTICE PROGRAMME

Technical Review of Office Case Studies and Related Information

General Information Report GIR 15

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SECTION 1

INTRODUCTION, SUMMARY AND CONCLUSIONS

1 INTRODUCTION, SUMMARY AND CONCLUSIONS

1.0 Acknowledgment

BRECSU and the authors would like to express their grateful thanks to all the people and organisations: occupiers, landlords, designers, researchers and managers who have furnished information and provided access for these case studies and the related background work, freely and enthusiastically. The information obtained has been invaluable and we hope that it will help people to understand how energy is used in offices and how their energy and environmental performance could be improved. The studies have produced evidence of a virtuous circle: a good client is more likely to appoint a good building team who are more likely to provide a cost-effective energy-efficient, productive and humane building which a good occupier is then likely to manage well. Good briefing, good design, good building and good management - with attention to the user and to detail all along the way - appears to be the basis for an energy-efficient office, with technology used in support of this effort, not as an end in itself.

1.1 Introduction

1.1.1 This report gives the technical background to a series of Office Case Studies, undertaken between July 1988 and June 1990. Although the case studies were the best we could find of a range of types of office, they are not necessarily the very best, and there is none which does not offer scope for improvement, often quite substantial in some respects. The studies should therefore be seen as interesting and instructive sources of information, not icons to emulate in every respect.

1.1.2 The report was first produced to make the link from the individual Case Studies to overview documents and to Good Practice Guides and Consumption Guides under the Best Practice programme. It was not initially intended for publication, but BRECSU is now making it available in response to demand from researchers and others.

1.2 Structure of the report

1.2.1 *Chapter 2 - Energy use characteristics of offices*

As background to the Case Studies, information on energy use in the UK office stock is first reviewed. We attempted to seek consistency between a variety of published information and material we had collected. We conclude that some published targets may be more exacting than might be expected, for the following reasons:

- Sometimes not all energy uses are included in the target.
- Theoretically-based targets can overlook some inefficiencies which occur in practice.
- When information is collected by questionnaire, offices at the low-energy end of the sample are likely to include many with faulty data.

Organisations who routinely collect office energy use and cost data do not always seem to be getting the best value out of this information. It would be worth collaborating with them to improve the quality and scope of the data available. BRE is developing standard formats to allow information from different sources to be compared more readily and rigorously.

Although our work was largely concerned with the private sector, the information available suggests that public sector offices may well use less electricity and more fossil fuel than private sector ones. Some possible reasons are put forward, but this needs exploring in more detail. The situation is also changing rapidly at present with the growth in office information technology and with changing arrangements for the management of public sector buildings.

Owner-occupied buildings are the minority in the UK office market. The speculative development process and the landlord/ tenant split does little to improve energy-efficiency, and this tends to discourage an integrated approach to energy-efficient design and management of office buildings as a whole. Indeed, even good data on energy use in multi-tenanted offices is hard to come by. While there is scope for discussing energy-efficiency in lease and service charge negotiations, this seldom seems to happen: tenants have little to say about the energy-efficiency of their building shells, and they and their consultants often seem to have had limited interest in the energy-efficiency of their fitting-out either. In the current buyers' market, things are beginning to change, increasing opportunities for energy-efficiency measures which are usually most cost-effective when considered early in the briefing and design process.

1.2.2 *Chapter 3 - Selection of the case study buildings*

It was more difficult than expected to find suitable buildings for case studies. Not only did people not volunteer them easily, but many of the offices that seemed good at first sight proved to be inappropriate. The main problems were poorly-integrated or operating designs; claims based on design data, not measured results; over-normalisation of energy performance indicators (particularly for hours of use); single-technology (or single-fuel) measures, rather than an all-round approach; and over-complicated solutions which often used more electricity than anticipated. On the other hand simple, unpublicised buildings which are quietly performing very well may be difficult to find and therefore have been overlooked in the process.

1.2.3 *Chapter 4 - Case study methodology*

This discusses how the analyses were carried-out, attributing energy consumption and costs to end-use. Two important points were a consistent definition of treated floor area (see Appendix C) and to take account of the higher costs, primary energy use and environmental impact of electricity in relation to fossil fuel. A standard methodology and reporting format for office energy use information could be very helpful, allowing statistics to be collected consistently and reviewed within and between organisations. BRE is developing such a methodology.

1.2.4 *Chapter 5 - Characteristics of the case study buildings*

This outlines the structure, services and occupancy of the buildings in order not to slow down the argument in Chapter 6.

1.2.5 *Chapter 6 - Energy consumption of the case study buildings*

This is the core of the report, and by far the longest chapter. It outlines the detailed patterns of energy use in the the twelve case study buildings, and four others *(which are given generic names in this report)* which were analysed to the same level of detail but were not published: either because they did not meet the final case study criteria or because the owners did not wish their buildings to be identifiable. It discusses the reasons for the - sometimes large - differences in energy consumption and costs for different buildings and end-uses.

1.2.6 *Chapter 7 - Energy costs for the case study buildings*

The project focused on energy consumption, not costs, although information on costs was also collected. This chapter reviews the reasons for the differences in the fuel prices paid by different buildings, relates them to tariff structures etc., and suggests some simplified unit rates which might be employed in Best Practice programme (BPP) material.

1.2.7 *Chapter 8 - Performance yardsticks for typical offices*

Many offices contain a diverse range of space, services and equipment and really require an individual energy target, derived most easily in a parametric manner via a microcomputer programme with question-and-answer screens. Meanwhile, however, we have identified four typical offices with very different characteristics and energy consumption and cost profiles for both "average" and "good practice" buildings, and these have been incorporated in BPp material, particularly Energy Consumption Guide 19.

1.3 Some conclusions from the Case Studies

1.3.1 The sixteen buildings reviewed have diverse patterns of energy use and are seldom good in every respect, offering opportunities for further improvement. Their efficiency cannot readily be gauged by total annual energy consumption per unit floor area, and even this simple index can vary over a wide range for the same building, depending on the area measured (gross, nett or treated), the items included (normal building services only, or everything), and the energy units (primary, delivered or otherwise weighted). Here we use the following primary standards:

- Treated floor area as the usual denominator *(see Appendix C for definition).*
- Fossil Fuel + 3.5 x Electricity (F+3.5E) as a simple index of the very different costs, primary energy consumption, and environmental impact of these two distinct energy supplies.

We also concentrate less on the overall figures per unit area and more on their fine structure.

1.3.2 The naturally-ventilated buildings usually have considerably lower energy costs per unit treated area for "normal" building services than the fully air-conditioned ones. This is not just because of the air-conditioning: there are clusters of complementary features which tend to reinforce their relative positions:

- Naturally-ventilated offices are more likely to be more cellular, more narrowly-planned and better-daylit, reducing their overall electricity use substantially.
- High lighting energy use is strongly correlated with open-planning (whether good daylight is available or not) which in turn is correlated with air-conditioning.
- Air-conditioned offices tend to be considerably larger, with more IT, more catering, higher occupation densities, and more diverse occupancy patterns all adding to their energy intensity.

The extra pumps, fans and refrigeration for the air-conditioning itself usually add at least 50 and typically 70-100 kWh/m^2 per annum to annual electricity consumption. In the buildings studied and visited, differences in energy use often depend more on detailed design, commissioning, control, operation and management than on the technologies adopted. On the other hand, there is some indication that air-conditioned buildings may be somewhat more densely-occupied than their naturally-ventilated counterparts, making their energy-intensity more affordable than it looks on an area basis. This was certainly claimed some years ago but never fully verified: further investigation here could be of interest, though it would need to be very detailed to give reliable results.

1.3.3 The Case Studies suggest that although heat gains from office equipment are currently rising, at their present levels they can often be accommodated without air-conditioning, particularly if equipment which does not need to be on or near the desk-top can be located where it does not raise the temperature of the general office space. Future increases in equipment consumption may not be as steep as anticipated if the office equipment continues to become more efficient. The *mixed-mode* building, which combines natural and mechanical systems, may offer an intermediate - and potentially more humane - step between natural ventilation and sealed buildings with full air-conditioning, and allow the building to be "tuned" to suit the actual needs. Three of the Case Studies *(NFU Mutual & Avon Group, Refuge Assurance,* and *Hereford & Worcester County Hall)* offer high quality office space - to a standard normally associated with full air-conditioning - at energy consumption levels closer to naturally-ventilated offices. However, the margins may be getting fairly close as the building services energy consumption of *One Bridewell Street* (admittedly the lowest-energy fully air-conditioned UK office yet identified by us, and which owes much of this to an exceptional level of management), is very similar.

1.3.4 Human management can be at least as important as technology in securing good energy performance, particularly in air-conditioned buildings. as these have much more potential for wastage if fans and pumps run for excessive hours, heating fights cooling, and pressure drops are too high. At *Quadrant House, One Bridewell Street,* and *Hereford & Worcester,* management has fine-tuned systems and exploited their potential for closer control, with impressive results While BEMSs can be a powerful aid to good management, they are no panacea: in many buildings they have proved to be incompatible with, or too complicated for, the level of management available and - in hindsight at least - could have been better specified and detailed.

1.3.5 This brings us on to behavioural issues. The Case Studies and other candidates surveyed often contain things which do not work properly owing to a lack of attention to simple, practical user needs, and such problems seem to be widespread. At the individual scale, windows and their ironmongery may give poor control of ventilation and light switches may be in the wrong place. At the building scale, electronic controls can be difficult to understand and to troubleshoot, and in the wrong place. More work on these issues is recommended - they often fall between professional boundaries and are not addressed properly by anyone.

1.3.6 Grand technological gestures, by architect or engineer, are usually just that: they may be interesting but seldom seem to be the answer to practical and cost-effective low-energy offices. For example, high insulation may not help much if the engineering is not designed and managed to deal efficiently with the smaller loads; passive solar gains may merely cause glare; daylight does not guarantee that the lights will stay off; complex energy systems may well not be operated and maintained as the designers intended; and saved heating and cooling energy may turn up instead as extra parasitic losses from pumps, fans and unforeseen control problems. While it is important to innovate (and to learn from monitoring that innovation) the greatest savings nationally are likely to be come from simple applications of available technology in a manner which integrates architectural, engineering and user requirements, and provides control and management systems to suit.

1.4 Future steps

1.4.1 Looking forward from the Case Studies, the main priorities appear to be as follows:

1 Planning to avoid excess energy dependency
2 Effective and user-friendly control and management, both manual and automatic.
3 Care in the design and operation of computer rooms, where present.
4 Efficient natural and artificial lighting
5 Efficient fans, pumps and refrigeration in air-conditioned buildings.
6 Reasonable insulation and efficient, well-controlled heating.
7 Energy-efficient and well-managed catering and vending operations.
8 Careful selection, location and operation of office equipment.
9 Keeping everything as simple as possible.

These are be outlined in the paragraphs below.

1.4.2 Planning to avoid excess energy dependency

People often design for the worst case, so if an office is noisy on one side it is not just protected there but sealed-up entirely, or if internal heat gains are likely to be high in one area, air-conditioning with high cooling capacity is specified throughout. A more measured approach is required, which uses plan, section and location to use areas with either dominant requirements for HVAC systems (computer rooms, kitchens, conference rooms etc) or minimal ones (plant rooms, stores, circulation etc.) to buffer other parts of the building from hostile external environments. Similarly, servicing systems need to be less of a blanket provision and more able to accommodate ad hoc changes. At the same time, more information would be useful, on a continuous basis, and perhaps as part of consumer reports, on actual levels of energy use of typical equipment used in offices and how to minimise them - and the impact of their heat output on the office environment - through selection, location, operation and servicing systems. Some information is available in Energy Consumption Guide 35.

Today many people think that full air-conditioning is essential to counter heat gains from office equipment. However, in all but one of the Case Study offices internal gains from desk-top equipment were quite modest, with mechanical cooling essential in a few areas only. Much of the small power consumption was actually by things not in the general offices but in their own rooms (print rooms, machine rooms, telephone exchanges), or from vending machines, photocopiers, file servers etc which could often be - and sometimes are already - in areas with local heat extraction or cooling, reducing internal gains at the workspace. The scope for natural ventilation in much of the office of the future - assisted, where necessary, by low-powered mechanical ventilation and cooling - may be greater than conventional wisdom suggests: such approaches are already demonstrated more widely in Scandinavia and Germany. While future growth in IT is sure to occur, a parallel growth in heat gain at the desk-top is by no means inevitable, at least in the longer term.

1.4.3 Effective control and management systems

Control and management must be more central to the design of the building and its services, not something that gets added-in piecemeal. Clients and design teams need to think more about how a building is likely be used - even if it is a speculative one - and to design systems which not only do their job, and do it efficiently, but can also simultaneously satisfy the different needs of individual users, individual tenants and the building's management. It is not enough for designers to complain that clients do not appoint management and maintenance staff of the calibre necessary to run their building: some things can also be selected and designed differently, to relieve the burden on management, which needs to be recognised as a scarce resource.

Behavioural and ergonomic issues are also important, both for sophisticated controls (where, for instance a device can easily be over-ridden permanently ON without giving any clearly-visible warning), and for manual systems, for example light switches, window ironmongery, room thermostats and sunblinds. Many of these issues fall between professional boundaries and are seldom addressed methodically by anyone. Indeed, the environmental performance of the building fabric and envelope as a whole tends to fall unsatisfactorily between the professional responsibilities of the architect and the engineer.

1.4.4 Careful design and management of computer rooms

Where they exist, mainframe computer installations and their air-conditioning can cost more to run than anything else in the building, and are an often-neglected target for cost-effective energy-saving measures. Many buildings visited offered scope for reducing computer air-conditioning energy consumption by improved control and management, but these did not often seem to have been considered: once the system was stable nobody was inclined to touch it - even if much more plant was often running than was really needed - for fear of disturbing an environment which, however inefficiently created, had proved satisfactory for the computer in practice. On one site, the whole boiler plant was kept on year-round for LPHW to be available on the rare occasions when the computer plant required reheat (which would have been much more appropriately electric in this instance). At another, the modular plant hunted over its full control range every 20 minutes or so!

The first thing is to be sure that the computer equipment and its operation use no more energy than necessary, and that the room is also economically lit, and operated in darkness where possible. The air-conditioning should be designed and managed to minimise its energy demands, remembering that pumps, fans and humidity control systems often use more energy than the refrigeration itself. The costs and benefits of heat recovery and free cooling should be related carefully to the overall efficiency of the base systems, and not just the bad bits. Sometimes money will be best spent on simple modifications to a standard system, for example larger coil sizes. Indeed, a general rule for most building services is to make the essential equipment as efficient as possible before considering additional devices for energy-saving purposes only.

1.4.5 Efficient natural and artificial lighting

Lighting energy costs are very variable and can be very high: in many offices most of the lights are not very efficient and are on for all the working day and beyond. Considerable savings are possible by combining good daylight, high-efficiency light sources and fittings, and good controls. There are horses for courses: for example in a cellular office, with good daylight and sensible switching, the low running hours may make it difficult to justify the very best fittings on grounds of cost-effectiveness, and electronic controls may be at best of marginal benefit. In open-planned offices, lights will tend to be on for much longer, making the case for efficient fittings and/or good controls much stronger: any extra costs can sometimes be met by reducing the size of any air-conditioning, or sometimes avoiding it altogether. If one compares good practice open-planned offices of the 1970s with those of the late 1980s, the reduction in annual energy consumption by the lights is often greater than the increase in annual energy use by office equipment.

The mere availability of daylight and a control system does not guarantee that they will be used: this needs care in lighting design to avoid glare, and a user-friendly controls specification. Tinted glass seems to make people want the lights on all the time whatever the daylight levels, and some studies correlate them positively with "building sickness" problems: clear glass is preferable provided it is suitably designed and shaded to control glare and solar gains. However, with today's computer screens etc., daylight is not always a good thing: local controls need to be fine-grained and automatic switching patterns readily-adaptable to accommodate the different and changing needs of individuals. The Case Studies indicate that any dislike of Big Brother automatic control is much reduced where there is good individual control (for example by telephone or hand-held unit) and if the system is well and comprehensibly managed. for example with switching-off (even under photoelectric control) only at known, regular times.

Many offices visited were over-lit in places, often it seems because designers feared they might be taken to task for falling below a specified illuminance standard. Sometimes twin-tube fittings were specified where a single tube of the same length or one size up might well have done, perhaps in a somewhat more efficient fitting. For installations near the border-line, more discussion between clients and designers is recommended: uncertainties can sometimes be resolved in a test room, particularly for refurbishments and fit-outs. Where the lights have to be on for long periods (as in internal corridors), high efficiency, effective control, and avoiding over-lighting is particularly important, but many designers did not seem to have recognised this, even where they had gone to great lengths to improve daylight and energy efficiency at the workstation. Naturally-lit corridors and stairs also offer amenity value and are good candidates for photoelectric control.

1.4.6 Efficient air-conditioning: fans, pumps and refrigeration

The need for air conditioning and the cooling loads falling upon it should be kept to a minimum by effective plan, section and location of the building, using shading to control solar heat gain, minimising internal heat gains, and removing unwanted gains at source rather than by refrigeration. Fabric heat losses should also be kept down: claims that offices with high heat gains only need to be poorly-insulated are usually specious.

Economical air-conditioning requires the energy consumption by refrigeration, fans and pumps *as a whole* to be minimised: people often seem to be more concerned with the chillers, while fans in all-air systems run for much longer and frequently use more energy over the whole year. Fan energy consumption can be reduced by:

i *Minimising air volumes.* Potentially this is a problem in view of the current concern to improve indoor air quality, but better management of air quality and air circulation does not necessarily mean more fan power or fresh air loads. Variable air volume is no panacea, its annual fan energy consumption in practice is seemingly little different from comparable constant-volume systems, where design operating pressures tend to be lower.

ii *Minimising pressure drops.* Measured pressure drops in many systems are excessive, sometimes owing to space restrictions which reduce duct and plant sizes or introduce constrictions. Another common problem is where fan power has been increased to overcome balancing problems at commissioning stage: generous, compact, largely self-balancing ductwork systems are preferable.

iii *Considering whether the cooling effect might better be transported by pipe.* Direct transfer of chilled water or refrigerant may be more economical in some circumstances.

iv *Reducing hours of operation.* Frequently main fans operate for excessive hours because there is a demand in one part of the building. Zoning is important, but should not be too elaborate: local plant is often better for areas with occupancy patterns very different from the norm.

The building must be seen as a system, not as a set of discrete parts. For example, relatively high-quality air is often exhausted direct from the building while new outside air is conditioned to meet lower-quality requirements, for example ventilating stores, toilets and circulation areas, where the high quality exhaust air could sometimes be re-used. Similarly, in winter, it may be possible to pre-heat incoming fresh air in a simple way by passing it through roof voids and circulation spaces and over condensers.

While pumps tend to use a lot less energy than fans, chilled water and condenser water pumping energy is significant and often wastefully applied, particularly if the constant-volume systems run for long hours at low loads and the water simply by-passes at 3-port valves and returns to source. For large systems with diverse use patterns, constant-pressure systems with variable volume pumping might be better. However, small out-of-hours loads are usually best serviced individually.

Refrigeration plant should be efficient and well-managed. Efficiency is particularly important where the plant has necessarily long running hours. For significant wintertime cooling loads, options for "free cooling" need to be investigated. Normally this will involve using outside air, which is more viable today now humidity control limits seem to have been relaxed in practice. For loads which persist day and night, waterside and thermosyphon free cooling may be worth investigating, particularly for the larger building. Good management is essential for all systems and frequently seems to be absent: many chiller installations appear to be poorly-controlled and sequenced and the associated pumping systems can be on - usually at full output - for far too long.

Reference 50 describes some commonly-used air-conditioning systems and the potential for improving their energy-efficiency in an engineering sense, though with less attention to the control and management issues. One problem with air-conditioning is that once you have it - and it may be invaluable in certain parts of the building and at certain times of the year - you continue to run it, even at times when natural-ventilation would require little or no energy to achieve a similar result. The alternative *mixed-mode* designs might offer the best of both worlds, with a base provision of a low-powered air handling system, windows that can be opened for more ventilation if the occupants wish, and additional cooling which is mobilised only when and where required. Until heat gains from office equipment are properly tamed, mixed-mode shells and more adaptable air-conditioning could well be the low-energy way forward.

1.4.7 Better heating and insulation

Many people think that improving insulation is still the single most important thing to do. The case studies indicate that this only applies in very simple naturally-lit and ventilated offices and even here we are at the point of diminishing returns unless high insulation is part of a very carefully-considered scheme. With 1990 Building Regulations insulation and good (preferably low-emissivity) double-glazing, ventilation/infiltration and heating system efficiency usually become the more important targets, and these in turn may be less significant than lighting and sometimes fan power. Even in old, poorly-insulated buildings, better insulation is often fairly low on the list of cost-effective priorities, though with the advantage of potentially being a long-term, low-maintenance investment.

Heating plant, systems and controls often offer great scope for improvement. Only one of the Case Study offices had condensing boilers (and they were not optimally controlled) and in all of them more boilers were usually on line than strictly necessary, sequencing systems almost universally not working as the designers expected. Heating seasons in air-conditioned and mechanically-ventilated offices were usually longer than in naturally-ventilated ones: after a chilly night in summer the latter can delay opening their windows while the former need to heat their ventilation air. Ventilation heat recovery could therefore have a double benefit, provided systems are simple with minimum extra electrical power requirements, which can otherwise cut rapidly into the value of the heat saved.

1.4.8 Energy-efficient catering

Office catering kitchens are normally run by contractors who often have no financial incentive to conserve energy as their client pays for it. Wasteful operation seems to be common and equipment is often specified without taking energy-efficiency into account. Changes in contract conditions, for example where contractors are metered and charged for their energy use, could give mutual benefits. On the equipment side, low energy does not always come cheap and so may not be cost-effective in relatively lightly-used office kitchens. Vending machines can use a significant part of the small power: they tend to be left on all the time and some do not appear to be particularly efficient, again perhaps reflecting that the market at present is not energy-conscious. Ideally all devices would be put through standard test cycles (including the ability to recover from being switched-off overnight and at weekends) and the results published and compared.

1.4.9 More economical office equipment

Although office equipment is proliferating rapidly, power levels are not quite as high or rising quite as fast as many had anticipated a few years ago. Some of the growth is also in back rooms and not necessarily at the desk top. The need for air-conditioning therefore seems to have been exaggerated, with most parts of most offices capable in principle of functioning for at least the greater part of the year in a well-designed naturally-ventilated building. Naturally-ventilated and mixed-mode offices making better use of fabric heat storage and overnight "free" cooling should have a wider margin. Whether this situation will continue will depend upon:

- *The rate at which IT becomes more energy-efficient.* New developments (converging technologies, low-energy displays, new printer techniques) are beginning to take things in this direction and the pace could quicken rapidly if better information was available and consumers began to select equipment partly for low energy use and demand upon building services.

- *The degree to which occupants will accept a management solution to high heat gain areas.* In any office there may be clusters of equipment which require additional cooling. If management is prepared to put these in parts of the building designed to accommodate them, or alternatively can bring in local "spot" cooling, then many offices may be able to cope without full air conditioning.

- *The degree to which people can be persuaded to switch off their equipment when they do not need it.* Keeping office equipment on permanantly is a worrisome habit which seems to proliferate as equipment becomes networked and people become more familiar with it. This typically quadruples hours of operation and makes dissipating surplus heat from the office overnight difficult if not impossible. Continuous operation is seldom necessary and people must either be talked-out of it or the equipment itself needs to take care of the problem and power-down automatically.

More understanding of the pattern of internal gains in offices is essential, both ongoing for individual items of equipment (best perhaps done via international standards and test cycles) and with investigations of usage patterns in individual offices (now under study by BSRIA and others). Better information here could advance the cause of energy-efficiency by avoiding oversized and sometimes even unnecessary air-conditioning systems.

1.4.10 Keeping things simple

It is tempting - and seemingly common - for people to reach for the technological miracle cure when the real answer lies in good, sound design, good management, and simple means of making sure that people can get the services they require while not wasting energy unnecessarily. A good rule is to make all the essentials: passive design features, boilers, lights, fans, as effective, efficient and as well-controlled as practicable before including any additional equipment, and particularly any which requires careful attention and whose failure wouldn't necessarily be noticed. Items which are not essential, have a much higher chance of not being properly looked after! Where possible, controls should default to off, or at least to an energy-efficient standby state: too often at present the opposite occurs, with systems left on just-in-case. Simplicity is particularly important for the smaller building which will seldom have suitable management or engineering staff on site to deal with complex systems.

SECTION 2

OFFICE ENERGY USE CHARACTERISTICS AND TARGETS

2 OFFICE ENERGY USE CHARACTERISTICS AND TARGETS

2.1 Units of measurement

2.1.1 For comparison purposes, energy consumptions and costs in buildings are usually stated in annual units of energy, divided by some measure of extent: normally area, volume, production, or number of occupants. The figures are sometimes standardised for degree-days, exposure, and hours of use, but the corrections themselves tend to introduce their own inconsistencies and here we have preferred to work with the raw data and correct it separately afterwards.

2.2 Energy and cost units

2.2.1 kWh per annum is used as the main energy unit here. We started with the SI unit of MJ, but we found that, in spite of the simple conversion factor (1 kWh = 3.6 MJ), most people had some understanding of what a kilowatt-hour was, but no feeling at all for a megajoule! Average energy costs paid for the period of measurement were collected and are discussed in Chapter 7, where they are also converted to a standardised 1990 base.

2.2.2 Frequently delivered energy units are summed directly, whatever the source and cost of the fuel. This approach was adopted, for example, in CIBSE Building Energy Code Part 4 (reference 5) and subsequently developed by the Audit Commission for their Normalised Performance Indices (NPIs - reference 8) and used in the EEO's 1988 "Energy Efficiency in Buildings" series (Reference 1). This is unfortunate, as it ignores the fact that - at least in recent years - electricity has tended to cost three to five times as much as heating fuel. Hence two buildings with the same NPI can have vastly different annual energy costs, and indeed the NPI of a building can be lowered by transferring load from heating fuel to electricity, while energy costs usually rise! Conversely, improving energy-efficiency by installing CHP plant usually increases NPI! The EEO's Energy Efficiency in Buildings series have now been revised and contain performance indicators which treat fossil fuels and electricity separately.

2.2.3 Since arguments continue about the relevance of primary energy and greenhouse gas contributions, and the correct factors to be used, we treat the consumption of each fuel separately where possible. Where a single combined index is necessary, the simple Fossil + 3.5 x Electrical, 'F+3.5E' index used by the PSA gives rankings very similar to those for primary energy, carbon dioxide emissions, and cost.

2.3 Units of extent

2.3.1
- Volume is interesting when comparing between different building types, but creates inconsistencies within types: for example, an air-conditioned building with a higher floor-to-floor height would have a reduced index, which seems somewhat illogical.
- Occupancy is instructive, but difficult to quantify without undertaking a detailed survey. Organisations can usually tell you who is based in a particular building for payroll purposes, but not how much time they spend in it.
- Floor area is the unit most commonly used, and we have found it the most practical and convenient here. It is the unit in which offices are briefed, designed and sold, and is a figure which will be commonly to hand (albeit often inaccurately, in our experience).

2.3.2 Three measures of office floor area are in common use:

GIA	Gross internal area (normally in square metres), by the building design professions.
TA	Treated (or heated) area, by building services engineers and energy consultants.
NLA	Nett lettable area (in square feet), by the property industry.

While the RICS has clear definitions of GIA and NLA, it does not say anything about TA. CIBSE mentions TA in several of its publications, but does not have a consistent definition, sometimes including plant rooms, sometimes not. For all the case studies GIA, NLA and TA were measured on a consistent basis by DL&E. Working definitions of these terms, including one of TA which was developed for this project, are outlined in Appendix C. For comparability where necessary, data from other sources has also been converted to TA, using the conversion factors in Table 2.1 where no better information is available.

TABLE 2.1

STANDARD AREA CONVERSION FACTORS

	Treated to gross	*Nett to treated*
Naturally-ventilated	*95%*	*80%*
Simple air-conditioned	*90%*	*80%*
Sophisticatedair-conditioned (with restaurants, computer suite etc..)	*85%*	*80%*

2.4 Theoretical energy consumption targets

2.4.1 Procedures for estimating office energy consumption (some of which are outlined in Appendix D) usually assume fairly simple, homogeneous office space, services and operations, without the complications which often occur in real buildings, for example differing intensity of use and equipment, special areas like computer rooms, conference areas, stores, restaurants and car parks, and irregular occupancy patterns. With more complex dynamic models, there are also concerns about verification and the correct inclusion of control and management aspects where detailed design, user behaviour and management practices can be very important. The main discrepancies between predicted and actual figures can often arise less from physical models of heat transfer etc. as from incompatible, unrealistic, or optimistic assumption sets and differences in measurement conventions for floor area etc.

2.4.2 CIBSE Building Energy Code 2A (reference 2) is most commonly used for naturally-ventilated office designs in the UK. Part 2C, for air-conditioned offices, is due for publication in 1994. Both are based on theoretical calculations only and are seen to be more applicable for comparison of options than for prediction of actual consumption levels. Documented comparisons between 2A predictions and actual performance are rare, and those that have been published suggest that:

- *For heating,* it is difficult to meet the thermal demand targets, let alone the Code values, as is discussed, for example, in monitoring reports on the *BRE Low-energy office* (reference 3) and *South Staffordshire Water Co* (reference 4).
- *Electricity consumption* tends to be highly variable, both above and below target and code figures. For example, in references 3 and 4, lighting energy use was very low, owing to good daylight, automatic controls, and at *BRE LEO* cellular offices with low initial occupancy.

For offices completed in the mid-1980s, Part 2A often predicts annual energy use for heating and hot water between 60-100 kWh/m^2 of treated floor area (as in the PSA targets in Appendix D). In practice, recorded fossil fuel consumptions of under 100 kWh/m^2 seem to be much rarer.

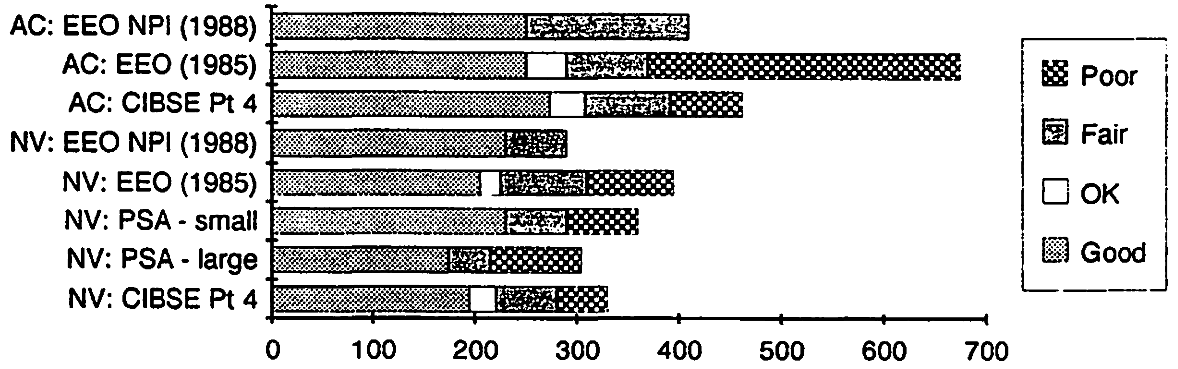
2.4.3 Part 2A only deals with electrical consumption by lighting and by heating pumps and fans. All other electrical uses "are not considered to be an environmental factor". This can lead to considerable inconsistency between claimed office electrical consumptions. For example, quoted figures which appear to include all sources of energy consumption in fact refer to lighting and heating ancillaries only, or to landlord's services alone, sometimes in buildings where these are merely the tip of the iceberg. On the other hand, other offices can be inappropriately classified as "poor" in energy terms when the building itself is satisfactory: office equipment and particularly computer rooms accounting for the excess energy consumption.

2.5 Practical energy consumption targets.

2.5.1 Practically-based targets address a range of offices, not only naturally-ventilated ones. Because they tend to look at the stock as a whole, they can be lenient for recently-completed buildings where a drop in low-cost fossil fuel consumption owing to better insulation levels etc. often masks a worrying growth in electricity use. CIBSE Building Energy Code Part 4 (reference 5) and the EEO performance indicators (references 1 and 6) are the main UK sources: these are reviewed in Appendix E, where all the figures are converted into kWh/m^2 of treated floor area.

2.5.2 Figure 2.1 compares the various yardsticks, shown here for the sum of delivered fossil fuel and electricity for consistency across the various sources. For the naturally-ventilated buildings, only 15% ± 5% of the delivered energy consumption within the yardstick is electrical; with air-conditioning typically 40% ± 5%. While some published yardsticks do not quote "Satisfactory or OK" levels, all include either "Poor" or a "Very Poor" to the right of the bars drawn.

FIGURE 2.1 Annual energy use yardsticks (kWh/sq m treated)



2.5.3 The figures from the various sources are all reasonably consistent, except for a high "poor" range for air-conditioned buildings in EEO 1985 (reference 6), probably because the sample included offices with computer suites. The association of "poor" with high energy consumption is not necessarily a good one: the energy may be being used for legitimate business purposes. "Computer centres" were treated separately in EEO 1988 (reference 1), where the meaning of this term was not defined: the energy consumption levels are consistent with head offices with mainframe computer suites occupying perhaps 5% of total floor area, not dedicated data processing centres whose energy consumption would be very much higher altogether.

2.6 Targets for preliminary selection of Case Study buildings

2.6.1 A review of the various published targets indicates that - excluding computer rooms and assuming a normal flexitime 5-day week - the annual delivered energy consumption of a "good" naturally-ventilated office would be 200 kWh/m^2 or less: about 175 kWh/m^2 of fossil fuel and 25-30 kWh/m^2 of electricity. A "good" air-conditioned office would less than 275 kWh/m^2, about 175 kWh/m^2 again of fossil and 100 kWh/m^2 electricity. Depending on source, "good" is likely to represent something between the lower quartile and the lower decile of the stock.

2.6.2 Similar criteria were used as an initial coarse filter for Case Study candidates (see section 4), but proved more difficult to meet than might have been expected: a second search for future Case Studies in early 1990 (reference 7) was more productive, though a detailed follow-up in 1991 revealed very few buildings which performed significantly better than those already identified. Even in offices which met the overall totals, the electrical component was nearly always higher than the target values. This was not only due to the recent growth in electronic office equipment: "good" electrical targets in naturally-ventilated offices were often exceeded by lighting alone, and were usually only achievable if daylight was both good and efficiently utilised, and artificial lights low-powered. But many - probably most - offices rely upon permanent or near-permanent artificial lighting and it did not seem reasonable to dismiss them all from further consideration.

2.7 Review of the published targets

2.7.1 There seem to be five main reasons why offices within the published "good" energy targets proved relatively difficult to find, particularly for their electrical consumption:

i Not all the energy use has been reported (see also 2.4.3 above).

ii The energy and area statistics used in determining energy targets usually rely on self-completion questionnaires, not independent audit. "Low" energy users therefore include those with large positive errors in floor area, or negative errors in energy consumption.

iii People often err on the generous side in reporting hours of use, so energy consumptions get scaled-down by normalisation when occupancy patterns are in fact perfectly normal.

iv Data from the PSA and the Audit Commission has been widely-used in compiling targets. PSA's definition of treated area includes plant rooms, lowering the target levels slightly in naturally-ventilated buildings and by 10% or so in air-conditioned ones.

v This contract concentrated on the private sector. Background information suggests that - at least in the recent past - public sector naturally-ventilated offices often consumed less electricity than private sector ones, or at least those which provide data on energy consumption! This is a consequence of a higher proportion of cellular offices and lower illuminance levels in the public sector, with more routine occupancy and operating patterns. At first, the public sector was also slower to adopt office information technology.

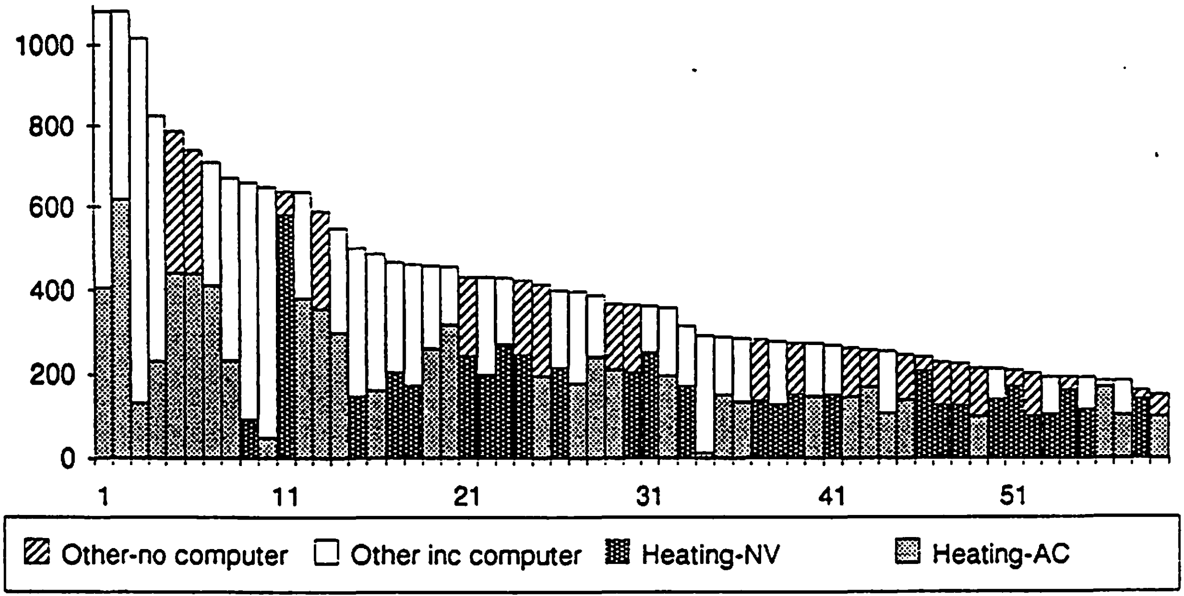
Conversely, public sector offices seem to have slightly higher heating energy consumptions than single occupants in the private sector: this probably originates from older plant and lower insulation levels on average, slower refurbishment cycles, and arguably different management procedures which distance responsibility for building and plant management from the occupiers.

2.7.2 Comment 2.7.1 (i) and to a lesser extent (ii) were confirmed on reviewing questionnaire returns used in compiling reference 1, and telephoned some contacts in the buildings concerned. We had hoped that offices within the "good" criteria might be candidates for Case Studies, but in fact several of the lowest NPIs had suffered reporting errors or were anomalous in other respects, for example partially-occupied or part-industrial, or having excessive quoted occupancy hours. Many of the lowest surviving consumers were then all-electric, so their energy costs would have been relatively high and a lower target more appropriate (CIBSE

Building Energy Code Part 4 suggests x 0.8). Of the offices which survived, *North-West Insurance* was surveyed, but that too fell away on detailed analysis owing to shrinking floor area, not very efficient lighting, and uncertainty about the true electrical costs of recovering heat from the computer installation.

2.7.3 Figure 2.2 shows the raw questionnaire data, uncorrected for exposure, degree-days or hours of use and with the anomalously low energy-consumers removed. Owing to the way in which the data was collected, the figures were split into "heating" (taken in the survey to be 75% of fossil fuel use unless it was separately measured or estimated) and "other uses", before they were entered into the computer. To extract the raw fossil fuel and electricity consumption figures would require reference back to the questionnaire forms.

FIGURE 2.2 Annual kWh/sq m treated from office questionnaires



2.7.4 In order to identify different types of office, the bars in figure 2.2 are shaded differently for:

- "Heating" in naturally-ventilated offices (NV: this category includes partial air-conditioning of up to 12% of the floor area in some cases)
- "Heating" in air-conditioned offices (AC: largely fully air-conditioned but including five offices with partial air-conditioning of between 22% and 62% of floor area.
- "Other" for offices with and without computer suites.

2.7.5 The higher consumers of both heat and "other" tend to be air-conditioned and to have computer suites. Three out of the four lowest energy consumers show as air-conditioned but this is anomalous: they are all all-electric and the lowest two partially (30% and 22%) comfort cooled only; the third also has short operating hours and an impossibly low "other" energy consumption. Interestingly, a number of the low energy consumers reported computer suites, but these seem to have been minicomputers or terminal rooms, not mainframes and often not air-conditioned. Some statistics are recorded in Table 2.2 below, excluding the anomalously high and low consumers and partially air-conditioned buildings (the sample size of 6 was too small to give meaningful results).

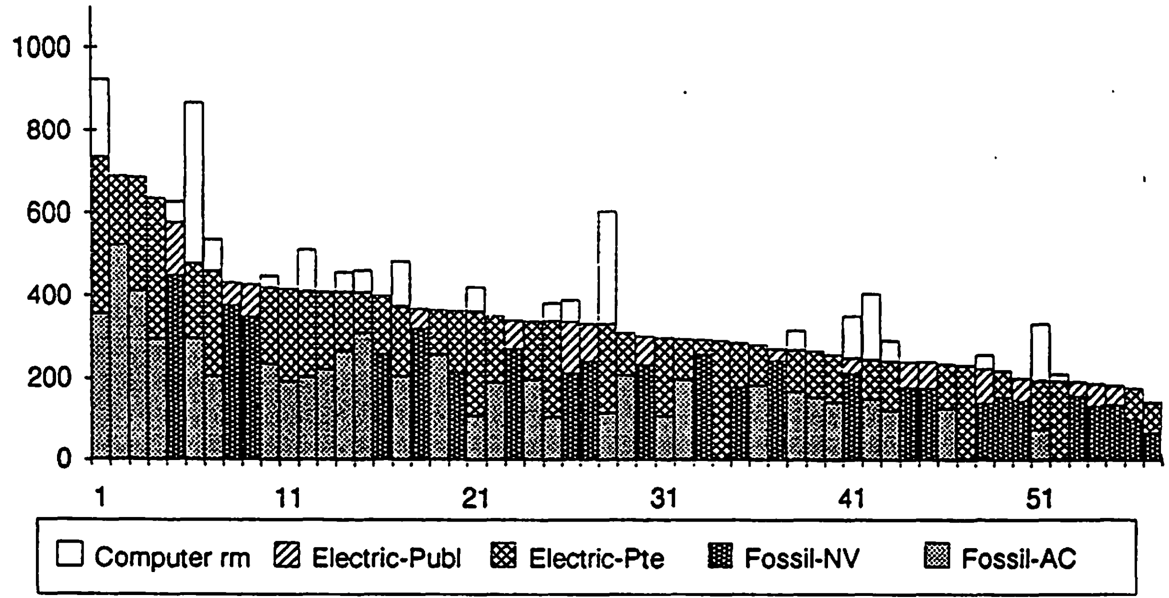
TABLE 2.2

AVERAGE ANNUAL ENERGY CONSUMPTIONS FROM THE QUESTIONNAIRE DATA kWh/m^2 treated

	Sample size	"Heating"	"Other"	Total
All offices	59	208	211	409
Fully air conditioned	26	238	288	526
Naturally ventilated	27	186	152	338
WITHOUT COMPUTER SUITE:				
Fully air conditioned	6	246	186	432
Naturally ventilated	13	202	99	301
WITH COMPUTER SUITE:				
Fully air conditioned	20	236	318	554
Naturally ventilated	14	171	201	372

2.7.6 A review of the data suggests that published "good" targets for total delivered energy - although readily attainable by building services in recently-completed offices designed and managed to good current practice - are more rigorous than might be expected, at least for those private sector buildings well-managed enough to be able to furnish data. The simple summation of delivered fossil fuel and electricity consumption must also be discouraged as fossil consumption is fairly easily reduced, and this masks growth in consumption and cost of the more expensive electricity.

FIGURE 2.3 Annual kWh/sq m gross from office energy surveys



2.8 Data from extended energy surveys and other sources

2.8.1 Figure 2.3 shows energy use information (here per m^2 *gross*), from a selection of extended energy surveys (EESs - reference 7), with electrical consumption of computer rooms separately identified. After allowing for the gross area measurement and the computer suites, the distribution for private sector offices is similar to figure 2.2, with little indication that the offices which had extended energy surveys were particularly high consumers. Figures for other buildings reviewed as background to the Case Studies also gives similar results, though the sample is rather uneven. The samples also include some public sector buildings (all naturally-ventilated and nearly all council offices), whose electrical consumption is differently shaded in figure 2.2. When all-electric buildings are set aside, and in naturally-ventilated offices, public sector electricity use averages only about 70% of the private sector level (see 2.7.1 above).

2.8.2 Average data from the surveys, converted to treated area figures and rounded, is summarised in table 2.3 below. For the private sector, the totals agree closely with those from table 2.2, also summarized in the last column. In the public sector, the totals for naturally-ventilated buildings without computer suites agree well, though with compensating increases and decreases in fossil fuel and electricity consumption, but the offices with computers seem to have higher fossil fuel consumptions. This may be largely a function of sample size, although public sector offices generally seem to use more fossil fuel and less electricity than their private sector counterparts. The private sector offices with computer rooms use less heating energy, but they appear to be newer buildings with better insulation standards and heating systems.

TABLE 2.3

AVERAGE ANNUAL ENERGY CONSUMPTION FROM ENERGY SURVEY DATA

kWh/m^2 treated.

	Sample size	*Fossil*	*Electrical*	*Computer room*	*Total from EES*	*Total from Table 2.2*
PRIVATE SECTOR (excluding all-electric):						
Fully air conditioned	*15*	*250*	*180*		*430*	*432*
A/C with computer	*15*	*215*	*200*	*125*	*540*	*534*
Naturally ventilated	*7*	*185*	*100*		*285*	*301*
PUBLIC SECTOR NATURALLY VENTILATED:						
Without computer	*13*	*240*	*60*		*300*	*301*
With computer	*4*	*265*	*100*	*65*	*430*	*372*

2.8.3 The Anderlyn Consultancy publishes a regular review of the energy costs of office buildings, based on analysis of postal surveys. SCOPE 90, the latest available (reference 11), is based on 1989 data. Methodologically, the survey potentially suffers from the uncertainties discussed in paragraph 2.7.2: this is confirmed by substantial variations in the statistics from year to year.

- Converted to units of treated area and at average gas tariffs, SCOPE's average heating energy consumption is low at 145 kWh/m^2 (not separately stated for air-conditioned and naturally-ventilated buildings). We have found three main reasons for this relatively low figure: it was a warm year, some buildings may have benefited from very cheap oil, and all-electric offices and those with heat supplied from elsewhere were given zero heating costs and so weighted the average downwards.
- On the electrical side, SCOPE suggests 100 kWh/m^2 for naturally-ventilated, 235 kWh/m^2 for partially air-conditioned and 375 kWh/m^2 for fully air-conditioned offices. The averages agree with Table 2.3 for naturally-ventilated private sector buildings but are on the high side for air-conditioned ones, because here `offices with computer rooms and all-electric buildings contribute to the sample averages.

Anderlyn kindly offered future access to their database to review their information and methodology.

2.9 Tenanted buildings

2.9.1 The discussion so far has been on the energy consumption of whole buildings. However, most offices in the UK are built speculatively. Some of these pass into private ownership and single or head tenancies, where the occupier takes the responsibility for managing the entire building and its services. For the rest - perhaps 50% of the stock as a whole - the buildings are managed by the landlord or their agents and the tenants pay a service charge for "landlord's services", which normally include:

- Space heating throughout.
- Central air-conditioning, where fitted, but not local supplementary systems added by the tenant for conference suites, computer rooms etc..
- Lighting in common parts.
- Hot water in common parts, and quite commonly throughout.
- Lifts and escalators.
- Other common systems such as lifts, security, water pressure boosting and car park ventilation.

2.9.2 Tenants usually pay separately for the electricity used by:

- Lighting within their demise.
- Their office and catering equipment.
- Their computer rooms, telephone exchanges etc., and any associated air-conditioning.
- Ventilation and air conditioning which replaces or supplements the central service.
- Kitchens and serveries.

2.9.3 How tenants pay for their electricity varies:

A Some have separate electricity meters which are read by the supply authority, who send them individual electricity bills.

B Some have electrical sub-meters which are read by the landlord and used to apportion the monthly electricity bill between tenants in relation to their unit consumption. This can produce anomalies as very seldom are day/night use patterns and maximum demand charges taken into account by the landlord. Tenants with peaky uses (e.g: from restaurants and humidifiers) may therefore benefit at the expense of other tenants, while tenants with more uniform uses (e.g: from computer suites) might lose out.

C Sometimes the overall electricity bill is simply apportioned by the landlord between tenants in relation to their individual nett lettable areas, perhaps with some weighting factor for estimated intensity of equipment use. This occurs more commonly than one might expect (even in some recently-completed prestige developments), and can potentially be unfair to tenants who are low electricity consumers, although sometimes the landlord may have the advantage of a better tariff than the tenants could enjoy if they were individually billed.

2.9.4 The landlord/tenant split therefore tends to be a disincentive to energy-efficiency:

i) Developers, landlords and managing agents have little incentive to invest in thought, capital, or management expertise to minimise energy costs which are going to be recovered from the tenant anyway, and to which tenants do not appear to be sensitive. However, just recently tenants have begun to become more aware of occupancy costs and developers are also beginning to use energy-efficiency and low service charges as a selling point. This is now being reinforced in the present tighter market, growing awareness of "green" issues, and the availability of independent assessment methods such as BREEAM (reference 9). To date perhaps the activity has been more in marketing departments than on the ground, but if tenants become more demanding about energy-efficiency in negotiations about leases and service charges, then the situation could change. Some of the potential is reviewed in Reference 12.

ii) Tenants also find it difficult to invest in energy-efficiency if they do not benefit in full, particularly where the landlord adopts methods B or C above for re-charging, though in principle there is nothing to stop tenants formulating their own energy-efficiency improvements and discussing them with the landlord.

iii) The landlord/tenant management split also makes it difficult for the landlord's services to be operated at peak efficiency: for example the whole HVAC system may have to run regularly late into the evening because a single tenant sometimes needs it, or might possibly need it. This is not only a problem of mechanical engineering design: frequently where the plant is in zones the way the controls are arranged makes it difficult to exploit this potential in practice. In some developments, probably mistakenly, landlord's central chilling is also made available to tenants to cool their equipment rooms, oversized plant then having to run inefficiently year-round to meet relatively small loads which would usually have been better dealt with locally. In some developments, more energy is used out-of-hours by the chilled water pumps alone than would have been necessary to meet the entire tenant cooling demand! The problem is too often consolidated by poor hydraulic design which makes it impossible to sequence the pumps and chillers reliably, let alone use variable volume pumping. *(NOTE: the use of controls in office buildings is now being studied by BRE and major opportunities for waste avoidance in multi-tenanted buildings through better control and management are beginning to be identified).*

iv) Where landlords have provided BEMS and lighting control systems, these are also often under-used owing to difficulties in communication between the tenants, the landlord, and the building services maintenance contractor. In one recently-completed energy award-winning building we found that the single tenant was actually removing the lighting control systems provided because nobody could understand how they were supposed to work. This was partly a matter of poor design documentation, but it is not unusual for offices to be fitted-out in a hurry by people who have little understanding of energy-efficiency, and sometimes even for building services and their controls!

2.9.5 Multi-tenanted offices are therefore likely to be less energy-efficient than their single-tenanted and owner-occupied counterparts. Unfortunately this project was able to collect very little first-hand information on energy use and costs in such buildings and in all the multi-tenancies which finally proved suitable for Case Studies the largest tenant also managed the entire building and its services on the landlord's behalf.

2.9.6 There were three main reasons why it proved extremely difficult to get information both from the landlord and from all the tenants:

- More parties had to agree.
- Mutual suspicion between the parties, particularly that the energy figures and our assessment of energy-efficiency might become bargaining chips in a rent review.
- Concern by the landlord that the tenants might find that their offices were not very energy-efficient or that the apportionment of fuel bills had been inequitable.

2.9.7 Approaches to building services maintenance contractors were largely disappointing, owing partly to confidentiality. They also usually only tended to know in detail about landlord's fossil fuel consumption, for which - as a rule of thumb - figures below 200 kWh/m^2 were generally regarded as quite good. Although this is just below the average for the stock as a whole (see tables 2.2 and 2.3), most good modern office buildings should require much less, as shown by the Case Studies in Section 6.5 and the proposed good practice guidelines in Section 8.

2.9.8 Data on annual service charges is published annually by Jones Lang Wootton (reference 10). This information may not be representative as it is restricted to buildings which JLW manage, but on the other hand its collection is likely to have been more consistent. Only overall energy costs are given, so heating and electrical consumption cannot be isolated individually. Assuming average levels of heating energy consumption and fuel prices, working back from the JLW costs suggests average landlord's electrical consumptions of just over 100 kWh/m^2 of treated area in fully air-conditioned buildings and just under 50 kWh/m^2 in other office buildings. While the air-conditioned component is not inconsistent with our other data, the landlord's electrical figure for other buildings is rather high: this may well be explained by the inclusion of partially air-conditioned and all-electric buildings, higher heating energy consumption than we have estimated, or higher energy costs generally.

2.10 Conclusions

2.10.1 This review has been able to find some underlying consistency between available energy use data and published energy targets for offices. However, it also suggests that existing "good" targets may be more exacting than might have been expected:

- Theoretical heating targets appear difficult to meet in well-insulated offices with conventional heating systems.
- A significant number of the "low" energy consumers revealed by questionnaire data may have had their floor areas over-estimated and some energy sources overlooked.
- Electrical consumption targets based on public sector building data from some years ago may be inappropriate for private sector offices today.

Conversely, some buildings have been unjustly berated for being "poor" while in fact the excess energy has been legitimately used, particularly in computer suites. Although there is close correlation between high energy consumption and cost and a "poor" rating, the two are not tautologous.

2.10.2 It is not enough to say that energy-efficient offices are those with a low delivered annual energy consumption. It is necessary to identify what energy is being used, what it is being used for, and whether the energy consumption for each purpose is reasonable. One must also dispel the common myth that energy-efficiency in offices is primarily about heating and insulation, which is perpetuated by adding electricity and fossil fuel consumptions together with no weighting at all, as in CIBSE Building Energy Code Part 4, and the Audit Commission and EEO's former NPI procedures. PSA's weighting of electricity by 3.5 is a simple and practical way of recognising this, and one we used here in preference to primary energy, energy cost or air pollution indices, which all give very similar rankings of results but can lead to endless arguments about their relevance and the precise factors used.

2.10.3 Ideally each office would have a tailor-made energy target, preferably using a simple PC-based computer model which would seek information on the building, its services and its operations and make reasonable assumptions if not, perhaps along the lines of the Energy Designer/Energy Targeter domestic models or the Electricity Association's ESICHECK. The model would have to be broad in scope, asking questions for instance about car parking, storage, computer rooms, and catering, not merely about the general office space itself. A 5-day flexitime working week can probably be taken as standard and other occupancy patterns related to it.

2.10.4 Until this is possible, then people should be encouraged to consider where their building fits on the "map" and to look at the individual components of their energy consumption. Not only should the technical differences between air-conditioned, naturally-ventilated and buildings with computers be recognised, but so should the differences in use and management, for example between open-planned and cellular offices, between private and public sectors, and between singly-occupied and multi-tenanted buildings. These points are returned to in Section 8 once the Case Studies have been reviewed in some depth.

SECTION 3

SELECTION OF THE CASE STUDY BUILDINGS

3 SELECTION OF THE CASE STUDY BUILDINGS

3.1 It proved more difficult than expected to identify suitable offices for Case Studies:

i) Open-ended requests (eg: in *Facilities* and *Building Services* journals and at conferences and meetings) brought no responses at all!

ii) Articles in the press tended to repeat claimed energy-efficient designs and energy-saving projects, rather than carry out methodical analyses of actual energy use and energy savings. For a while, the Architects' Journal did an energy analysis as part of their building studies, but this ceased in about 1985 owing to difficulties in finding good information and a lack of readership interest. Unfortunately files were not kept of the analyses themselves.

iii) Many of the energy-efficiency measures that had been adopted were *single technologies,* while we were seeking examples of *integrated approaches.* Claims were often based on design calculations and not actual results, which had seldom been monitored, even in the simplest manner. And where monitoring had been carried-out - even quite expensively - it often focused only on a few specific aspects of the building's energy consumption.

iv) Organisations who claimed to have good data were often reluctant or unable to let us see it, and for those who did, their "good" buildings were seldom good by the standards we were using. Often the buildings which were statistically best were those with the biggest mistake - usually either partially unoccupied, landlord's or tenant's consumption omitted, measured area too large or wrongly converted to metric, or incorrect units of fuel consumption.

v) Many consultants were hesitant to let us have information, perhaps fearing that buildings which their clients thought were energy-efficient would turn out not to be. One major firm of building services engineers said this explicitly, though adding that they might relent once some case studies had been published and they could make their independent checks first.

vi) The fuel industries were initially enthusiastic but information was slow to emerge and only seldom met our criteria: *Cornbrook House* (suggested by British Gas) and *Magnus House* (suggested by the Electricity Association) being the two exceptions.

vii) Many people - particularly architects and maintenance contractors - often saw energy conservation as being about heating only, even in air-conditioned buildings. Electricity consumption - although usually the higher-cost item and often offering the largest money savings, was somehow regarded as inevitable and uncontrollable.

viii) Manufacturers, installers and consultants seldom knew how the equipment they had supplied, installed or specified was actually performing on site.

3.2 Suitable before-and-after examples from energy survey work, energy conservation programmes, and refurbishments were difficult to find, because:

i) Many upgrading projects, although achieving good energy and money savings, did not necessarily reach good energy and environmental performance standards afterwards.

ii) Few consultants who had undertaken office energy surveys were involved in the follow-through, or in monitoring the results of completed projects.

iii) Where offices had undergone major refurbishments, reliable "before" data was seldom available, and often major changes in occupancy and use made comparisons impossible. It was also impossible to verify the "before" situation if one had not seen it.

iv) Frequently energy costs had gone <u>up</u> following refurbishment, with natural ventilation replaced by air-conditioning, natural by artificial lighting, and more information technology was added. Whether the refurbished building did its job more energy-efficiently than the original was at best difficult to argue.

v) We also initially feared that offices subject to energy surveys might have been abnormally high energy consumers, though the review of office Extended Energy Surveys suggested that in fact this was not so, as discussed in section 2.8 above.

3.3 The most effective method of identifying buildings proved to be from published articles and from personal and telephoned contact trails. In spite of their shortcomings, the press articles and research contacts generally gave more reliable leads than word-of-mouth. However, since some of the best-performing buildings were simple, unexceptional, and not widely-publicised, many good performers may well remain hidden. Of the buildings identified, 42 were reviewed in some detail for Case Studies, 30 of these were visited and 23 surveyed. Case Studies on 16 were finally drafted, of which 13 were suitable for publication and 12 published.

3.4 Initially we were seeking approximately equal representation of offices in:

i) *New, major refurbishments and minor refurbishments*

Most of the examples were new 1980s buildings: 1960s buildings in particular had poor success rates, particularly for heating. Energy considerations seemed to figure less highly in refurbishments and hardly at all in fitting-out projects, though success rates were similar once suitable projects had been identified. Minor refurbishments and energy conservation projects usually had limited measures rather than an all-round approach, and although the outcomes were more energy-efficient than before, the case study criteria were seldom met.

ii) *London, Southern England, and elsewhere*

The Case Study buildings have a similar distribution about the country, as the office stock as a whole, with 25% in London, 25% in Southern England, and 50% elsewhere. Unfortunately,no Case Studies were carried out in Scotland, Wales or Northern Ireland: two good candidates were identified but permission to survey could not be obtained.

iii) *Owner-occupied, single and multi-tenanted*

The distribution of initial candidates was quite good, but information on multi-tenanted buildings proved very difficult to obtain, see Section 2.9. In the tenanted offices surveyed *(Hempstead House, City Atrium* and *One Bridewell Street)*, the main tenant also managed the building and at *Victoria* the landlord paid all the fuel bills and apportioned them to the tenants.

iv) *Private and public sectors*

Public sector representation is low largely because when selections were made in 1988 the programme had a private sector emphasis.

v) *Naturally-ventilated, fully air-conditioned, and hybrids*

While our targets were achieved in the long list, the air-conditioned buildings proved much less likely to survive review than naturally-ventilated ones. Mixed-mode hybrids had a very high survival rate, probably because departure from the standard fully air-conditioned formula was both interesting in itself and evidence of thoughtful, integrated design and an energy-aware owner-occupier.

vi) *Presence of mainframe computer suite*

Over half the candidates and nearly 40% of the Case Studies had mainframe computer suites, showing a bias towards the head office and the owner-occupied and head-tenanted buildings. While these types of office will tend be better-known and demonstrate higher levels of design and management skills, they also tend to be innately higher energy consumers (see Section 8).

vii) *Level of office information technology*

Offices were broadly classified as high, medium and low-IT. High IT had about one screen per person or more; medium IT about one screen per two persons; and low-IT one screen per three persons or less. Most Case Studies were in the medium category. The drop-out rate was high for the high-IT candidates: this was largely due to security, multi-occupancy, and monitoring difficulties in large buildings with poor sub-metering.

viii) *Building, lighting and energy management systems*

Nearly one-third of the candidates and half the Case Studies had electronic building management and/or lighting control systems. Again, this is much more than the office stock as a whole. Not all these systems were being effectively used.

ix) *Building size*

Most of the Case Studies were medium (1500-6000 m^2), or large, with a few very large (over 15000 m^2). Small offices (less than 1500 m^2 treated area) were difficult to find and usually did not meet the selection criteria. This may well reflect difficulties in identification as much as an absence of suitable examples among the building stock.

3.5 Once suitable buildings and contacts had been identified, preliminary information was obtained by two main methods:

- Published breakdowns: from monitoring projects, energy surveys, or press reports.
- A questionnaire (reproduced in Appendix A).

Although these both helped preliminary screening, visits to the buildings themselves were essential, and frequently revealed problems and inconsistencies with the written material.

3.6 Organisations who responded rapidly and concisely tended to furnish better buildings and information than those who had to be chased. Similarly, organisations who mentioned payment for access to information usually seemed to have poorer buildings and information than those who did not. No access fees were therefore paid. Well-informed, responsive, open management appeared to be an important attribute of an energy-efficient building.

SECTION 4

CASE STUDY METHODOLOGY

4 CASE STUDY METHODOLOGY

4.1 General Approach

4.1.1 The key to the Case Studies was to identify <u>all</u> records of fuel consumption and cost for a minimum of one year. As a coarse filter, the total delivered energy consumption of a suitable building (excluding computer rooms) would not normally exceed about 250 kWh/m^2 gross, or 600 kWh/m^2 for F+3.5E (Fossil + 3.5 x Electricity). In the 1989-90 search for new Case Studies (reference 15), we were able to tighten the criteria to 200 and 500 kWh/m^2. More recently, more detailed criteria based on the particular type of office have been used, as discussed later in Section 8.

4.1.2 We tried to avoid relying upon any information from the first year after occupancy or refurbishment, where figures are often anomalous: too high owing to drying-out and to commissioning and management problems; too low if the building was not fully occupied or comfort standards were not being properly achieved. This meant that most of the Case Study buildings were completed before 1986 and designed no later than the early 1980s: this affected the coverage of some modern energy-efficient technologies, particularly low-energy lighting and condensing boilers. For example, high-frequency fluorescent lighting was seldom found and some tungsten lighting for decorative purposes and in WCs etc. was not uncommon.

4.2 Analysis of Fuel Bills

4.2.1 For the larger building, with monthly billing, the fuel bills also gave a useful "energy fingerprint", which could help one identify the sources of energy consumption and the likelihood of the systems being energy-efficient. For heating, degree-day plots gave an indication of whether the system was well-controlled and managed. For electricity, summer/winter unit consumption and maximum demand ratios gave a good feel for the likely energy use attributable to lighting and refrigeration, while night:day ratios helped to confirm consumption by computer rooms and other 24-hour services.

4.2.2 For the smaller buildings, quarterly bills were rather blunt instruments, especially with British Gas' practice of using estimated readings in alternate quarters. Fossil fuel - normally gas - consumption had to be split between heating, hot water and catering, which required some professional judgement, based on monthly fuel consumption patterns and on the equipment and usage surveyed on site. This was probably the least accurate part of all the analysis, although simplified in many of the Case Study buildings because:

i) Gas to large kitchens was often sub-metered.
ii) Several of the buildings had independent gas or electric water heating.
iii) Independent monitoring data was sometimes available.

4.3 Site Visits

4.3.1 Having got a feel for the building's energy behaviour, suitable candidates were visited, and about one-third of these were fairly rapidly rejected, for the following reasons:

i) Poor design features.
ii) Insufficiently balanced approach.
iii) Incomplete or inaccurate energy or area information.
iv) Poor environmental conditions, occupant satisfaction, or murmurs of "building sickness".
v) Partial occupancy.
vi) Imminent change, so the building as reported would no longer exist.
vii) Suspect cost-effectiveness.
viii) Systems too elaborate for the task in hand.
ix) Insufficient client time to support a full survey.

x) Evidence of poor maintenance or management,

For the buildings that survived, further visits were made in order to gain a better understanding of the building's operation and use and the breakdown of electrical consumption.

4.3.2 A typical building of 2000 m^2 or more required one day's visit to understand it and its energy systems and to collect initial information for preliminary analysis, a second visit to collect detailed information - leaving monitoring equipment where necessary - and a third to check any inconsistencies and to run through findings with the hosts. The smaller EED buildings were dealt with on a 1-day visit, while the larger buildings required an extra day on site for each 3000-5000 m^2, plus more for any low-level monitoring.

4.4 Measurement of Building Area

4.4.1 After the first visit, if the building and its energy figures looked potentially suitable for a Case Study, floor plans were obtained and annotated and measured by DL&E for gross, nett and treated area (for definitions see Appendix C). Often the re-measured areas turned out to be smaller than the figures initially quoted.

4.5 Assignment of Electrical Consumption

4.5.1 Although seemingly rather laborious, the most complete and accurate method developed during the project for assessing the breakdown of electrical consumption was to schedule each item of equipment on an electronic spreadsheet, with numbers of items, load factors, diversity factors and hours of use. Table 4.1A is an example. Each distinct type of plant and equipment was listed and given one of fifteen standard headings (column C). Section 4.7 discusses exactly how the items were classified. The number of units and the nominal (or monitored average) electrical loading of each was recorded in columns D and E and then multiplied by a "load factor" (column G), usually 100%, but sometimes higher (for example for fluorescent lamps, to include gear losses) or lower (for example typically in the range 60-90% for pumps and fans which do not usually run at full power). In columns H-K the figures were then multiplied by estimated running hours/day, days/week and weeks/year, and a usage factor where usage was intermittent, to give estimated annual totals in column M which were reconciled to the metered annual totals and to any sub-meter data. Column AD shows the total annual electricity bill (from cell G4), apportioned over the individual items in the ratio of their annual energy consumption only. This is shown per square metre gross in column AE and as a percentage in column AF.

4.5.2 Rows 65-69 of Table 4.1A show the annual consumption and apportioned costs, summarised under the fifteen standard headings as coded in column C.

4.5.3 The amount of detail recorded increased as the Case Study surveys continued: this proved to be worthwhile in the long run, and assumptions became easier to make as the database expanded. In several buildings, electrical sub-meters and monitoring results also provided independent checks. Where figures were uncertain, electrical consumptions were measured, initially using a clip ammeter, then a HCK portable electric power meter (which took account of power factor - low for some items of office equipment), and finally a Sension Hawk demand profile recorder. The spreadsheet method proved very powerful and in the later Case Studies the very first estimates were frequently within 10% of the metered totals. Wider discrepancies were usually traced to errors and omissions: for example at *South Staffordshire Water Company* part of the computer room was being fed - and had been fed for several years - from an emergency link from the office supply, which had been forgotten about.

4.5.4 Collecting data on the energy consumption of individual items of office equipment was also an unobtrusive way to discover staff attitudes to the building. After a while most building managers allowed us to move around unaccompanied, counting items and making measurements. Staff were very helpful, telling us how much they and their colleagues used their lights and equipment and giving us their general opinions on the building. Informal interviews often took place when measuring power consumption of their computer, typewriter, fax or whatever, which involved unplugging the equipment concerned, inserting an extension lead complete with meter test points, and then asking staff to start-up and to use the equipment normally. A table of measured office equipment energy consumptions is given in Appendix B. These were spot measurements: certain equipment, particularly photocopiers, has very peaky demand patterns, and monitoring over an extended period would be necessary to obtain reliable results. *(NOTE: more detailed information is now becoming available from a number of sources, including BSRIA, and has been published in EEO Consumption Guide 35).*

Table 4.1a

	A	B	C	D	E	F	G	H	I	J	K	L	M	AC	AD	AE	AF	AG	AH	AI	AJ	AK
1	TABLE 4.1A		EXAMPLE OF APPORTIONMENT OF ANNUAL ELECTRICITY CONSUMPTION																			
2	ENERGY EFFICIENCY IN OFFICES - ELECTRICAL CONSUMPTION ESTIMATION WORKSHEET																					
3	BUILDING NAME		BRE LEO - EED VERSION 1988/89								GROSS INTERNAL AREA			1977	m2	Annual kWh/m2			80.1			
4	Annual consumption (kWh)			158449	Annual cost £		8153	ESTD			Average elec cost (p/kWh)			5.15		Ave cost/m2		£	4.12			
5	NOTE: CALCULATED CONSUMPTION AND COSTS EXCLUDE OFF-PEAK USE, INSERTED SEPARATELY													35586	kWh	COSTING			£ 650	ESTD		
6		ENTER THE INFORMATION IN THE COLUMNS BELOW>>>>>>>>>>>>>>>>>>										THESE FIGURES ARE CALCULATED-DO NOT ENTER										
7																						
8					RATED		ELEC	AVAILABILITY:				RATED										
9			ITE	NUMBER	WATT	UNITS	LOAD	HRS	DAY	WKS	USAG	FL HR	CALCULATED ANNUAL USAGE:									
10	No	ITEM NAME	CO	OF UNITS	/UNIT	USED	FACTO	/DAY	/WK	/YR	FACT	/DAY	kWh	kWh/m	£/item	£/m2	%			COMMENTS		
11														(Costs here by direct apportionment only)								
12	1	Lights offices N	7									0.0	9,818	5.0	505	0.26	6%			701m2@8.1 kWh/m2		
13	2	Lights offices S	7									0.0	5,468	2.8	281	0.14	3%			701m2@14.5 kWh/m		
14	3	Corridor lights	7	575	8	W/m2	100%	15	6	52	40%	6.0	8,611	4.4	443	0.22	5%			Check Wm2		
15	4	Day rate heating	1									0.0	51,557	26.1	2653	1.34	33%			Given 27 kWh/m2		
16	5	Off peak heating	1			Assumes electricity at 1.89 p per kWh						0.0	34,371	17.4	650	0.33	22%			Given 18 kWh/m2		
17	6	HWS	6									0.0	9,548	4.8	491	0.25	6%			Given 5 kWh/m2		
18	7	Ground floor loovents	4	2	35	Weach	100%	9	5	52	100%	9.0	164	0.1	8	0.00	0%					
19	8	Nu-Aire TEF 220DD/1	4	1	340	Weach	80%	9	5	52	100%	7.2	636	0.3	33	0.02	0%			From catalogue		
20	9	HWS sec pump	3	1	60	Weach	100%	10	5	52	100%	10.0	156	0.1	8	0.00	0%			Check rating		
21	10	Data loggers/controls	15	1	2400	W/set	100%	24	7	52	100%	24.0	20,966	10.6	1079	0.55	13%			RJ baseload figure		
22	11	Kettles/Corvettes	12	12	3000	W eacl	100%	0.2	5	52	100%	0.2	1,404	0.7	72	0.04	1%					
23	12	Conference tea boiler	12	1	3000	W eacl	100%	1	5	52	100%	1.0	780	0.4	40	0.02	0%					
24	13	DEC VT220 terminal	9	9	38	W ave	100%	9	5	52	60%	5.4	480	0.2	25	0.01	0%					
25	14	Telephone ans M/Cs	9	3	7	W ave	100%	24	7	52	100%	24.0	183	0.1	9	0.00	0%					
26	15	DEC VT100 terminal	9	1	100	Wave	100%	9	5	52	50%	4.5	117	0.1	6	0.00	0%			Elderly unit		
27	16	DEC LN03 laser prtrs	9	5	200	W ave	100%	9	5	52	100%	9.0	2,340	1.2	120	0.06	1%					
28	17	Infotec 9015Z copier	9	1	300	W ave	100%	12	5	52	100%	12.0	936	0.5	48	0.02	1%					
29	18	Amstrad PPC512	9	5	25	Wave	100%	9	5	52	30%	2.7	88	0.0	5	0.00	0%					
30	19	BBC micro	9	1	80	Wave	100%	9	5	52	60%	5.4	112	0.1	6	0.00	0%					
31	20	Cub screen	9	1	72	Wave	100%	9	5	52	60%	5.4	101	0.1	5	0.00	0%					
32	21	Epson FX80 printer	9	5	10	Wave	100%	9	5	52	20%	1.8	23	0.0	1	0.00	0%					
33	22	Philips monitor 80	9	4	60	Wave	100%	9	5	52	30%	2.7	168	0.1	9	0.00	0%					
34	23	DEC VT240 terminal	9	4	50	Wave	100%	9	5	52	60%	5.4	281	0.1	14	0.01	0%					
35	24	Fridges	12	3	60	W ave	100%	24	7	52	100%	24.0	1,572	0.8	81	0.04	1%					
36	25	DEC Vaxmate inc scn	9	2	123	W ave	100%	9	5	52	80%	7.2	461	0.2	24	0.01	0%			One on all wkg day		
37	26	Decwriter	9	2	250	W ave	100%	9	5	52	25%	2.3	293	0.1	15	0.01	0%					
38	27	Olivetti ET typewriters	9	3	30	W ave	100%	9	5	52	20%	1.8	42	0.0	2	0.00	0%					
39	28	Desk lamp 60 W	7	3	60	Weach	100%	9	5	52	30%	2.7	126	0.1	7	0.00	0%					
40	29	DEC VT320 terminal	9	14	40	W ave	100%	9	5	52	70%	6.3	917	0.5	47	0.02	1%					
41	30	Micron microfilm reade	9	1	80	W eacl	100%	9	5	52	15%	1.4	28	0.0	1	0.00	0%					
42	31	Canon microfilm printe	9	1	450	W eacl	100%	9	5	52	20%	1.8	211	0.1	11	0.01	0%					
43	32	Canon ASS printer	9	1	50	W ave	100%	9	5	52	25%	2.3	29	0.0	2	0.00	0%					
44	33	Laboratory ovens	14	2	1500	W eacl	50%	24	7	52	10%	1.2	1,310	0.7	67	0.03	1%					
45	34	Electric fan heaters	1	3	2000	W eacl	100%	9	5	20	20%	1.8	1,080	0.5	56	0.03	1%					
46	35	HP85 calculator	9	1	20	W ave	100%	9	5	52	30%	2.7	14	0.0	1	0.00	0%					
47	36	HP 9121 PC	9	1	70	W ave	100%	9	5	52	30%	2.7	49	0.0	3	0.00	0%					
48	37	HP 7470A A4 plotter	9	1	15	W ave	100%	9	5	52	15%	1.4	5	0.0	0	0.00	0%					
49	38	Microvax	9	1	300	W ave	100%	24	7	52	100%	24.0	2,621	1.3	135	0.07	2%					
50	39	Nefax 3 fax	9	1	15	W ave	100%	24	7	52	100%	24.0	131	0.1	7	0.00	0%					
51	40	DEC LA75 printer	9	1	40	W ave	100%	9	5	52	30%	2.7	28	0.0	1	0.00	0%					
52	41	DEC Rainbow & scn	9	1	84	W ave	100%	9	5	52	100%	9.0	197	0.1	10	0.01	0%					
53	42	DEC printer LQP02	9	1	40	W ave	100%	9	5	52	30%	2.7	28	0.0	1	0.00	0%					
54	43	Tally 86 printer	9	1	40	W ave	100%	9	5	52	30%	2.7	28	0.0	1	0.00	0%					
55	44	Other small items, say	9									0.0	968	0.5	50	0.03	1%			Balancing figure		
56		eg: projectors, OHP, TV, video, microscopes, calculators etc..																				
57																						
58											TOTALS		158449	80.1	8153	4.12	100					
59											METERED		158449									
60											DIFFERENCE		0						AGGREGATED COSTS			
61																			FROM TARIFF CALC			
62	CLASSIFIED BREAKDOWN OF ANNUAL ELECTRICITY CONSUMPTION AT											BRE LEO - EED VERSION 1988/89							ON NEXT PAGE:			
63													CALCULATED /	APPORTIONED:					EEB as in LEO Feb 1990 rpt			
64		ITEM NAME	CODE										kWh	kWh/m	£/item	£/m2	%		£/item	p/kWh	£/m2	£%
65		HEATING	1	Includes 1080 kWh of local fan heaters									87,008	44.0	4477	2.26	55%		5051	5.81	2.55	59.5%
66		COOLING	2										0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
67		PUMPS	3										156	0.1	8	0.00	0%		9	5.53	0.00	0.1%
68		FANS	4										800	0.4	41	0.02	1%		45	5.64	0.02	0.5%
69		CONTROLS	5	NB transfer something from item 15									0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
70		DHWS	6										9,548	4.8	491	0.25	6%		487	5.10	0.25	5.7%
71		LIGHTS	7										24,024	12.2	1236	0.63	15%		1180	4.91	0.60	13.9%
72		TELECOMS	8										0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
73		SMALL POWER	9										10,880	5.5	560	0.28	7%		552	5.07	0.28	6.5%
74		COMPUTER	10										0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
75		COMPUTER A/C	11										0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
76		CATERING	12										3,756	1.9	193	0.10	2%		223	5.93	0.11	2.6%
77		LIFTS ETC	13										0	0.0	0	0.00	0%		0	0.00	0.00	0.0%
78		OTHER NORMAL	14	Lab ovens									1,310	0.7	67	0.03	1%		81	6.16	0.04	1.0%
79		OTHER SPECIAL	15	Monitoring and control									20,966	10.6	1079	0.55	13%		864	4.12	0.44	10.2%
80																						
81											CHECKSUM		158449	80.1	8153	4.12	100		8491	5.36	4.30	100%
82											DISCREPANC		0	0	0	0	0		0	0	0	
83											METERED		158449									
84											Discrepancy		0	Equivalent to daily load of					kWh			
85																						

Table 4.1B

	AL	AM	AO	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB
1	TABLE 4.1B	EXAMPLE OF TARIFF CALCULATION LINKED TO ANNUAL APPORTIONMENT													
2	ENERGY EFFICIENCY IN OFFICES					TARRIFF CHARGES				(NB S/C is extra availability chg for first 80 kVA)					Average
3	BRE LEO - EED VERSION 1988/89					EEB as in LEO Feb 1990 rpt					PRELIMINARY DRAFT			ANNUALLY	p/kWh
4	1977 sq m gross	Total		Night		STANDING CHARGE				£ 16.00	per	1 months	= per year.	£ 192.00	0.12
5	Annual consumption	158449	kWh	44596		AVAILABILITY CHARGE / kVA				£ 0.67	Per month	for 100 kVA	= per year.	£ 804.00	0.51
6	Average CS price	5.15	p/kWh	28%		MD CHARGES per kW				£ 2.12	in Nov+Feb	£ 6.76	in Dec+Jan	£ 1,642.89	1.04
7	Annual CS bill	£ 8,153				UNIT CHARG		pence/kWh		Day@ 4.40		Night@ 1.89	FIXED>>>>	£ 2,638.89	1.67
8	Load factor	19.6%						cost/year		£ 5,009.55		£ 842.86	UNIT>>>>>	£ 5,852.41	3.69
9													TOTAL	£ 8,491.29	5.36
10		Total	Contrib	%	kWh	%	kWh		STANDING	AVAIL	MD	DAY UNIT	NIGHT UNIT	TOTAL	Pence
11		kW	tc MD	Winter	Winter	Night	night		CHARGE	CHARGE	CHARGE	CHARGE	CHARGE	CHARGE	per kWh
12	Lights offices N	10.00	2.00	45%	4418	5%	491		£ 11.90	£ 17.38	£ 35.52	£ 410.39	£ 9.28	£ 484.47	4.93
13	Lights offices S	10.00	2.00	45%	2461	5%	273		£ 6.63	£ 17.38	£ 35.52	£ 228.56	£ 5.17	£ 293.26	5.36
14	Corridor lights	4.60	1.00	40%	3444	10%	861		£ 10.43	£ 8.69	£ 17.76	£ 341.00	£ 16.28	£ 394.16	4.58
15	Day rate heating	96.00	75.00	65%	33512	0%	0		£ 62.47	£ 651.86	£ 1,332.00	£ 2,268.51	£ 0.00	£ 4,314.84	8.37
16	Off peak heating			65%	22341	100%	34371		£ 41.65	£ 0.00	£ 0.00	£ 0.00	£ 649.61	£ 691.26	2.01
17	HWS	6.00	3.00	35%	3342	10%	955		£ 11.57	£ 26.07	£ 53.28	£ 378.10	£ 18.05	£ 487.07	5.10
18	Ground floor loovents	0.07	0.07	33%	54	0%	0		£ 0.20	£ 0.61	£ 1.24	£ 7.21	£ 0.00	£ 9.26	5.65
19	Nu-Aire TEF 220DD/1	0.27	0.27	33%	210	0%	0		£ 0.77	£ 2.35	£ 4.80	£ 26.01	£ 0.00	£ 35.92	5.64
20	HWS sec pump	0.06	0.06	33%	51	0%	0		£ 0.19	£ 0.52	£ 1.07	£ 6.86	£ 0.00	£ 8.64	5.54
21	Data loggers/controls	2.40	2.40	33%	6919	28%	5871		£ 25.41	£ 20.86	£ 42.62	£ 664.22	£ 110.95	£ 864.06	4.12
22	Kettles/Corvettes	36.00	1.50	35%	491	0%	0		£ 1.70	£ 13.04	£ 26.64	£ 61.78	£ 0.00	£ 103.15	7.35
23	Conference tea boiler	3.00	0.70	35%	273	0%	0		£ 0.95	£ 6.08	£ 12.43	£ 34.32	£ 0.00	£ 53.78	6.90
24	DEC VT220 terminal	0.34	0.20	33%	158	5%	24		£ 0.58	£ 1.74	£ 3.55	£ 20.07	£ 0.45	£ 26.40	5.50
25	Telephone ans M/Cs	0.02	0.02	33%	61	28%	51		£ 0.22	£ 0.13	£ 0.27	£ 5.81	£ 0.97	£ 7.40	4.03
26	DEC VT100 terminal	0.10	0.05	33%	39	5%	6		£ 0.14	£ 0.43	£ 0.89	£ 4.89	£ 0.11	£ 6.47	5.53
27	DEC LN03 laser prtrs	1.00	0.50	33%	772	5%	117		£ 2.84	£ 4.35	£ 8.88	£ 97.81	£ 2.21	£ 116.08	4.96
28	Infotec 9015Z copier	0.30	0.30	33%	309	5%	47		£ 1.13	£ 2.61	£ 5.33	£ 39.12	£ 0.88	£ 49.08	5.24
29	Amstrad PPC512	0.13	0.05	33%	29	0%	0		£ 0.11	£ 0.43	£ 0.89	£ 3.86	£ 0.00	£ 5.29	6.03
30	BBC micro	0.08	0.05	33%	37	0%	0		£ 0.14	£ 0.43	£ 0.89	£ 4.94	£ 0.00	£ 6.40	5.70
31	Cub screen	0.07	0.05	33%	33	0%	0		£ 0.12	£ 0.43	£ 0.89	£ 4.45	£ 0.00	£ 5.89	5.83
32	Epson FX80 printer	0.05	0.03	33%	8	0%	0		£ 0.03	£ 0.22	£ 0.44	£ 1.03	£ 0.00	£ 1.72	7.35
33	Philips monitor 80	0.24	0.20	33%	56	0%	0		£ 0.20	£ 1.74	£ 3.55	£ 7.41	£ 0.00	£ 12.91	7.66
34	DEC VT240 terminal	0.20	0.15	33%	93	5%	14		£ 0.34	£ 1.30	£ 2.66	£ 11.74	£ 0.27	£ 16.31	5.81
35	Fridges	0.18	0.16	33%	519	25%	393		£ 1.91	£ 1.56	£ 3.20	£ 51.89	£ 7.43	£ 65.99	4.20
36	DEC Vaxmate inc scn	0.25	0.20	33%	152	0%	0		£ 0.56	£ 1.74	£ 3.55	£ 20.26	£ 0.00	£ 26.11	5.67
37	Decwriter	0.50	0.25	33%	97	10%	29		£ 0.35	£ 2.17	£ 4.44	£ 11.58	£ 0.55	£ 19.10	6.53
38	Olivetti ET typewriters	0.09	0.03	33%	14	0%	0		£ 0.05	£ 0.26	£ 0.53	£ 1.85	£ 0.00	£ 2.70	6.41
39	Desk lamp 60 W	0.18	0.10	40%	51	0%	0		£ 0.15	£ 0.87	£ 1.78	£ 5.56	£ 0.00	£ 8.36	6.61
40	DEC VT320 terminal	0.56	0.40	33%	303	5%	46		£ 1.11	£ 3.48	£ 7.10	£ 38.34	£ 0.87	£ 50.90	5.55
41	Micron microfilm reade	0.08	0.00	33%	9	0%	0		£ 0.03	£ 0.00	£ 0.00	£ 1.24	£ 0.00	£ 1.27	4.52
42	Canon microfilm printe	0.45	0.20	33%	69	0%	0		£ 0.26	£ 1.74	£ 3.55	£ 9.27	£ 0.00	£ 14.81	7.03
43	Canon ASS printer	0.05	0.03	33%	10	0%	0		£ 0.04	£ 0.26	£ 0.53	£ 1.29	£ 0.00	£ 2.12	7.23
44	Laboratory ovens	1.50	1.00	33%	432	15%	197		£ 1.59	£ 8.69	£ 17.76	£ 49.01	£ 3.71	£ 80.76	6.16
45	Electric fan heaters	6.00	0.00	70%	756	15%	162		£ 1.31	£ 0.00	£ 0.00	£ 40.39	£ 3.06	£ 44.76	4.14
46	HP85 calculator	0.02	0.01	33%	5	0%	0		£ 0.02	£ 0.09	£ 0.18	£ 0.62	£ 0.00	£ 0.90	6.41
47	HP 9121 PC	0.07	0.05	33%	16	0%	0		£ 0.06	£ 0.43	£ 0.89	£ 2.16	£ 0.00	£ 3.54	7.21
48	HP 7470A A4 plotter	0.02	0.01	33%	2	0%	0		£ 0.01	£ 0.09	£ 0.18	£ 0.23	£ 0.00	£ 0.50	9.55
49	Microvax	0.30	0.30	33%	865	25%	655		£ 3.18	£ 2.61	£ 5.33	£ 86.49	£ 12.38	£ 109.98	4.20
50	Nefax 3 fax	0.02	0.02	33%	43	25%	33		£ 0.16	£ 0.13	£ 0.27	£ 4.32	£ 0.62	£ 5.50	4.20
51	DEC LA75 printer	0.04	0.02	33%	9	0%	0		£ 0.03	£ 0.17	£ 0.36	£ 1.24	£ 0.00	£ 1.80	6.41
52	DEC Rainbow & scn	0.08	0.08	33%	65	0%	0		£ 0.24	£ 0.70	£ 1.42	£ 8.65	£ 0.00	£ 11.00	5.60
53	DEC printer LQP02	0.04	0.02	33%	9	0%	0		£ 0.03	£ 0.17	£ 0.36	£ 1.24	£ 0.00	£ 1.80	6.41
54	Tally 86 printer	0.04	0.02	33%	9	0%	0		£ 0.03	£ 0.17	£ 0.36	£ 1.24	£ 0.00	£ 1.80	6.41
55	Other small items, say	0.00	0.00	33%	319	0%	0		£ 1.17	£ 0.00	£ 0.00	£ 42.59	£ 0.00	£ 43.76	4.52
56															
57															
58	*NOTE: Heating costs are actually lower if one compares buildings and tariffs with and without EED heating*														
59															
60															
61															
62															
63															
64															
65															
66															
67															
68															
69															
70															
71															
72															
73															
74															
75															
76															
77															
78															
79	TOTALS	181.4	92.6	52%	82865	28%	44596		£ 192.00	£ 804.00	£ 1,642.89	£ 5,009.55	£ 842.86	£ 8,491.29	5.36
80					% OF TOTAL CHARGES				2.3%	9.5%	19.3%	59.0%	9.9%	100.0%	
81					Charge per average kWh				0.12	0.51	1.04	3.16	0.53	5.36	
82	NB: Cost of heating =	£ 5,006	Of which non-		Charge per sq m gross				£ 0.10	£ 0.41	£ 0.83	£ 2.53	£ 0.43	£ 4.30	
83	per kWh	5.83	unit charges		CHECK TOTALS				£ 192.00	£ 804.00	£ 1,642.89	£ 5,009.55	£ 842.86	£ 8,491.29	5.36
84	per m2 gross	£ 2.53	£ 1.06		DISCREPANCY				0.00	0.00	0.00	0.00	0.00	0.00	0.00
85			41.7%												

4.6 Energy Costs and Tariffs

4.6.1 Initially we were asked to concentrate on energy *consumption* only, and not to consider costs because these were so tariff- and time-dependent. Fossil fuel and electricity were to be presented separately owing to their widely differing costs and primary energy factors, and combined where necessary using the F+3.5E (Fossil + 3.5 x Electricity) index.

4.6.2 However, before the first presentation of the preliminary Case Study data, it was agreed with EEO that one should use kWh/m^2 of treated area for building design professionals and £/ft^2 of nett lettable area for the property industry. The figures initially given were simply the annual costs actually paid per fuel, apportioned back to the end-uses according to their annual energy consumption, as shown in column AE of Table 4.1A.

4.6.3 Later we began to analyse the tariff implications in more detail. The most convenient method proved to be a tariff module, Table 4.1B, which took data from the standard electrical consumption breakdown, Table 4.1A. It works as follows:

- Tariff information is entered in cells AW4-7 and AY4-7. Fuel cost adjustments and reactive power charges are ignored, but could easily be added if required.
- Column AM calculates the installed kW per row by multiplying columns D, E and G.
- Estimated contributions to MD are inserted in column AO, and related to known MD profiles where available. *(NOTE: for all-electric offices such as BRE LEO Electric and Magnus House, heating costs were taken to be the difference between electrical costs for the building as a whole on the most economical tariffs with and without the electric heating).*
- Contributions to electrical costs are also weighted in terms of proportions of night-time (normally 0030-0730) and wintertime (November to February) use. For a completely level load, as for example from telephone equipment, the ratios would be 29% and 33%. A daytime summer load, as for example from a chiller, might have ratios of 0% and 0%, while a load that peaked at daytime in winter, like lighting, would be perhaps 5% and 45%.

4.6.4 The result is an attribution of standing, availability, MD and day/night unit charges to each individual item, giving an annual total in column BA and an average cost per unit in column BB. Tariff components are also calculated for the building as a whole in the top corner of columns BA and BB and by summing the individual items in rows 79 and 81. Row 84 provides a cross-check between the two methods of calculation, to trap any errors which could arise where figures were inserted manually from monitored data, as for rows 12, 13, 15, 16 and 17 in this instance. The summed figures for items under each of the 15 standard headings are shown in the lower corner of Table 4.1A, in columns AH to AK and rows 65 to 79, with totals in Row 81.

4.6.5 The spreadsheet technique of Table 4 is potentially powerful and helps to identify the energy costs attributable to each item or group of items. Within the time available we were not able to develop and test it fully and apply it rigorously and consistently across all the Case Study buildings. Further development of the technique is now under consideration by BRE.

4.7 Apportionment of Annual Energy Consumption

4.7.1 A summary of annual energy consumption and cost, with key building data, was held on a spreadsheet (table 4.2), developed from the London Energy Group's original standard Energy Reporting format (reference 13). LEG's current simplified format (reference 14) - which was produced after comments that the original was too complicated - was not detailed enough.

4.7.2 Annual delivered energy use for the Case Studies was broken down by individual fuel (and standard/off-peak electricity where appropriate, as in EED buildings) and into fifteen standard end-use headings as listed below. Fuel for standby generators used in emergencies only was not included, partly because oil deliveries were so infrequent, with the main use being for testing. Normally the apportionment of delivered energy included all system losses (eg: combustion losses, distribution losses, and standing losses). Where independently-monitored figures of losses were available, these were normally assigned back to the end uses.

1 HEATING

Delivered energy consumption for space heating and ventilation only, excluding domestic hot water, process heating, and unusual end-uses such as path de-icing and the swimming-pool at NFU (both of which are classified as "other special")

2 COOLING

Energy consumption for chillers, cooling towers, and air-cooled condensers for comfort cooling purposes, including fans, immersion heaters and ancillaries BUT NOT pumps and excluding computer, telecommunications and machine room cooling systems.

3 PUMPS AND BOILER ANCILLARIES

Pumps used for central heating, hot and cold water, chilled water and condenser water. The category also includes boiler ancillaries: burner fans, flue boost or dilution fans, and gas pressure boosters.

4 FANS

Ventilation fans, including kitchen and restaurant fans, mechanical plant room fans where installed, but not condenser and cooling tower fans, or car park fans.

5 CONTROLS

Controls for mechanical and electrical services. Building energy management systems.

6 DOMESTIC HOT WATER

Heat sources for domestic hot water, including electrical consumption of any heat recovery systems, but not pumps and controls.

7 LIGHTS

All interior lights within the measured gross area, including task lights, emergency lights and plant room lights, but not lights outside the gross area, e.g: exterior and car park lights.

8 TELECOMMUNICATIONS

Telephone switching systems and other telecommunications equipment, modems etc. in separate rooms, and including any associated ventilation and air-conditioning systems.

9 OFFICE EQUIPMENT

Small power users within the general office space, except for catering equipment, task lighting, and telephone exchanges.

10 COMPUTER SUITE

Computer equipment in dedicated machine rooms only.

11 COMPUTER AIR CONDITIONING

Air-conditioning attributable to the dedicated machine rooms in category 10 above, normally for dedicated packaged systems but occasionally apportioned amounts from a central system. The heading includes all energy consumption attributable to the computer suite for heating, refrigeration, pumps, fans, and humidity control.

12 CATERING EQUIPMENT

Largely kitchen, servery, dishwashing and food storage equipment. Also local vending machines, kettles, coffee-makers and so on BUT NOT domestic hot water (other than local boosters for dishwashers), heating, and ventilation for kitchens and restaurants.

13 LIFTS etc.

Lift traction including ancillaries such as controls and motor-generator sets. Lift motor room ventilation and air-conditioning. Lift car ventilation, cooling and lighting.

14 OTHER NORMAL

Typically print rooms, external lighting, security and alarm systems.

15 OTHER SPECIAL

Unusual items, eg: the swimming-pool at NFU, underground car parking (which is not included in our treated area measurement), fountains and signs.

TABLE 4.2	TYPICAL SUMMARY OF BUILDING DATA AND ANNUAL ENERGY CONSUMPTION																	
ENERGY EFFICIENCY IN OFFICES: BUILDING AND ENERGY SUMMARY BASED ON LONDON ENERGY GROUP FORMAT																COUNTRY		UK
PROJECT NAME	BRE low energy office -			EED ELECTRIC UPGRADE			ADDRESS	BRE, Garston, Watford, Herts								31-Jan	1991	10:34
ARCHITECTS	PSA						BUILDER	Y J Lovell										
ENGINEERS	PSA						SUBCONTRACTORS			M&E:	Haden Young							
Date completed			1981	FLOORS:	Above gd	3	KEY FEATURES		Simple, low-rise office. Good space standards. Relatively low occupancy.									
Date Bldg Refurb			1988		Below gd				Upgraded to EED electric heating, electric central HWS + two local instantaneous.									
Date Plant Chgd			1988		Total	3	Data from	Jan	1989	To	Dec	1989	DDs in period		7°C base	20 yr DD	2115	
SIZE	Sq feet	Sq m	Origin	USAGE AND ENVIRONMENT DATA							TOTALS	TYPICAL U-VALUES				W/m2K		W/m3K
Gr. area	21280	1977	DL&E	Square metre area used in ratios:					Gross		1977		Wall	Window	Roof	Floor	DHL	G
Net area	15091	1402	Net:gross	No of occupants	Average daytime (100 at 80% occupancy)						80		0.45	2.20	0.30	0.40		
Treated	21000	1951	70.9%	Occ: hrs/day							9	ENERGY SAVING SYSTEMS						Saving?
Trtd. Vol		4450	ft3/m3	days/wk							5	Low emissivity double glazing						
Calculated space standard				wks/yr							52	Panel electric heaters in rooms						
	(m2 gross/person)		24.71	Htg ssn weeks							30	Central control for electric heaters						
ENERGY TARGETS				Space Temp (°C)							19	Lighting control system					Now disconnected	
kWh/sq m	Del elec	Del fuel	Primary	Office lighting		Typical illuminance (lux)					350	Window size optimisation and shading						
Overall				Typical watts per square metre							14	Upgraded fabric insulation - roof & floor dubious						
BREAKDOWN OF ANNUAL ENERGY USE					TOTAL		HEAT+3.5*ELEC		kWh/SQUARE METRE				kWh/	Directly apportioned			kWh/m2:	
kWh/annum		Gen elec	Gas	Elec htg	kWh/year	%	kWh/year	%	Elec	Heat	Both	BLDG	persn	£/m2	£/person	£%	Nett	Treated
Heating				85928	85928	54.2%	85928	25.3%	0.0	43.5	43.5	SERV	1074	£2.28	£56.33	53.07%	61.3	44.0
Fan heaters		1080			1080	0.7%	3780	1.1%	0.5	0.0	0.5	ONLY	14	£0.03	£0.74	0.70%	0.8	0.6
Pumps		156		HWS only	156	0.1%	546	0.2%	0.1	0.0	0.1	kWh/	2	£0.00	£0.11	0.10%	0.1	0.1
Fans		800		Toilets only	800	0.5%	2800	0.8%	0.4	0.0	0.4	sq.m.	10	£0.02	£0.55	0.52%	0.6	0.4
Controls		968		Estimated	968	0.6%	3388	1.0%	0.5	0.0	0.5		12	£0.03	£0.66	0.63%	0.7	0.5
HVAC Sub-total		3004	0	85928	88932	56.1%	96442	28.4%	1.5	43.5	45.0	45.0	1112	£2.36	£58.39	55.01%	63.4	45.6
DHWS		9548			9548	6.0%	33418	9.8%	4.8	0.0	4.8	4.8	119	£0.27	£6.56	6.18%	6.8	4.9
Lights		24024		Incl corridors	24024	15.2%	84084	24.7%	12.2	0.0	12.2	12.2	300	£0.67	£16.50	15.55%	17.1	12.3
Telecoms					0	0.0%	0	0.0%	0.0	0.0	0.0		0	£0.00	£0.00	0.00%	0.0	0.0
Small power		10880			10880	6.9%	38080	11.2%	5.5	0.0	5.5		136	£0.30	£7.47	7.04%	7.8	5.6
Computer suite					0	0.0%	0	0.0%	0.0	0.0	0.0		0	£0.00	£0.00	0.00%	0.0	0.0
Computer A/C					0	0.0%	0	0.0%	0.0	0.0	0.0		0	£0.00	£0.00	0.00%	0.0	0.0
Catering equipment		3756		Kettle+fridges	3756	2.4%	13146	3.9%	1.9	0.0	1.9		47	£0.10	£2.58	2.43%	2.7	1.9
Lifts/escalators					0	0.0%	0	0.0%	0.0	0.0	0.0	0.0	0	£0.00	£0.00	0.00%	0.0	0.0
Other normal		1310		Ovens+fan ht	1310	0.8%	4585	1.3%	0.7	0.0	0.7	0.7	16	£0.04	£0.90	0.85%	0.9	0.7
Other special		20000		Data loggers	20000	12.6%	70000	20.6%	10.1	0.0	10.1		250	£0.56	£13.74	12.94%	14.3	10.3
TOTAL DELIVERED		72522	0	85928	158450	100%	339755	100%	36.7	43.5	80.1	62.6	1981	£4.29	£106.14	100.0%	113.0	81.2
x Factor		0.98	0.72	0.98														
TOTAL NET		71072	0	84209	155281				35.9	0.0	78.5		1941				110.8	79.6
x Factor		3.82	1.07	3.00	3.38	.= Calculated mean PE factor												
TOTAL PRIMARY		277034	0	257784	534818				140.1	0.0	270.5		6685				381.5	274.1
FUEL COST/yr		£3985		£4506	£8491		FUEL COST/unit		£2.02	£2.28	£4.29	£3.33					£6.06	£4.35
Fuel cost/del kWh		£0.0549		£0.0524	£0.0536	COMMENTS		Info from R John + S Willis					Fuel costs EEB 1989			Data loggers included		
Fuel cost/gr sq m		£2.02	£0.00	£2.28	£4.29			DDs unclear - 7°C calc base					UPDATED EED VERSION					

Table 4.2

4.8 Comments on the Apportionment

4.8.1 There is no single way of apportioning energy consumption. While we took some care in developing ours, in retrospect yet more detail, and a range of different possible groupings, might be better, and would not add greatly to the effort where data is held electronically. Among others, the issues below are now being addressed in a BRE study on energy assessment and reporting methodologies which is now underway.

4.8.2 *Definition of floor area*

4.8.2.1 We think that treated floor area is a more meaningful denominator than gross floor area which, for example, introduces a bias in favour of highly-serviced buildings with large plant rooms. Our definition (Appendix C) is seen as a step forward. Further discussion may be necessary about the detailed assumptions, and which areas and their energy consumption should be left out of the main calculation and regarded as "special". However, nett area might be preferable as a well-understood figure in common use, though also subject to some misinterpretation.

4.8.2.2 The Case Studies use total treated floor area as denominator for all end uses. This was simple, convenient, and something which designers, energy auditors and facilities managers could easily operate - but not the complete answer. An alternative approach would be to use the denominator for the relevant area or service (for example computer room energy divided by computer room area; and heating energy to exclude computer room area). However, the figures rapidly become complex and potentially inconsistent and confusing. Ideally, energy use and area information would be kept in as finely-divided a form as possible, so that it could be aggregated in various ways, and for future work we recommend keeping more detailed schedules of accommodation.

4.8.3 *Assignment of pumps, fans and controls*

Transport and control energy should perhaps not be considered in isolation but assigned to the relevant services. So "cooling" would include cooling fans and chilled and condenser water pumps, "hot water" would include the associated primary and secondary pumps, and "catering" would include the associated HVAC, hot water and lighting. While this would make a lot of functional sense, the information would become more diffuse and sometimes difficult to assign, for example what proportions of an air handling unit's energy consumption should be attributed to heating, to cooling, to ventilation?

4.8.4 *Assignment of small power uses*

From a design point of view, it is less important to know how much energy is used by office equipment, lighting, telecommunications, catering etc. as to know where spatially it will occur and how it might affect cooling loads and the need for - and sizing of - air-conditioning systems. For example, it would be helpful to assign small power usage in offices to:

A Equipment which for functional reasons has to be on or near the desk-top.
B Equipment which for functional reasons would not normally be in the general office (eg: because it is noisy, requires a special environment, or is a central service).
C Items (eg: vending machines, shared printers, file servers, communications controllers, minicomputers), which are often in the general office but need not be there, and can often be conveniently located near entrance points.

By lumping equipment in these three categories together, one can often become convinced that full air-conditioning is essential. However, if the three categories of consumption are separated issues, one can find that less of the office area than anticipated requires air-conditioning, with hot equipment not needed at the desktop concentrated into small, specially-ventilated or cooled areas.

4.8.5 *Climate corrections and other methods of standardisation*

In the Case Studies, we chose not to make degree-day or similar corrections, but to keep normalisations of any kind to a minimum. When reviewing published energy data we became discontented with the use of unspecified corrections (for example by degree-days, aggregation of delivered electricity and fossil fuel, unspecified primary energy factors, unclear floor areas, and particularly occupancy hours). Information was also often selectively-presented, for example not including office or catering equipment. We therefore felt it best to present the raw data for a given year and to leave the corrections to others, including ourselves in any overview. In hindsight, it might have been better to present the degree-day performance in some detail.

4.8.6 *Energy costs*

It would be useful to have some standardised and possibly simplified tariff structures against which energy costs could be evaluated.

SECTION 5

CHARACTERISTICS OF THE CASE STUDY BUILDINGS

5 CHARACTERISTICS OF THE CASE STUDY BUILDINGS

5.1 Building data

5.1.1 This Chapter reviews some of the characteristics of the buildings, their occupants and their services which would otherwise slow down the discussion of energy consumption patterns in Chapter 6. It includes both general items and unusual features, both good and bad, but hopefully instructive. Key data is summarised in Table 5.1, which also includes the unpublished work on *Westminster, North-West Insurance* and *Victoria* which, following survey and analysis, did not reach Case Study standards, and *City Atrium* where owing to management changes we could not obtain approval to publish. *BRE LEO* appears twice, both in its originally-monitored and in its all-electric form *(Marked by the electricity industry as "EED" - Energy Efficient Design - to embrace a package of electric heating with advanced controls in very well-insulated buildings - see Reference 47).* The text fills in the background to the information in Table 5.1, column by column. More detail may also be found in the published Case Studies themselves.

5.1.2 DATE OF CONSTRUCTION

Most of the buildings were completed in the early to mid 1980s. The exceptions are:

1850s	*Heslington Hall.* This was included particularly to show that improved building services technology, management and controls could raise old buildings to higher standards of energy-efficiency without altering the fabric. It also shows the value of traditional methods of daylighting.
1920s	*PSI.* This was one of the few examples of an imaginative, low-cost refurbishment where energy-efficiency had been improved, although still showing scope for further savings.
1975	*Westminster.* Although substantial savings were claimed from energy-efficiency improvements: new boilers, window film, and new reflectors allowing two fluorescent tubes to be replaced by one, the energy consumption of this building was ultimately still too high for a Case Study.
1977	*Hereford & Worcester County Hall.* This is an interesting application of "mixed mode" principles which combine mechanical systems with openable windows. Its energy performance is good in relation to the fully air-conditioned building that it might easily have been, and to comparable buildings in the private sector.

In most of other pre-1980 buildings considered, heating consumption or cost was too high.

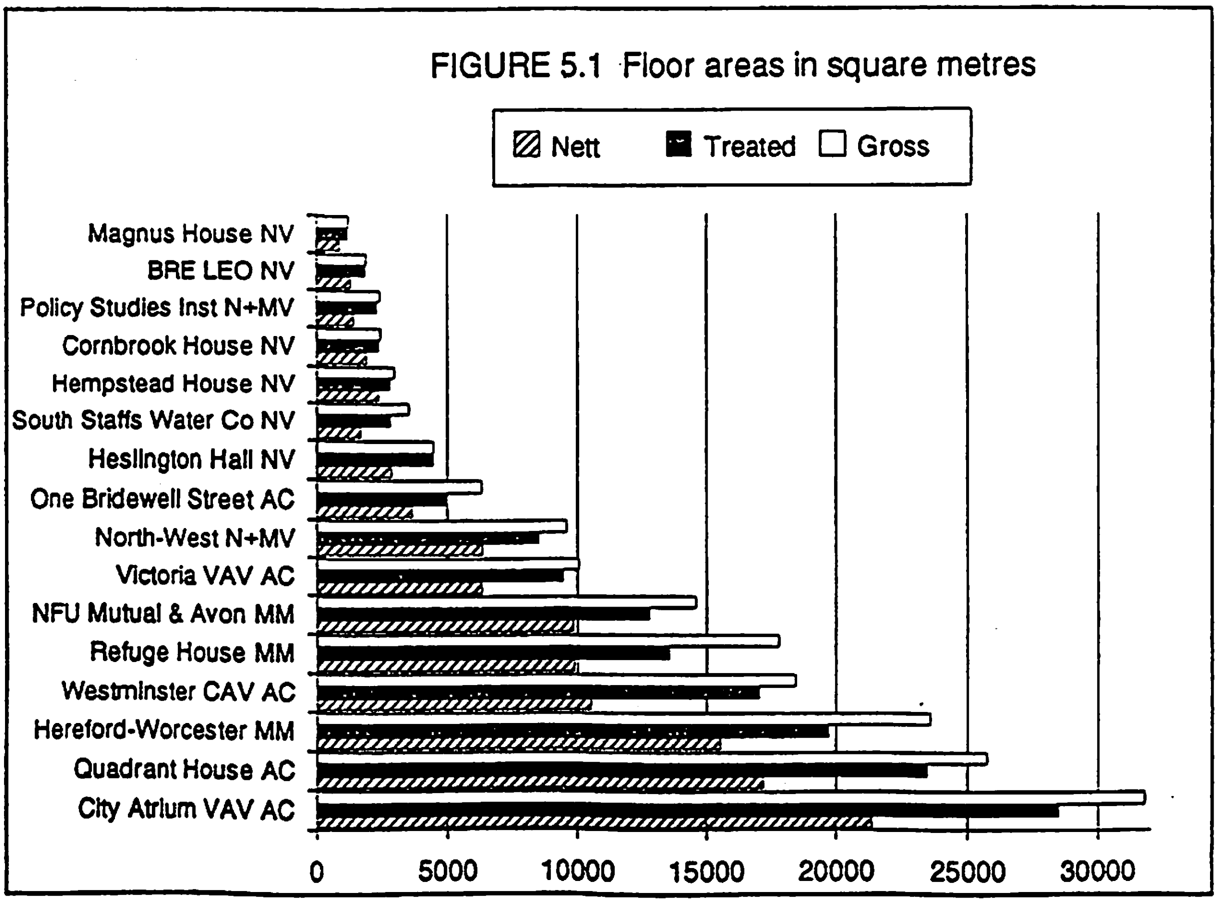


FIGURE 5.1 Floor areas in square metres
▨ Nett
■ Treated
☐ Gross
Magnus House NV
BRE LEO NV
Policy Studies Inst N+MV
Cornbrook House NV
Hempstead House NV
South Staffs Water Co NV
Heslington Hall NV
One Bridewell Street AC
North-West N+MV
Victoria VAV AC
NFU Mutual & Avon MM
Refuge House MM
Westminster CAV AC
Hereford-Worcester MM
Quadrant House AC
City Atrium VAV AC
0
5000
10000
15000
20000
25000
30000

TABLE 5.1

KEY FEATURES OF THE CASE STUDY BUILDINGS AND MAIN ALSO-RANS

Sorted in order of decreasing treated floor area

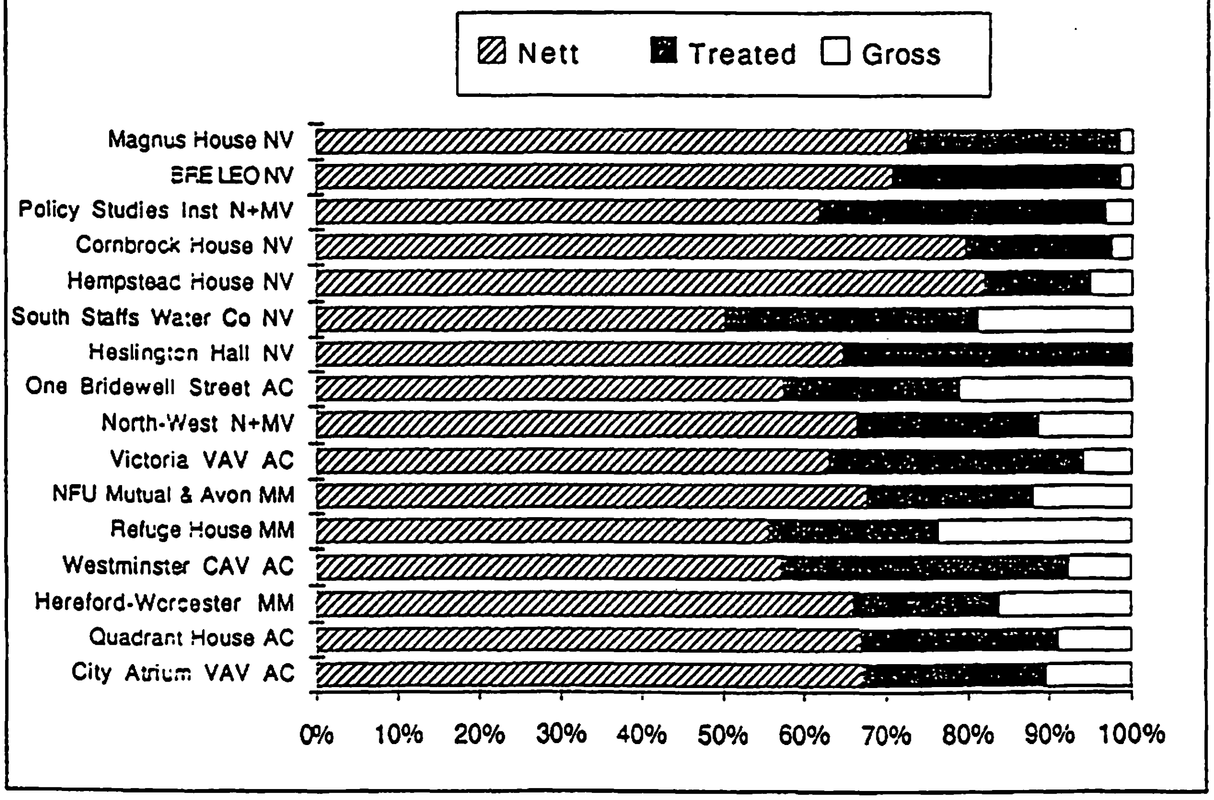
	DATES:		Floors:	Floor area (sq m):			Tenure	Occu-	Space	CONSTRUCTION:					WINDOWS:			HEATING:			VENTILATION	CONTROLS:	LIGHTING:		W/ m2/		IT level >>	Computer room >>	Restaurant >>
(Italics = also-ran)	Built	Refrb		Gross	Trtd	Nett		pants	plan	Frame	Walls	U	Roof	U	Frame	Glass	U		Boilers >>		& COOLING:		Source	Lux	100	Controls			
																				HWS >>					lux				
City Atrium VAV	1984	NA	9.5	31820	28510	21360	Head	1800	Open &	Steel	Curtn	0.6	Steel, flat	0.6	Aluminium	Double	3.3	Heated	2	E	Fully VAV air-	BEMS	Fluorescent	400-	4.2	Local and	H	Y	Y
FAC							tenant		cellular		wall		inverted			Tinted		mullions			conditioned		recessed	500		block			
							Financial trading								External lattice shading						Centrifugal chillers, water cooled								
Quadrant House	1980	EC	21	25760	23475	17210	Owner	1000	Cellular	Concrete	PCC	0.6	Flat concrete	0.6	Aluminium	Double	3.3	Versatemp	2	C	Heated/cooled	BEMS	Fluorescent	450	3.8	Local, grp	M	N	Y
FAC							tenant		& open		panel				sealed			heat pumps			primary air		recessed			and auto			
							Magazine publishing								Internal blinds & some film						Reciprocating chillers, water cooled								
Hereford-Worcester CC	1977	EC	3.5	23600	19750	15550	Public	1050	Open &	Concrete	Brick	1.0	Pitched zinc	0.6	Aluminium	Double	4.3	Radiators	2	C	Const+VAV+	Conventional	Fluorescent	500-	5.5	Group &	M	Y	Y
MM: AC + MV + NV							Sector		cellular				on aerated		plus fanlight	Single					Comfort cooling	time & OSC	recessed	600		automatic			
							Local authority						concrete		External overhangs & sunbreakers						Reciprocating chillers, water cooled								
Westminster CAV	1975	1985	12	18470	17060	10560	Single	1300	Cellular	Concrete	Curtn	1.0	Flat concrete	1.0	Aluminium	Single	5.5	Perimeter	3	C	Const Vol +	Conventional	Fluorescent	400	5	Group &	M	Y	Y
FAC							tenant		& open		wall				sealed	filmed		induction			induction A/C	OSC	recessed		2.3	local			
							Accountancy								Solar reflecitve film retrofit						Reciprocating chillers, water cooled								
Refuge House	1987	NA	3	17820	13600	9900	Owner	700	Open &	Concrete	Brick	0.6	Pitched tile	0.4	Aluminium	Double	3.3	Underfloor	3	C	Natural & mech	BEMS	MBI uplight	400	4.8	Local &	M	Y	Y
MM: AC + MV + NV							occupier		cellular				on steel		tilt/turn			fan coils			with cooling		wall/column			automatic			
							Insurance								Mid-pane venetian blinds						Screw chillers, water cooled								
NFU Mutual & Avon HQ	1984	NA	4	14610	12850	9870	Owner	700	Open &	Concrete	Stone	0.5	Flat concrete	0.4	Hardwood+	Double	3.0	Radiators	2	C	Natural and	BEMS	Fluorescent	350	4.0	Local &	M	Y	Y
MM: MV + NV + local AC							occupier		cellular		clad		inverted		Aluminium			with TRVs			mechanical		suspended			automatic			
							Insurance								Overhangs, shelves, mid-pane blinds						Reciprocating chillers, air cooled								
Victoria VAV	1984	NA	7	10089	9500	6352	Multi	600	Open &	Concrete	Curtn	0.4	Flat concrete	0.6	Aluminium	Double	2.8	Perimeter	2	C	VAV air	Conventional+	Fluorescent	450	3.6	Group &	L	N	N
FAC							tenant		cellular		wall				sealed	tinted		convectors			conditioning	crude BEMS	recessed			local.			
							Various								Tinted and internal blinds						Centrifugal chillers, water cooled					Auto unused			
North-West Insurance	Varies	EC	2 to	9620	8520	6380	Owner	450	Open &	Concrete	Varies	1.2	Various	1.0	Various	Varies	3.5	Various	3	H	Natural or	Conventional	Fluorescent	300-	5.5	Local and	M	Y	y
NV+MV in parts+local AC			9				occupier		cellular						Some secondary glazing						mechanical	time & OSC	recessed	750		group			
							Insurance								Mixture of internal curtains and blinds						Reciprocating chillers, air cooled								
One Bridewell Street	1987	NA	6.5	6360	5020	3650	Head	310	Open &	Steel +	Curtn	0.6	Pitched	0.4	Aluminium	Twin	3.0	Ceiling	2	E	VAV air-	Conventional	Fluorescent	350-	2.4	Local, grp	M	m	N
FAC							tenant		cellular	concrete	wall		stainless		sealed	clear		fan coils			conditioning	plus BEMS	recessed	800		and auto			
							Accountants and sub-tenants						on timber		Internal blinds						Reciprocating chillers, air cooled								
Heslington Hall	1850s	1962	4	4475	4470	2890	Public	150	Cellular	Brick	Brick	1.2	Pitched tile	1.0	Steel and	Single	6.0	Radiators +	3	G	Largely	Simplified	Various	300	3.5	Local	L	m	N
NV							Sector			loadbearing			on timber		timber			natural + fan			natural	BEMS							
							University administration								Internal curtains & blinds			convectors											
South Staffs Water Co	1985	NA	4.5	3525	2860	1770	Owner	160	Cellular	Concrete	Brick	0.2	Pitched tile	0.3	UPVC	Double	1.6	Radiators	3	C	Largely	BEMS	Fluorescent	350	3.0	Local, grp	L	N	y
NV							occupier		& open		panel		on steel		tilt/turn	Lo E argon		with TRVs			natural		recessed			and auto			
							Water company administration								Overhangs, light shelves, internal vertical blinds														
Hempstead House	1982	NA	4.5	2980	2830	2440	Head	150	Open &	Concrete	Brick	0.6	Flat concrete	0.6	Aluminium	Double	3.3	Radiators +	4	E	Natural	Conventional	Various, incl	150-	5.0	Local, grp	M	m	N
NV							tenant		cellular				Steel		Pivot			zone stats				time & OSC	uplighting	600		and auto			
							Engineers and sub-tenants						penthouse		Mixture of internal curtains and blinds														
Cornbrook House	1985	NA	3.5	2500	2440	1990	Owner'	160	Cellular	Concrete	Brick	0.4	Pitched tile	0.4	Aluminium	Double	2.2	Radiators	2	G	Largely	Mini-BEMS	Fluorescent	450	3.1	Local	M	m	N
NV							Property Div		& open				on timber		Sash	Low E		with TRVs			natural		recessed			& group			
							Building contractor's regional office								Very small windows: internal blinds														
Policy Studies Institute	1920s	1985	5	2460	2380	1520	Charity	80	Cellular	Concrete	Brick	1.2	Flat- largely	0.6	Aluminium	Double	3.3	Radiators	2	E	Mechanical to	Conventional	Fluorescent	500-	3.5	Local	L	N	y
NV + local MV							landlord						concrete		Pivot			with TRVs			internal rooms	time & OSC	surface	600					
							Research institute and charity tenants								Internal venetian blinds														
BRE Low-energy Office	1982	1988	3	1980	1950	1400	Public	80	Cellular	Concrete	PCC	.45	Flat concrete	0.4	Aluminium	Double	2.2	Electric	E	E	Natural	Electronic	Fluorescent	350	4.0	Local	M	N	N
NV							Sector				panel		inverted		pivot	Low E		convectors				Controller	surface						
							Government agency - research								South side awnings + internal blinds														
Magnus House	1988	NA	3	1310	1290	950	Owner	60	Cellular	Brick	Brick	0.3	Pitched tile	.25	Aluminium	Double	2.2	Electric	E	E	Natural	Electronic	Fluorescent	700	2.5	Local	M	m	N
NV							occupier			loadbearing			on timber		tilt/turn	Low E		convectors				Controller	surface						
							Builder and developer								Internal vertical blinds														

NV = Natural Ventilation
MV = Mechanical Ventilation
NA = Not applicable
MM = Mixed mode
EC = Energy conservation project without associated refurbishment
AC = Air conditioning (FAC = Full AC)
C = HWS calorifier from heating boiler
E = Electric
H = Heat pump
H=high, M=medium, L=low >>
m=minicomputer only >>
Y=yes, y=yes but little used, N=no >>

5.1.3 FLOOR AREAS

5.1.3.1 The gross floor areas range from 1300 to over 30,000 square metres, a factor of 25. The distribution curve (figure 5.1) shows a cluster of buildings in the 2000-3000 m^2 range and a rapidly-rising progression thereafter. The larger buildings (average floor area 18,500 m^2) tend to be air-conditioned or *mixed-mode (a mixed mode building is one with management and user choice between natural and mechanical systems, for example background mechanical ventilation and openable windows)* while the smaller ones (average 2600 m^2) are largely naturally-ventilated. The five air-conditioned buildings in the sample had 52% of the floor area surveyed, while the eight naturally ventilated offices (including *PSI* and *North-West Insurance* with some mechanically-ventilated areas) comprise 16% of total floor area only.

FIGURE 5.2 Nett and treated: gross floor area ratios



5.1.3.2 Figure 5.2 shows that treated and nett areas are normally significantly less than gross, with low treated areas particularly for the larger buildings. This emphasises the inconsistencies that can occur between reported energy consumption figures where the areas concerned are uncertain. The following points are of particular interest:

- *Magnus House* has only a small amount of untreated area: the electrical cupboard and lift motor room, helping to substantiate the electricity industry's claim that all-electric buildings are more space-efficient. However, owing to its corridors and shallow depth the nett:gross ratio overall is no better than for comparable gas-heated buildings.
- The difference between *BRE LEO's* treated and gross areas is partly in the boiler room, which is irrelevant in its EED guise. It has no lift and its ventilation plant is on the roof and not in a room.

- *PSI's* apparent lack of space-efficiency results from its triangular shape, small room sizes and circulation for the conference area.

- The untreated area at *Hempstead House* is relatively large for a naturally-ventilated building, owing to an unheated store and escape stair.

- The large untreated area at *South Staffordshire Water Company* is largely the attic space under the pitched roof, which is used for "dead" storage and plant. Some published literature on this building uses the gross area in the denominator and therefore shows lower unit energy consumption than the Case Study. On the other hand, the good insulation at pitched roof level stops the attic getting excessively warm or cold, and the storage space is very useful and part of it might otherwise have needed to be within the treated area.

- *SSWC* also has a fairly poor nett:treated area ratio. This arises from a fairly generous main stairway and relatively inefficient circulation around the central core, which was structurally necessary to concentrate and balance the load of the building in an area of mining subsidence.

- In spite of the boiler room etc, there is little difference between gross and treated areas at *Heslington Hall.* This is a consequence of measurement definitions in attic rooms with sloping ceilings: treated area is measured to the perimeter of the room but the RICS definition of gross area excludes areas with headroom under 1600 mm. In some top floor rooms, the treated area therefore exceeds the gross area!

- The large difference between treated and gross area at *One Bridewell Street* arises from the ground floor car park, and a fairly generous plant space under the pitched roof.

- The large difference between treated and gross areas at *Refuge House* arises from the concrete-floored attic spaces beneath the pitched roofs, some of which are used for plant only, the rest being empty. The designers' gross area figure for the building (14,400 m^2) appears to exclude these empty spaces.

- The poor nett:treated ratio at *Westminster* arises largely from an inefficient "race-track" double-corridor plan around two cores.

5.1.3.3 Not all the lettable area is typical office space. Many of the buildings had computer rooms and substantial kitchens and restaurants (several at *City Atrium* and *Quadrant House*), as indicated in the last two columns of Table 5.1. In addition:

- *Policy Studies Institute* has large conference and meeting rooms for its size, which are also rented-out. It also has a substantial kitchen for the conference lettings, though this is seldom used other than as a servery by outside caterers.

- *Heslington Hall* has a large printing department and several large meeting rooms.

- *One Bridewell Street* includes a gym.

- *North-West Insurance* has a large archive stack, with a low lighting load, operated on-demand and a reduced floor-to-floor height. Having heating and mechanical ventilation it counts as treated area but it does not really merit the full weighting - another reason why this building ultimately proved inappropriate for a Case Study.

- *NFU Mutual & Avon Group HQ* has a conference and training suite, and a swimming-pool which is largely warmed by reject heat from the computer room.

- *Hereford & Worcester CC* includes a council suite and a civil defence centre, both with low hours of normal use which tend to depress annual energy consumption.

5.2 Occupancy data

5.2.1 TENURE PATTERN

The tenure of the Case Study buildings varies substantially. However, in all but the also-ran *Victoria*, the main occupant (were they owner, single tenant, or head tenant) also managed the building. *Cornbrook House,* although owned and occupied by the same organisation, is managed by their property division in London and they - and not the occupants, who actually include the designers of the building - appoint the building services operation and maintenance contractor. This creates a lengthy management chain similar to those found in many private rented and public sector buildings where (at least in theory) the occupants of the building have no direct influence over the operation and management of the plant, often not even the occupancy time schedules.

5.2.2 TYPES OF OCCUPANT AND LEVELS OF USE OF INFORMATION TECHNOLOGY

The occupants' businesses and levels of Information Technology varied:

- IT use in the general offices was highest by far for the financial trading and services companies at *City Atrium.*
- Perhaps surprisingly, most of the tenants at the prestige *Victoria* were not very high IT users, except for a financial services company with a dealing room in part of one floor: this had independent air-conditioning which turned out to be much oversized and possibly unnecessary as the room was little used with most equipment off out-of-hours.
- The three insurance companies *(Refuge, Provincial and NFU)* had large mainframe computer installations serving many terminals about the offices and elsewhere. However, the terminals used were seldom "intelligent", with only half or one-third the heat output each of a PC and screen.
- The three public sector offices: *BRE LEO, Heslington Hall* and *Hereford & Worcester* have rather lower levels of IT and again a higher proportion of terminals to PCs. *(NOTE: Since the Case Studies were completed, the use of PCs in low-IT offices such as these has been growing rapidly).*

5.2.3 OCCUPATION DENSITY

The number of occupants were given to us by the buildings' facilities managers or personnel departments. In the smaller buildings, we could make rough checks on numbers as part of the energy survey visits, but in the larger ones this was impossible. The figures collected indicate average occupation densities of about 15 m^2 of total nett area per person in the naturally-ventilated offices and 10 m^2 nett per person in the air-conditioned ones, suggesting that air-conditioned offices could make up for their higher energy consumption by better space-efficiency. However, discussions with researchers into space planning and building use surveys (reference 17) suggests the quoted densities of occupancy in the larger air-conditioned buildings are almost certainly too high and that people's estimates of occupancy are notoriously unreliable, usually high, and need to be confirmed by detailed surveys. At this stage, we therefore recommend that the occupancy figures are ignored, but a future study of occupancy densities and servicing systems would be rewarding.

5.3 Building construction

5.3.1 STRUCTURE

Most of the buildings are of concrete frame construction, with insitu concrete floors. The air-conditioned *City Atrium* is typical 1980s developer's fast-build steel frame and composite steel/concrete floor construction. Amusingly, both the oldest *(Heslington Hall)* and the newest *(Magnus House)* are of loadbearing brickwork: the latter a small building by a housing developer who used techniques with which they were familiar.

5.3.2 CLADDING

Most of the buildings are clad in brick, occasionally loadbearing but usually as an outer skin. Three *(Quadrant House, BRE LEO and SSWC)* have precast concrete cladding; *NFU* is ashlar stone-faced. *Westminster, City Atrium, and Victoria* have lightweight curtain walling/insulation systems. *One Bridewell Street* was designed for minimum cooling loads and has concrete walls, external insulation, a ventilated cavity and white rainscreen cladding. *Heslington Hall and PSI* have solid, uninsulated - but very thick - walls. *Hereford & Worcester* has a cavity wall with an aerated concrete blockwork inner leaf. The others have cavity insulation of one kind or other, usually with partial fill but with full-fill and multiple layers in some of the more highly-insulated buildings such as *South Staffs Water Company*. No technical problems with the insulation were reported, such as condensation or water penetration. The actual effectiveness of the insulation was not tested, and it is not known whether the theoretical U-values were attained, though studies at *BRE Low-Energy Office* and elsewhere suggest that shortfalls (through missing insulation, settlement, detachment, dampness, air circulation and thermal bridging) are quite common.

5.3.3 ROOFING

The roofs are generally quite well insulated and are predominantly flat and concrete or pitched with a void space, which is then often used for plant. In the buildings which were not fully air-conditioned, the designers had often used these forms of construction deliberately (instead of the steel often favoured by structural engineers), to help avoid summer overheating by increasing thermal capacity and reducing or delaying transmitted solar gains. *Hereford & Worcester* made up for its steel structure by placing aerated concrete slabs on top, predominantly for mass and time lag, but also providing much of the insulation.

5.3.4 WINDOWS

5.3.4.1 Nearly all the offices have double-glazing, except for *Heslington Hall* (too old) and *Westminster.* Although 1990 Building Regulations do not require it, double-glazing now seems to be very much standard in most new or refurbished office buildings of any size in the private sector *(NOTE: this made virtually all-glass double-glazed office buildings acceptable from a Building Regulations point of view in spite of their poor thermal performance in respect of unwanted solar gains as well as excessive heat losses. The proposals for the 1994 Regulations will make this almost impossible to do). North-West Insurance* has only partial secondary glazing (in the 1971 extension - about half the office area), while at *PSI and Hereford & Worcester* double glazing is omitted - quite sensibly - for a few details where it would have been disproportionately expensive and the frames intrusive. Windows take up typically 25-40% of external wall area, with less (only about 10%) at *Cornbrook House* and more at *Westminster, City Atrium and Hereford & Worcester.* Only at *BRE LEO* is individual window size systematically varied with orientation, though other buildings (such as *NFU* and *Refuge*), have more total window area exposed to the south and west respectively, using sloped sites to expose restaurants etc. on the one side, and to bury computer and plant rooms on the other.

5.3.4.2 Aluminium is the predominant window frame material, not always with thermal breaks. Only *Heslington Hall* (steel and timber), *SSWC* (UPVC) and *NFU* (hardwood to external facades:

aluminium to courtyards) used other materials. The glass was normally clear, except at *City Atrium, Victoria,* a few parts of *Quadrant House* and *Westminster,* where film was applied in the mid-1980s to reduce solar gains through its large windows. Four of the offices have low-emissivity glass (argon-filled at *SSWC* for still higher insulation) which, in spite of the slight tint, occupants seemed to regard as "clear".

5.3.4.3 The fully air-conditioned *City Atrium, Quadrant House, Westminster, Victoria* and *One Bridewell Street* all have sealed windows. The others have openable windows, though at *Hereford and Worcester* (a mixed-mode building with mechanical ventilation permanently operating and comfort cooling also available in hot weather) largely restricted to fanlights only.

5.3.4.4 The Case Studies, and visits to related buildings, revealed that openable windows frequently did not give optimum natural ventilation: this was also confirmed in a survey of recently-completed buildings (reference 52). More attention is required by designers to the design of opening elements and the related ironmongery.

i) Users were not entirely happy with the *tilt-and-turn windows* at *Refuge House, SSWC, Magnus House* and elsewhere. These windows have both drop-down "hopper" action for background ventilation and open inwards for maximum ventilation and for cleaning. The following problems were reported:

- With no fine control of hopper action, ventilation is either insufficient or excessive, particularly where there is cross-ventilation between opposite windows under the control of different users, as often happens in an office.
- When the windows are in "turn" position in warm or still weather, they blow about in wind gusts and can slam annoyingly and sometimes damagingly.
- The inward-opening action is unfamiliar in the UK and can interfere with blinds, objects left on window cills, and intrude upon the occupied space.

Discussions with a major UK supplier of tilt-and turn gear revealed that the problems could be reduced by specifying more appropriate hardware (reference 18):

- A "slit catch" or "trickle vent" can be used for secure minimum ventilation.
- The tilt gear can be supplied with an intermediate stop position.
- Inward turning can be restricted by specifying a friction stay.

However, few specifiers in the UK ever seem to specify these features.

ii) Many naturally-ventilated offices overheat in summer because they are shut up tight for security overnight. This traps much of the heat from the previous day, leading to a ratchet effect, where temperatures can build up to unacceptable levels over a warm spell. Secure night ventilation could be a great asset, possibly under automatic or semi-automatic control (where manually-opened windows can be shut if it subsequently gets too cold, for example over a weekend). Tests at *Hempstead House* in the hot summer of 1989 showed that ventilation in the early hours significantly improved daytime temperature. Provision of secure night ventilation, perhaps with automatic control, could significantly improve summertime comfort in naturally-ventilated offices, reducing the need for air-conditioning.

iii) Window gear needs to be easy to use and intuitively obvious in its operation. For instance, the upper parts of modern aluminium sash windows are difficult to use effectively as the minimal frames without projecting glazing bars give nothing to grip and fingers can also be trapped. At *NFU*, the upper hopper windows - intended for cross-ventilation - had worm gear which was slow to operate and hence not used to the extent intended, though once they were opened in summer they tended to stay open overnight, providing a useful cooling effect more economically than the mechanical ventilation which the designers had originally intended to undertake this task.

iv) Unwanted air infiltration was not generally seen to be a problem in the case study buildings (except in high winds at *SSWC,* where some slight movement of the UPVC frames had been diagnosed and repairs were planned), but in some rejected candidates unexpected infiltration paths through cills etc. had been problematic and difficult to cure.

5.3.4.5 Unfortunately, effective window design (particularly for natural light and ventilation) tends to fall between the professional responsibilities of the architect and the engineer and often does not get addressed comprehensively by either, let alone both. Often architects seem either to specify general requirements or agree to whatever is suggested by the manufacturer. The CIBSE Window Design Guide (reference 19) also says little about the design of windows for optimum ventilation or the control functions of windows generally.

5.3.5 SOLAR GAIN AND GLARE CONTROL

5.3.5.1 All the offices have blinds or curtains of one kind or other, except for most of *Hereford & Worcester* where they were omitted from the building contract and not affordable afterwards. Sky and low sun causes some discomfort and glare, though not as much as might have been expected owing to internal shading by cupboards and acoustic screens.

5.3.5.2 Several of the offices have elaborate solar protection systems:

- In addition to internal venetian blinds, *City Atrium* has bronze-tinted glass and horizontal walkway screens which also provide access for maintenance and window cleaning.
- *Hereford & Worcester* has overhangs and horizontally-projecting louvred "sunbreakers", intended to intercept summer sun while permitting wintertime passive solar gains.
- The external walls at *NFU* also have overhangs and simpler louvred horizontally-projecting sunbreakers (not on the north side), with modest internal light shelves all round. Glazed areas are also kept to a minimum on the east and west office facades, where low sun can produce troublesome glare and direct radiation. The swimming-pool's west elevation - which can benefit from solar gains - is highly glazed.
- Exposed areas of the courtyard curtain walling at *NFU* have external motorised venetian blinds under a combination of manual and automatic control. Interestingly, while automatic control has proved acceptable for the south-facing open-office corridors, in the east- and west-facing cellular offices the occupants prefer individual control. Here the automatic controls are now only used to lower the blinds at night during the heating season to reduce radiation losses and to lift them in high winds. Low early-morning summer sun is not a problem here owing to self-shading within the courtyards.
- *SSWC* has external overhangs and reflective light shelves which provide some direct summer solar protection while reflecting daylight and sunlight onto the ceiling, assisted by very deep internal light shelves and window cills. These devices take up quite a lot of potential lettable floor area and would not be acceptable in a speculative office, where maximising floorspace is normally a prime requirement.
- At both *SSWC* and *NFU* the fanlights above the light shelves were unshaded, on the assumption that overhang and light shelf geometry would exclude high summer sun and at other times shafts of sunlight would be welcome. However, in both offices low sun through fanlights has been a nuisance, particularly at *SSWC* where the windows are in continuous strips, and in both offices for VDU users. *NFU* have subsequently installed vertical louvre blinds above the light shelves on the south side, while *SSWC* have resorted to ad-hoc methods in places, for instance brown paper. Both reduce daylight from the expected levels, but not by enough to undermine the lighting strategy.

- *BRE LEO* has automatically-controlled external canvas awning blinds on the south side. As at *NFU*, some cellular office users disliked automatic control and operation is now largely manual. Over the years, some of the blinds have become torn and have not been replaced owing to disagreements about whether the costs should fall on research or maintenance budgets. In any event, with a tree belt to the south side, summertime temperatures are not excessive and the internal venetian blinds have proved adequate in most rooms.

5.3.5.3 In the other offices, solar protection is more modest. At *Quadrant House, Westminster* and *Victoria*, presumably the designers felt that the air-conditioning could cope, though at the large-windowed *Westminster* only with difficulty until the window film was added. The air-conditioned *One Bridewell Street* has mid-pane venetian blinds, as has *Refuge House:* here presumably the designers felt that more elaborate solar control was not cost-effective in buildings with modest window areas and mechanical cooling available when required.

5.3.5.4 *Cornbrook House* was given small windows partly to reduce unwanted solar gains, though its designers appear to have over-reacted to the problem, and the windows on the north-east and north-west facades could have been much larger in any event. *PSI* and the highly-insulated *Magnus House* have windows over twice as big with no ill-effects - and much better daylight - though with more cellular offices and masonry internal walls they do have a higher thermal capacity, which helps to reduce temperature swings and peaks. *Hempstead House* is on the border-line for summer comfort, with a deep plan for a cross-ventilated office, few partitions, a lightweight ceiling and larger west-facing windows: its east side is now shaded by an adjacent building.

5.4 Heating, ventilation and air-conditioning

5.4.1 HEATING

5.4.1.1 Most of the naturally-ventilated buildings have perimeter hot water systems, all except *Hempstead House* with outside-temperature compensation, sometimes with room temperature feedback via a BEMS, and some with room thermostats or TRVs as well. The two electrically-heated buildings, *BRE LEO Electric* and *Magnus House*, are designed to the Electricity Industry's Energy Efficient Design (EED) concept (reference 47). Comparative information is also included on *BRE LEO* in its original gas-boilered form. Most buildings had a single compensated circuit, plus a constant-temperature circuit where necessary for domestic hot water and air-handling plant: only at *NFU* are different orientations separately compensated.

5.4.1.2 *Hempstead House* has no central compensation but the temperature of the water to the radiators on each orientation on each floor is separately controlled, via 3-port valve and averaging room temperature sensors. The system worked well and control interlocks shut the boilers down when no more heat is needed - sometimes as early as 11am even in winter - and start them up for any out-of hours requirements in individual zones.

5.4.1.3 TRVs worked most satisfactorily in individual offices (as at *PSI* and in parts of *NFU* and *Heslington Hall):* in open offices some radiators tend to run hot and others cold, causing local discomfort and disagreement. At *NFU* the TRVs were disconnected in the open offices, though they are still effectively used in the cellular ones. The problems of TRV mechanical failure which occurred originally in *BRE LEO Original* (reference 20) do not seem to have noticeably afflicted the other Case Study buildings, but in offices generally TRVs often seem to be set higher than necessary, unless they have good, robust, and well-calibrated tamperproof high limit stops.

5.4.1.4 The air-conditioned buildings (here including the mixed-mode *Refuge House* which has air-conditioning available throughout) have a more diverse range of perimeter heating:

- *City Atrium* has an interesting system of water-filled heated structural mullions for the curtain walling system, to offset fabric losses without encroaching into lettable area. The mullions are only fixed to the cladding extrusions at intervals via a thermal break detail, and so direct heat conduction to the outside from this detail are not excessive.
- *Quadrant House* uses modular water-to-air heat pumps for both heating and cooling. They are located largely under windows and controlled by integral thermostats.
- *Westminster* has perimeter induction units with reheat coils and return air thermostats.
- *Refuge House* has underfloor fan-coil units, blowing upwards through a flat stub duct to a grille at window cill level. The occupants have found maintenance access to the underfloor units cumbersome and time-consuming, and in hindsight would have preferred a perimeter solution, in spite of the loss in usable floor area which would have been entailed.
- *Victoria* has a simple perimeter cill-line convector running under the windows.
- *One Bridewell Street* has ingenious two-way linear diffusers which blow ceiling void air (heated if necessary by fan-convectors in the void) towards the perimeter from one side and cooled, conditioned air towards the core from the other (see Case Study for details).

5.4.2 BOILER PLANT

5.4.2.1 Most of the buildings had two identical pressure-jet cast-iron or steel shell boilers, sometimes with dual-fuel capability (though at the time of the surveys two fuels were only being used at Heslington Hall, all other systems burning gas). The exceptions to this rule are:

- *Westminster, Refuge House and North-West Insurance* - three equal boilers (the third used to have four plus a small summer boiler but energy-saving improvements allowed them to be disconnected)
- *NFU* - alternative off-peak electric water storage available (a legacy of the Iranian Crisis at the time of design when gas supplies were withdrawn), but not currently used.
- *Heslington Hall* - One high-efficiency atmospheric gas "lead" boiler plus duty/standby oil-fired cast-iron pressure-jet "lag" and cold weather baseload boilers.
- *SSWC & Hempstead House:* 3 and 4 modular atmospheric cast-iron boilers respectively.
- *Cornbrook House:* two equal cast-iron atmospheric gas-fired condensing boilers.

The small number of condensing boilers in the sample is disappointing but not unusual.

5.4.2.2 Boiler power is normally large in relation to the estimated heating demands of the buildings. The plant was seldom sequenced or managed with optimum efficiency, giving higher standing losses than necessary. There is room for more development and information on this front: the majority of boiler sequencing routines in practice do not appear to do the job intended, bringing-on all boilers first thing in the morning whether they are really necessary or not, and hunting all the boiler plant between zero and full output thereafter. Convective standing losses from unfired atmospheric boilers on standby can also be significant.

5.4.3 DOMESTIC HOT WATER

5.4.3.1 There is a range of domestic hot water systems:

- Seven of the sixteen buildings have conventional boiler/calorifier systems. *Quadrant House's* calorifier is electrically heated in summer (typically 20-22 weeks per year), when the boilers are off altogether. *NFU and Refuge* have high-temperature calorifiers for the kitchens and low-temperature ones for other uses. Make-up water to *NFU's* calorifiers is preheated by surplus heat from the swimming-pool dehumidification system, though at the time of our survey it was was not working effectively, and its contribution would have been small. (NOTE: when heat recovery systems are solely an energy-saving measure and systems work perfectly well without them, poor performance can easily pass un-noticed).
- *Heslington Hall and Cornbrook House* have central gas-fired storage water heaters.
- Six buildings have electric systems, using local storage water heaters, except at *BRE LEO* which has a central calorifier and two local instantaneous heaters.
- As well as their central systems, *NFU* and *Heslington Hall* have electric storage water heaters for remote toilets, *NFU* by design intent and *Heslington* for convenience.
- The electric heaters are on permanently at *City Atrium, Heslington Hall, BRE LEO Electric and Magnus House,* under BEMS control at *NFU and One Bridewell Street,* and time-switched elsewhere.

5.4.3.2 Office hot water systems using central heating boilers and calorifiers can be very wasteful in summer when the boilers are greatly oversized for the modest hot water duties for hand-washing, cleaning and local sinks, and standing losses from pipework etc. do not usefully offset heating loads (see references 21 and 22). However, all but two of the calorifier-heated Case Study offices *(Victoria and SSWC)* had large kitchens with substantial hot water demands, making the central plant more viable. Improved controls have also made boiler management more efficient than hitherto: the boilers and primary system need no longer remain warm when there is no HWS demand in summer and with central monitoring from BEMSs etc. time control can be more effective. For example, at *Hereford & Worcester,* a single one-hour period of boiler operation proved enough to meet the day's summertime HWS needs without complaint.

5.4.3.3 Only *City Atrium* had substantial catering facilities with electric water heating. This was a function of its multi-tenanted shell-and-core design, with individual electrically-heated calorifiers for each toilet group, with no central domestic hot water services, separate kitchens for different tenants, plus additional staff catering and private dining in several different places.

5.4.4 VENTILATION AND AIR-CONDITIONING

5.4.4.1 The seven smallest buildings are all naturally-ventilated, with mechanically-ventilated toilets at *SSWC, Cornbrook House and Magnus House* and local constant-volume mechanical ventilation at *PSI* for the core and conference facilities. Some of the naturally-ventilated offices also have small local mechanical systems for kitchens, meeting rooms, and print rooms. *Hempstead House* has an air-conditioned conference room and a self-contained air-conditioning unit (operated occasionally on-demand) for the print room in the lightweight, highly glazed, roof penthouse which can get very hot in sunny weather. The over-glazing was apparently a planning requirement. *Hempstead House* also used to have an air-conditioned mini-computer room which is now used for a large photocopier and where the air-conditioner still operates in hot weather.

5.4.4.2 The older parts of *North-West Insurance* are naturally-ventilated, with fan-coil air-conditioning in the data processing area and mechanical ventilation via a perimeter induction system in the 1971 extension, which forms about half the office space. The 1971 building also has openable windows but the secondary glazing added later made them very difficult to use, so they normally stay shut.

5.4.4.3 Of the other eight buildings:

- Five are sealed and fully air-conditioned, though four of these are not humidified: *City Atrium VAV* does not have any as developer's policy: in the others the humidifiers are disconnected owing to fears about bacteriological problems such as *legionella*. *One Bridewell Street's* electric steam humidifiers are only used in extremely cold weather.
- Two *(Hereford & Worcester and NFU)* are largely mechanically-ventilated but with openable windows to increase user choice and reduce energy-dependency. Cooling systems are also available in some areas and operated on-demand in hot weather and as necessary for conference rooms etc..
- *Refuge House* has background mechanical ventilation with both natural ventilation and underfloor fan-coil cooling available throughout to choice, with units addressable from the BEMS via local group controllers.

5.4.4.4 Variable-air-volume (VAV) air-conditioning predominates - at *City Atrium, Victoria* and *One Bridewell Street*, and indeed in 1980s air-conditioned offices as a whole. Variable speed fans are used on all three sites. *Hereford & Worcester* also has simple VAV supplementary cooling to the perimeters of its lower floors, operable floor-by-floor in hot weather only when the background constant-volume system and openable windows do not suffice.

5.4.4.5 The other common air-conditioning systems are also represented:

- Perimeter induction (with some ceiling void units) at *Westminster.*
- Room-by-room water-to-air perimeter heat pumps (plus conditioned minimum fresh air) at *Quadrant House.*
- Fan-coils, underfloor at *Refuge,* wall-mounted or concealed in parts of *NFU* and *Hereford & Worcester,* and in ceiling voids as supplementary dealing-room cooling in parts of *City Atrium* and *Victoria.*
- Constant-volume in the cores of *Westminster* and *Hereford & Worcester.*

5.4.5 REFRIGERATION SYSTEMS

5.4.5.1 All main chillers were chilled water units. As a general rule, centrifugal chillers tend to be more cost-effective for large installations, semi-hermetic reciprocating units for smaller ones, and hermetic reciprocating units for small packaged units. For the larger units, cooling towers tend to be cheaper than air-cooled condensers. The Case Study installations largely follow this pattern, with the following exceptions:

- In addition to the main centrifugal chillers and cooling towers, *City Atrium* also has a number of separate air-cooled reciprocating systems for supplementary equipment room and dealing room needs.
- The large *Quadrant House* has reciprocating central chillers because these are for the relatively small fresh air load only. The rest of the cooling needs are met by the (hermetic) room heat pump units and either transferred via the tepid water loop to room heat pumps in other parts of the building, or rejected directly through the cooling towers.
- The relatively large *Hereford and Worcester* and *NFU* have reciprocating central chillers because the mixed-mode buildings require only a limited amount of cooling, particularly at NFU where the chilled-water system serves only the executive offices and meeting rooms and is operated on-demand only via the BEMS. At *Hereford & Worcester* the chillers also need to operate at low capacity at many times, especially in winter, to meet the needs of the computer room. Centrifugal chillers would operate inefficiently for such low loads.
- *Refuge House* unusually has screw chillers. As technology develops, these are becoming more efficient, particularly in the size range between reciprocating and centrifugal machines, and offer advantages of compactness, low-noise and continuously

variable capacity. *Refuge* also contains plate heat exchangers which allow the chilled water to be evaporatively cooled by outside air in winter, without using the chillers at all.

- The air-cooled condensers at *One Bridewell Street* show the current reaction against cooling towers with their possible health problems. Although refrigeration efficiency tends to be lower than with cooling towers, air-cooling tends to have lower overall running costs - at least for the smaller systems - as it requires less maintenance and no water quality monitoring. At *One Bridewell Street*, the cooling costs are low anyway.

5.4.6 HVAC CONTROL SYSTEMS

5.4.6.1 Of the eleven largest buildings all have BEMSs, except *Westminster* and *North-West Insurance*. *North-West Insurance* has three JEL optimum start compensators only, separately controlling the original building (radiators), the 1951 extension (floor panels) and the 1971 extension (induction system).

5.4.6.2 The BEMSs operated with varying degrees of success and operator commitment:

- *City Atrium's* TA system overrides the local Satchwell controllers. It worked well on a good day but had been unreliable from handover until the main tenant took over the management of the building and ceased to use the bureau who had monitored the system remotely. When the telephone link was disconnected, the system operated sweetly!

- *Quadrant House* initially had an early BEMS which was virtually useless. In 1987 this was replaced by a Trend system which provided a much higher level of control and management information, and in the hands of a new building maintenance and contract energy management service with a diligent on-site engineer has achieved major energy savings.

- *Hereford & Worcester* has an elderly Satchwell Autoscan central monitoring system, which today hardly counts as a BEMS but nevertheless gives useful information which is used very effectively by the site engineers. A modern replacement is planned.

- *Refuge House* has the most comprehensive system, with Landis & Gyr BEMS modular local controllers for every plant item, including the 400 underfloor 4-pipe fan-coil units.

- *NFU* has a Satchwell BAS 700 system with intelligent outstations communicating with Satchwell "Keyboard" stand-alone controllers in the local plant rooms. The system operates satisfactorily although it is not as actively "tuned" as at *Quadrant House* and *One Bridewell Street*.

- *Victoria* has a Transmitton system of limited capability by today's standards, and also not used to its full extent. This is partly because the building is multi-tenanted (so there is no single point of contact for the occupants) and the plant is operated via a maintenance contract without full building and energy management responsibilities. Branches from the central VAV ducts to individually tenanted areas on each floor are dampered, with local over-ride controls so that tenants working late can maintain services to their parts of the building only.

- *One Bridewell Street* has stand-alone Staefa controls plus a Staefa BEMS added by the tenant and which has relatively limited capabilities. However, the system - and the building as a whole - is operated and managed extremely well by an engineer who also got the *Facilities Manager of the Year Award 1989*, and this is the most important single reason for the very low energy consumption of this air-conditioned building. It should perhaps be mentioned someone of this calibre would normally only be found in buildings at least two or three times as big, but the main tenants - Ernst & Young - decided that this high-quality building needed management to match.

- *Heslington Hall* could not justify a BEMS in its own right, and most of the functions were initially carried out by a stand-alone JELSTAR controller with extra thermostats, relays and timers. However, to fine-tune the optimum start and compensation and to manage the dual-fuel boilers effectively needed more processing power, so the University's BEMS was extended to monitor more room temperatures and to optimise system operation. The BEMS is well-managed by the University's maintenance department, who have, however, found that at current fuel prices it is not cost-effective for them to manage the systems as tightly as is technically possible: the extra staff time is better spent on other things.

- *SSWC* has a comprehensive Landis & Gyr system which also controls the lighting (see later). This building was designed to be very low-energy and the elaborate BEMS specification, with special software, has proved too complex and individual for a relatively small building, and the system now tends to be left alone. In hindsight a simpler, more standard configuration would have been preferable and could well have saved more energy.

5.4.6.3 All five smaller buildings have electronic time controllers with optimum start and all but *Hempstead House* have outside temperature compensation.

- Conventional heating controllers are used at *PSI* and *Hempstead House*, both located in the boiler rooms: readily-accessible opposite the caretaker's room at Hempstead House and out-of-the-way in a remote basement at PSI. *Hempstead House* also has local over-ride controls on each floor to suit tenants' out-of-hours requirements.

- The all-electric *BRE LEO Electric* and *Magnus House* use Johnson MP 1000 controllers, undertaking optimum start as for hydronic systems, compensation by time-proportioning, load management to minimise maximum demands, and zone temperature-limiting control. The controllers are located in store rooms, at *Magnus House* inconveniently above a door.
- *Cornbrook House* has a direct-digital-control (DDC) multifunctional controller, programmed to carry out the normal optimum start, stop and compensation features for the boilers, plus fixed time control for toilet ventilation and domestic hot water. The controller was also intended to optimise condensing boiler efficiency by managing the temperature of the primary circuit to the minimum level capable of meeting the space heating and ventilation demands.

5.4.6.4 Rather like *SSWC*, the more sophisticated and less readily-comprehensible controller at *Cornbrook House* has had the exact opposite to the intended effect, and made the system more difficult to understand and to check. The situation is also not improved because the plug-in hand-held controller used to set the system up initially did not form part of the permanent installation and so the occupants cannot change settings without reference to the maintenance contractor, who does not always bring one either. The controller functioned well at first, but after becoming corrupted it has never been restored to really effective operation, causing a drop in condensing boiler efficiency of ten percentage points, as monitored by British Gas (reference 23). This is disappointing, but since the wasted fuel is worth only about £ 200 per year, it has not been cost-effective to re-commission the system.

5.4.7 COMMENTS ON HVAC CONTROLS

5.4.7.1 The Case Studies suggest that for control technology to be effective, it must be well-designed and applied with an overall understanding of the related human and management systems. A good electronic control and building management system is ultimately only as good as the people behind it, the degree they use it to optimise the operation of their plant, and the degree to which they learn from the information it can provide. Small buildings (certainly below 5000 m^2 gross, perhaps below 10,000 m^2 or so) may seldom have people on site with the skill and time to deal with elaborate systems: they will benefit most from simple, standardised, packaged controls, which can be rapidly understood by a visiting maintenance engineer on call-out, and who may never have been to the building before. Larger buildings with appropriate management can tolerate more sophistication, provided that it is seen to be in the organisation's interest - most people will not want to devote much effort to things which they feel ought to be routine or where there is only a small amount to be saved. The problem gets worse in multi-tenanted buildings, where building management is quite separate (unless there is a head tenant), and tenants may well regard liberal provision of energy as a right, and any attempts at energy management as a wilful imposition, particularly where they pay for everything indirectly through a service charge.

5.4.7.2 Whatever the size of building, improved user-satisfaction and energy-efficiency could result if controls were more user-friendly. For example one should question why the programmer was in the inaccessible boiler room at *PSI* and why it runs all five ventilation plants - three of which are for specialised areas with timetabled use - to the occupancy time part of the heating programme. Sometimes *PSI's* conference rooms are required on Saturday and so the sixth day is activated for the building as a whole, and may subsequently remain set for weeks. If the programmer (which has clear ON/AUTO/OFF slider switches for each half-day) had been in the administration office, together with ventilation plant switches or controllers, the management would have been able to relate system operation much more closely to the day-to-day operational needs. Similar problems occur in many buildings: people seldom seem to think clearly about how the occupants (known or hypothetical) are actually likely to want to operate the systems. A paper on the balance between central and local control systems was written as part of this contract (reference 24) and BRE is now undertaking a study into these issues.

5.5 Electric lighting

5.5.1 OFFICE LIGHTING

5.5.1.1 Most of the offices have fluorescent lighting, typically recessed in the larger buildings (which - apart from *Refuge* and *NFU* - tend to have suspended ceilings) and surface-mounted in the smaller ones. The three main exceptions to this rule are:

- *Refuge House,* with purpose-designed wall- and column-mounted metal halide (MBI) uplighting in the general offices.
- *NFU,* with suspended fluorescent lighting on a tubular services "boom" in the general offices, carrying both ventilation supply ductwork and upward-and downward-facing tubes. Most cellular and executive offices have suspended ceilings and recessed lighting.
- *Hempstead House,* where the main tenant had furniture-mounted MBI uplighting *(changed to mini-fluorescent after comments and measurements on our survey visits).* On the other two floors, one had largely free-standing MBI uplighters and the other a rather poor scheme of surface-mounted fluorescents inherited from an earlier tenant.

The mixed-mode *Refuge* and *NFU* were both designed without suspended ceilings generally, in order to reduce peak temperatures by providing additional floor-to-ceiling height and exposing the mass of the concrete floor or roof slab directly to the room, though in both with a surface layer of sprayed acoustic plaster.

5.5.1.2 Single-tube fluorescent fittings are used at *NFU, Victoria* and parts of *Heslington Hall. SSWC* has square fittings with three 600 mm tubes each, controlled in steps. The other fluorescent systems use twin-tube fittings: at *Westminster* and *Hereford & Worcester* they were in the process of refurbishment with single 26 mm triphosphor tubes and high-efficiency 3M

"Silverlight" reflectors, giving a similar (usually 10% or so lower) light level for less than half the power consumption. Only the most recently-completed *One Bridewell Street* and *Magnus House* have electronic high-frequency lighting throughout the main offices, though some high-frequency fittings were also appearing at *North-West Insurance* as interiors were upgraded.

5.5.1.3 Horizontal illuminance levels at the desk-top from the artificial lighting averaged typically 300-500 lux, with natural light adding significantly to this in many of the buildings. The highest artificial light levels - 650 to 850 lux -occurred in the parts of *North-West Insurance* which had new electronic fittings, under the fittings (which were quite widely-spaced) at *One Bridewell Street,* and surprisingly in the cellular offices at *Magnus House*, where single tube fittings might well have sufficed. The lowest levels recorded were in the uplit areas of *Hempstead House,* where the ceilings and fittings had become dirty and the lamps were at the end of their useful life, and in parts of NFU where many people frequently used either the uplights (100 lux or less) or downlights (200-300 lux), but not both. In all the offices, most people seemed to be reasonably happy with their lighting *(this has more recently been confirmed by independent user surveys at Hempstead House, One Bridewell Street and Refuge House)*, but interestingly excessive brightness was mentioned at *PSI* and *Magnus House.* Often such complaints are associated more with glare than with illuminance levels, but it may be that in these cellular offices - where daylight is often sufficient or nearly so - some people prefer a gentle supplement rather than something which completely changes the character of the room. Further study here could be of interest.

5.5.1.4 A useful indicator of lighting energy-efficiency is watts per square metre per 100 lux, for which the EMILAS Awards set a qualifying standard of 3. Only the most recently-equipped Case Study offices achieve this level: *One Bridewell Street* and *Magnus House* with their high frequency lighting and *Westminster* in its upgraded form with high-efficiency reflectors. *SSWC* is on the border line. The other buildings either use less-efficient tubes and fittings, often of an older design, or have an uplighting component, as at *Refuge House, NFU* and *Hempstead House.* On the other hand, a number of EMILAS winners (one with as little as 2 W/m^2 per 100 lux) were visited as possible case studies and proved to be unsuitable in other respects, for example excessive lighting running hours or poor HVAC energy performance. W/m^2 is also not the only criterion by which lighting should be judged: additional energy may be required to make the lighting attractive and to meet today's more exacting glare criteria.

5.5.2 OTHER LIGHTING

5.5.2.1 In many offices, and particularly the larger ones, the "typical" space (with people sitting at desks etc.) may occupy only half or two-thirds of the treated floor area. The rest of the space is given over to corridors, stairs, toilets, reception areas, meeting and conference rooms, kitchens, restaurants, computer rooms etc. Lighting here tends to be either more decorative or more utilitarian than in the general offices: the two often seem to balance, making the overall W/m^2 for the remaining treated area (excluding plant rooms, stores, car parks etc.) similar to that in the main offices.

5.5.2.2 Energy-efficiency often seems to be less of a priority in these ancillary areas, but often - rightly or wrongly - lamps are on for longer in internal spaces and to make an impression. For example:

- In the daylit atrium at *City Atrium*, the lights also remain on as they add sparkle.
- *Refuge House's* circulation lighting is switched centrally, so some lights are on all day (for example in some of the stairs) even though there is good natural light. *All* the circulation lighting throughout the building also used to come on for a single visitor late at night, though we understand the system has now been modified.

- Tungsten and tungsten-halogen lamps are quite widely used in restaurants and reception areas, as at *City Atrium, Cornbrook House, PSI* and *Quadrant House.* In several offices we visited the facilities managers complained about the high maintenance costs of the modern low-voltage compact tungsten-halogen lamps, and the dangers of transformer fires, and several planned or had already undertaken the removal of schemes which had only recently been specified by their architects and interior designers. There seems to be a major need for better energy and maintenance awareness among the interior design professions. Only in *BRE LEO* and the most recently-completed offices *(One Bridewell Street* and *Magnus House)* was there virtually no tungsten or tungsten-halogen lighting.

- *Refuge House's* restaurant, although having fluorescent lighting, has an unusual problem: it is a large internal room used for lunch only, but a passage alongside it runs to the coffee lounge, which is open all day. The restaurant lights therefore remain on all day too: otherwise using the passage is a gloomy experience!

- Tungsten lights still persist in toilets, for example at *Quadrant House,* although conversion to compact fluorescents was in progress, as was already complete in the corridors as well at *Heslington Hall.*

- Corridors are often over-lit or inefficiently lit. For example at *SSWC,* where great effort was expended on the efficient natural and artificial lighting of the offices themselves, the corridors have twin-tube fluorescent lamps above dark-coloured egg-crate perforated ceilings which obstruct or absorb much of the light. Recessed or semi-recessed fittings could have provided similar (and potentially equally attractive) illumination, using at most one-third of the installed power. At *Cornbrook House and Quadrant House,* corridor illuminance and power levels were excessively high, with efficient lights at *Cornbrook* but not at *Quadrant,* where switching one-third of the lights during the day (and two-thirds at night) saved energy but gave a rather patchy appearance: more, lower-powered fittings would have been preferable.

5.5.2.3 User behaviour regarding lighting of common areas is capricious. A normal rule seems to be that the first person who wants the lights on turns on the whole bank of switches for the area concerned, and the lights then stay on until the security comes round at the end of the day. However, in a few offices, lights in corridors and toilets were off much more than this: at *PSI* this was understandable as one senior member of staff had a particular commitment to energy conservation, but the same also applied at *Magnus House,* where management pressure was not apparent. Partly this may be an effect of the scale of the building: in a "domestic" environment people may be more likely to use the lights as and when they need them, while in an "institutional" or "corporate" one they will be more inclined to leave the decisions to the management. This could be an interesting area for behavioural research.

5.5.3 AUTOMATIC LIGHTING CONTROLS

5.5.3.1 Automatic lighting controls are installed in half of the buildings and are described in the following paragraphs. Except for security and sometimes corridor lighting, all systems operate in a manual on or off/auto off mode and allow occupants to over-ride their own lights on or off as required until the next switching pulse. The system at *Hereford & Worcester* provides a fore-warning of switching-off by flashing the lights first: if a switch is then pressed within a few minutes its lights will not go off.

5.5.3.2 Three different types of system were found in the Case Study buildings:

1 Hard-wired system.

A central programmer sends signals to local relay units which govern groups of lamps. Control patterns are pre-determined and wiring alterations are required to change them.

2 Selectable system

Groups of lights are wired into control devices which have either selector switches or interchangeable "coding plugs" to tell them which signals they should respond to. For example, groups of perimeter lights can be set to respond to daylight-linked and time-switched signals and interior lights to time signals only. However, if a perimeter office normally has the blinds down, for example to control VDU screen glare, then it can be given an "interior" code by changing its plug or switch setting.

3 Fully addressable system

Each control device is individually addressable by a central supervisory computer - normally the building's BEMS computer - and may be assigned any time programme.

5.5.3.3 At *Quadrant House* an ECS Ltd coding-plug system was retrofitted in 1985 to replace group switching panels at the entrances to each floor. The office lights now have local controls - particularly appropriate in this building where people work in small clusters and sometimes need to work late. The system switches the lights off at lunch time and at the end of the day, when it also drops the corridor lighting to half-level; it also switches-off perimeter lights in mid-morning and mid-afternoon if daylight levels are sufficient. It works quite well but sometimes the groups are too large, with four or six lights being on when really only one or two are required.

5.5.3.4 *Hereford & Worcester* has an early Delmatic hard-wired system, designed very much on the principles of daylight availability. Lights are therefore switched in fairly large blocks and from centrally-placed group switch panels. The system has been partially undermined by:

- People disliking having to walk quite long distances to a light switch to re-start the lights.
- Flexitime working, which makes the lunchtime "off" difficult to implement.
- Problems of daylight glare (particularly on VDU screens) and excess solar gain, so that in some places people require artificial light when daylight is theoretically sufficient.

The result is that the system is now only used for daylight-linked control in the summer and for switching the lights off at the end of the working day. *(NOTE: if the OFF tests were restricted to set times, say 1100, 1330 and 1500 - which occupants of other buildings seem to prefer - some winter photoelectric control might still be achievable).*

5.5.3.5 *Refuge House* also has an ECS system, with each MBI uplighter having its own local control device and on/off switch. This admirable-looking arrangement has not been quite as effective as anticipated, largely because the MBI lamps take several minutes to warm-up and even longer to re-strike after they have been switched-off. The result is that people tend to leave them on if there is the slightest chance they might want them later, and some want their lights switched-on before they arrive. The local on/off switches are also a mixed blessing: although very convenient for individual users, to shut down an area locally one has to walk round to each fitting: common switches at strategic exit points would have been more likely to be used. The circulation lighting control was also problematic, as mentioned in paragraph 5.5.2.2.

5.5.3.6 *NFU* also has an ECS coding-plug system, which was designed to switch-off both the upward and downward-lighting in the general offices, plus lights in the corridors and toilets, water heaters in remote toilets, and vending machines. There are local over-riding wall switches: two in each cellular office and five for each structural bay of open office. The ECS control panel is in the security office, rather than the building manager's, to permit ready access outside normal office hours. The system works very well in the naturally-lit corridors and quite well for daylight-linked and end-of-day switching in the offices (lunchtime off proved impossible owing to flexitime), but it did not work for toilet lighting (people occasionally plunged into darkness) or for the vending machines (ingredients congealed when off overnight). Although typically only half the controlled lights in the building are on, the building manager regards the system's performance as disappointing and the effort involved in changing coding-plugs (which require cover panels to be removed first) as unreasonable. He would have preferred each fitting to have been individually addressable.

5.5.3.7 *Victoria* has a hard-wired system which has fallen into disuse. Essentially central control of lighting for the building as a whole was incompatible with the needs of individual tenants, particularly because here they do not pay for their electricity directly but via the landlord's Service Charge.

5.5.3.8 *One Bridewell Street* has a ECS selectable system, with coding switches on the receivers. Local switching uses hand-held infra-red transmitters rather than the traditional switch drops: this was a tenant requirement expected to add to the fitting-out cost, but in practice it did not owing to its flexibility and absence of wiring. Installation was simple and straightforward and partitions can now be moved without having to make any wiring alterations. The transmitters have magnetic backs and are "parked" on the steel-cored partitioning system, making them easy to find.

5.5.3.9 *SSWC* has an addressable system as an integral part of the BEMS. Although quite effective, it has some disappointing features:

i) Lights are controlled in relatively large groups.
ii) In the open office areas, the local controls consist of unlabelled group switch panels at the doors only.
iii) The light fittings have three 600 mm tubes. The central "safety" tube of each lamp was designed to be on through the working day. This is wasteful in empty rooms and in places where daylight is sufficient. The facility is now being disconnected but this involves substantial wiring alterations because the safety circuits were wired in large groups, with both perimeter and core lights on the same circuit.
iv) The local over-ride switches - although looking like ordinary light switches - do not control the lights directly, but activate status points which advise the BEMS that a switching operation has been requested. It may take 20 seconds and sometimes much more to act on the request, and sometimes the system decides to do nothing. The switches do not include any status indication and their uncertain function causes considerable frustration.
v) The tailor-made BEMS is too complicated for the size of building and the staff time reasonably available for looking after it (see also Section 5.4.5).

5.5.3.10 Two floors of *Hempstead House* had MBI uplighters with ECS controls similar to *Refuge House,* and suffering from the same problems owing to lengthy run-up and restrike times. The controls therefore only really saved by stopping people lighting-up the whole office on arrival and permitting lights to be switched-off automatically at the end of the day. Discussions with the occupants during our Case Study surveys led to the lamps being replaced by batteries of fluorescent U-tubes within the same casing: these give more uniform lighting with higher illuminance levels for slightly less power input, a better spread of light, lower lamp costs, and instant switching, allowing the local and automatic controls to be used much more intensively. Electrical savings of 20% have been reported but have not been verified by us.

5.5.3.11 *BRE LEO* had a hard-wired system initially, but this was no longer in use at the time of our survey. The system was difficult to commission (particularly in conjunction with the motorised external blinds) and caused adverse reactions from cellular office occupants. It was ultimately disconnected, with no great increase in energy use (see reference 20), though more recently lighting energy consumption has crept up, in part a consequence of increased occupancy levels. Reference 25 - published after *LEO* was complete - confirmed that in cellular offices such as this automatic control was unlikely to be appropriate or cost-effective.

5.5.4 MANUAL LIGHTING CONTROLS

5.5.4.1 The other seven offices have manual controls. In the smaller, more cellular offices such as *Heslington Hall, PSI, Magnus House,* and perhaps *Cornbrook House* this is entirely appropriate. However, in the larger, more open-planned spaces at *Westminster, North-West Insurance,* and particularly *City Atrium,* group switching from the main access points gave poor control and the lights in many large areas were usually either all-on or all-off, and tended to stay on well into the night. In these buildings, correctly-designed and specified automatic lighting controls with appropriate local manual over-rides could potentially have given major savings, as indeed were realised at *One Bridewell Street.*

5.5.4.2 The manual controls were not always optimally arranged. For example, to make the best use of daylight - and to top-up daylight selectively in cellular offices where desks are often close to the window - the lights near the window need to be switched separately from those inboard, but at *Magnus House* (which was probably over-lit anyway), there were two banks of lights but only one switch, and similar problems arose in parts of *PSI* and many of the other buildings.

5.5.5 LIGHTING CONTROLS - CONCLUSIONS

5.5.5.1 Controls are of key importance to energy-efficiency in lighting, particularly in open-planned offices where the responsibilities for switching become unclear and control and management ergonomics become much more important. While the principles, priorities and potential for lighting control were explored in work at BRE in the late 1970s and early 1980s (see reference 25 and reference 19, appendix B10), the findings have not always been well-applied, and sometimes an otherwise-good system has been undermined by some critical detail which has undermined its acceptability to users. Some practical design guidance, both on design and operation, may be useful here.

5.5.5.2 With developments in control technology, it is becoming cost-effective to build control devices into each light fitting in the factory. These can then be software-controlled and individually addressable from a central supervisor and locally-switched by remote control or possibly by telephone (telephone-operated switching is demonstrated at Woolgate House, reference 39). If considered from the outset, such controls could well be cheaper than conventional systems, as the specification and installation process would be simplified, less copper would be used, and most internal alterations could be accommodated without interfering with the wiring.

5.6 Computer rooms

5.6.1 Mainframe computers and their air-conditioning can sometimes account for the greater part of the annual electricity consumption and energy costs of office buildings: in one example we studied (not for this project) as much as 75%. Six of the eight largest Case Study offices have mainframe computer suites, as does *SSWC*. *SSWC's* was however outside the "building boundary" defined for Databuild's EPA monitoring report (reference 4), and for consistency with their results, we have used the same definition and not included it. *(NOTE: The computer room did, however, have an indirect influence on the gas consumption as the shared boilers operated round-the-clock just in case there was a computer reheat load, which should not have been very often! This made system efficiency very low, and the Case Study instead used the* *heat-metered consumption within the building boundary and assumed a boiler plant efficiency of 65%).*

5.6.2 *One Bridewell Street, Heslington Hall, Hempstead House, Cornbrook House* and *Magnus House* had minicomputer installations but only at *One Bridewell Street* and *Hempstead House* were they in air-conditioned rooms (NOTE: in both these offices the minicomputers have now been removed, in one with change of tenant and in the other supplanted by personal computers and networks). The annual energy use of these small systems is trivial in relation to the mainframe installations and they will not be considered further here.

5.6.3 *City Atrium* had several computer and machine rooms cooled by packaged direct-expansion and chilled-water equipment. The systems used were fairly standard, but with the high "churn" rate in City financial trading, things change rapidly and investments in "specials" and in added-cost features would only be justified if they had a very rapid payback. For instance, the tenant's main computer room which we surveyed at *City Atrium* had only been there for about three years and was re-located to another building in Docklands shortly afterwards. *Westminster* has a fairly modest computer room with packaged direct-expansion cooling units.

5.6.4 *Hereford & Worcester* also has a modest computer installation for the size of building, and one which unusually is normally operated for two shifts only and switched-off at night and weekends. The cooling system is also not independent, but fed from the central chilled-water site mains. Combining computer air-conditioning with a building's space cooling systems is usually not a good idea because:

- The integrity of the computer air-conditioning may be compromised by faults on the building side. This is clearly less of a problem here than in installations where the computer runs 24 hours a day, year-round.
- While building cooling loads frequently occur for only a small part of the year, computer loads are year-round, leaving the main chillers and ancillaries inefficiently oversized for the smaller cooling duty. In one building we found that in winter the energy consumed by the central chilled water and cooling-tower *pumps* alone would have been sufficient to run an entire packaged computer-room cooling system!

However, at *Hereford & Worcester* the system was reasonably economical at low loads: the well-insulated site mains appear to operate as an effective chilled water buffer vessel. Having chilled water available year-round has also proved useful: with fan-coils now installed ad hoc in some rooms for additional equipment-cooling, and connected to the system.

5.6.5 The three insurance companies have larger and continuously-operating computer installations, which justified, and received, greater attention to their energy-efficiency. The solutions were each very different:

- *Refuge House* has chilled-water room units, served by water-cooled screw chillers in the plant room and cooling towers on the roof. The type of refrigeration and heat rejection plant was identical with the building's comfort cooling system, which helped to standardise maintenance procedures. For the case study period, waterside free cooling was also incorporated, with the return chilled water passing through a plate heat exchanger cooled by a second cooling tower before going to the chillers, though the free cooling, by not being essential to computer operation, had not yet been fully fine-tuned. Unfortunately, when extra computer equipment was purchased, it was expedient to press the free-cooling tower into service for a third chiller and abandon the free cooling circuit, which Refuge Assurance hopes to restore in the future if computer room cooling loads diminish.

- *NFU* has a combination of water and air-cooled direct expansion units, all with modular hermetic reciprocating compressors. The cooling water from the water-cooled units heats the swimming-pool (with an alternative air-blast cooler if a heat surplus remains).

At the time of design NFU expected their central computer and cooling requirements to diminish as their offices became increasingly networked, and heat recovery to other building services (for example preheating ventilation air) was not considered though it could have been achieved very simply. As it happens, central computing power and its air-conditioning has grown substantially and more potential could have been realised, though the manager comments that any linkages with building systems are potential threats to the reliability of the computer system, which is the paramount requirement.

- *North-West Insurance* has a massive computer facility, with two large machines in their main computer room in the original building and a third "dark" computer room - with standard direct-expansion packaged units - in the undercroft of the 1971 extension. The main computer room was re-engineered shortly before the Case Study and has eight chilled-water air-handling units in a plant room overhead. Chilled water comes from three twin-compressor reciprocating units, with air-cooled condensers. When required, reject heat is recovered by diverting the refrigerant into a calorifier, from which low-temperature hot water at about 30-35°C is circulated to fan-coil units in part of the 1951 building and a pre-heater battery in the air-handling unit for the 1971 building's induction heating system.

Heat recovery and free-cooling systems are not necessarily free: there may be additional fan and pumping costs, and refrigeration efficiency will drop if condensing temperatures are kept higher than necessary. Within the scope of the Case Studies, it was not possible to carry out a detailed analysis of the energy flows and costs through the installed systems and compare them with conventional cooling-only alternatives. BRECSU is considering the value of detailed case studies on the in-use energy-efficiency of computer air-conditioning systems, with and without free-cooling, heat-recovery and supervisory control systems.

5.7 Catering Facilities

5.7.1 Most of the large buildings have substantial catering kitchens and restaurants, providing lunches for typically about half the staff (rather less at *City Atrium* and an all-day service at *Quadrant House*, with three separate dining areas around a central kitchen). *North-West Insurance* and *SSWC* have management dining facilities only; *SSWC's* main restaurant is in an adjacent building and does not form part of the areas studied. The large kitchens are all fairly similar, with predominantly gas and some electric cooking, electric serveries, and electric dishwashers. *City Atrium's* kitchens alone are all-electric. While *PSI's* kitchen is capable of serving up to 100 meals to their conference suite, it is only occasionally used and then by outside caterers who bring in the cooked food and use the kitchen for serving only, and sometimes for washing-up.

5.7.2 The rest of the offices have modest kitchens, largely for hot drinks, but with the occasional small cooker or microwave. *1 Bridewell Street* unusually has small dishwashers in all of these kitchens, used by the cleaners at the end of the day to wash up all the cups.

5.7.3 Half the offices have vending machines, ranging from one each at *Hempstead House* and *Magnus House*, two at *Cornbrook House*, 3 at *SSWC*, 5 at *Provincial*, 7 at *Refuge* and *NFU*, to a massive 38 at *City Atrium*. Some of these machines were quite energy-hungry, spot checks suggested typically 600 watts on average, 24 hours per day in most instances, for a cabinet unit serving both hot and cold drinks. Comparisons of different units would be interesting.

5.8 Conclusions on Characteristics

5.8.1 The Case Study offices include a wide range of buildings, servicing types, occupancy and IT levels. All but three were completed between 1977 and 1988. Modern high-efficiency building services technology, such as condensing boilers and high-frequency lighting, is rather poorly represented. The larger buildings - which comprise the majority of the floor area surveyed - tend to be air-conditioned, often also with computer rooms, and the smaller ones naturally-ventilated. However, three large buildings are mixed-mode, with a combination of natural and mechanical ventilation or air-conditioning. Energy-efficient air-conditioned buildings were difficult to find: two of the five discussed here ultimately proved unsuitable for published Case Studies and *City Atrium's* lighting controls were disappointing. Chapter 6 and Chapter 7 now compare the annual energy use and costs of the sixteen buildings.

SECTION 6

ANNUAL ENERGY CONSUMPTION OF THE CASE STUDY BUILDINGS

6 ANNUAL ENERGY CONSUMPTION OF THE CASE STUDY BUILDINGS

6.1 General Overview

6.1.1 This chapter reviews the patterns of annual energy consumption in the twelve Case Study offices, plus the unpublished *City Atrium* and the three *(Westminster, Victoria* and *North-West Insurance)* which were surveyed but ultimately found unsuitable.

6.1.2 The top part of table 6.1 summarises annual consumption of fossil fuel and electricity in kWh/m^2 of treated floor area as collected for the 12-month Case Study periods. The statistics are broken down under the standard headings (see section 4.7.2) with an extra column F for electric "EED" heating, as used in *Magnus House* and the refurbished *BRE LEO Electric.*

6.1.3 Rows 25 to 45 of Table 6.1 show the statistics summarised in a number of different ways, by column. The figures are in kWh/m^2 of treated floor area unless otherwise stated.

B+C	The annual totals of fossil fuel and of electricity.
D	B+C: the simple sum of fossil fuel and electricity.
E	B+3.5 C. Fossil + 3.5 x Electricity consumption. This F+3.5E measure takes into account (in a rough but straightforward manner) the higher costs, primary energy use and CO_2 production by electricity, and is a useful index for design and auditing which does not change with time or detailed assumptions as costs etc. do. It correlates fairly well with the order of energy costs of the Case Study buildings (see Section 7.4).
F-I	As in B-E, but excluding energy consumption by items not usually regarded as normal building services, particularly office and communications equipment, computer suites, and catering equipment.
J	The published heating degree-days for the 12-month period concerned for the building's degree-day region.
K-R	As columns A-I, but simply corrected to 2462 degree-days, the standard figure used in the EEO's series *Energy Efficiency in Buildings* (reference 16).
S	The percentage of F+3.5E (and so roughly energy costs) attributable to normal building services. For the simpler offices this is usually in the range 80-90%, but for the more sophisticated ones it can go under 50%.
T	kg/m^2 CO_2, for the normal building services element only. This is the BREEAM (reference 9) index, calculated using the figures in rows 47 and 48. See footnote.
U	An estimate of annual energy costs for normal building services only, based on simplified rounded fuel costs as shown in row 49. In practice, fuel costs vary substantially with building, tariff and load pattern, and are significantly lower in the larger buildings. Energy costs are reviewed in more detail in Chapter 7.
V-Z	Degree-day corrected figures from columns M, N, Q, R and U, all expressed per unit of nett lettable rather than treated floor area.

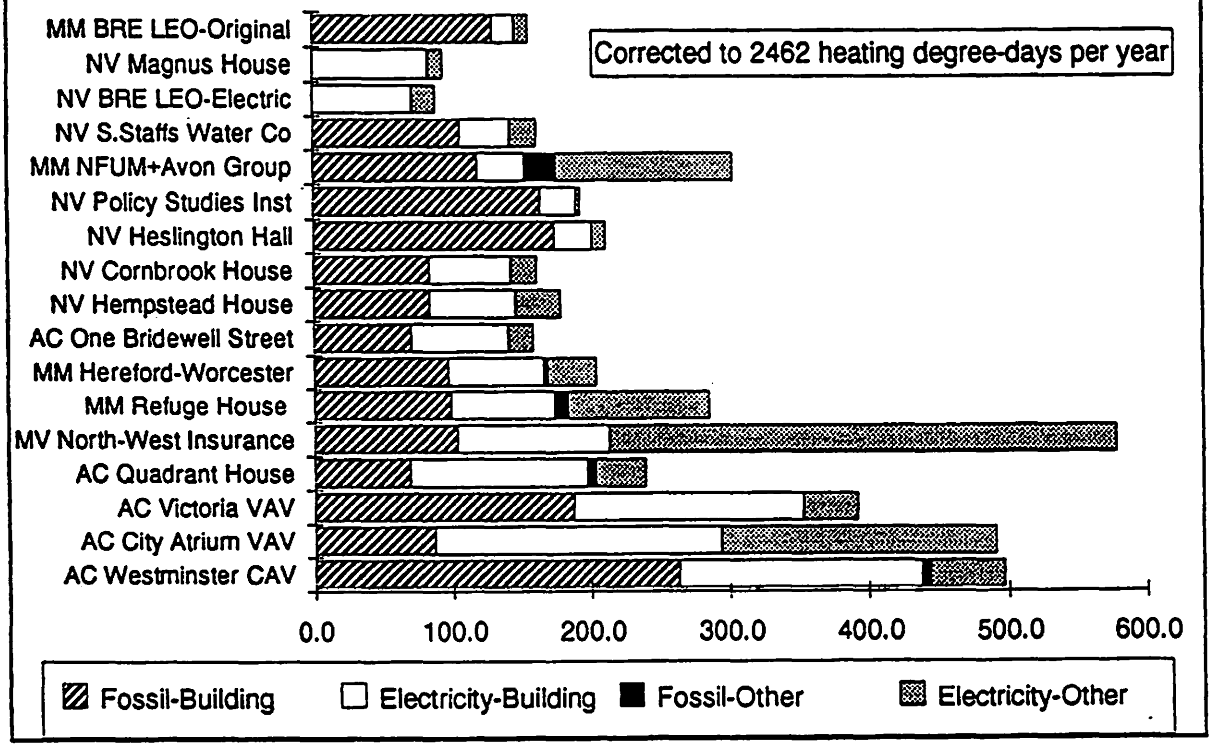
Table 6.1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	**TABLE 6.1**																									
2	**CASE STUDY OFFICES: RECORDED FUEL USE IN kWh/m2 TREATED AREA**																									
3	***Sorted by F+3.5E index for normal building services only (see Table 6.1B column I)***																					*SIMPLIFIED 1990 FUEL*				Actual
4	**TABLE 6.1A**	FOSSIL:				ELECTRICITY:													COMP SUITE:			*PRICE p/kWh-see Chapt. 7*				Elec
5	**INPUT DATA**	Heating		Catering		EED		Cooling		Fans		Controls		Lifts	Other	Other	Telecoms		Mainframe		Catering	*Size-related:*		*Uniform:*		Price
6	BUILDING NAME		Hot water		Other		Heating		Pumps		Hot water		Lights		Norma	Special	Equipment			Aircon		*Heat*	*Elec*	*Heat*	*Elec*	Paid
7	AC Westminster CAV	217.1	19.3	6.8	0.0	0.0	0.0	38.6	21.7	40.8	0.0	1.4	64.3	6.8	0.0	0.0	4.3	7.6	22.1	12.0	7.8	1.2	5.5	1.3	5.5	4.17
8	AC City Atrium VAV	68.9	0.0	0.0	0.0	0.0	0.0	29.0	11.4	49.2	3.5	3.0	106.4	4.7	0.0	3.7	15.7	60.0	59.4	36.3	22.5	1.2	5.0	1.3	5.5	4.07
9	AC Victoria VAV	159.0	7.3	0.0	0.0	0.0	0.0	25.3	22.7	45.3	0.0	2.8	63.4	5.2	0.2	10.9	8.1	12.2	0.0	0.0	8.9	1.2	5.5	1.3	5.5	4.58
10	AC Quadrant House	52.3	3.2	6.5	0.0	0.0	8.6	35.4	8.3	10.9	1.1	2.2	54.6	5.2	0.0	4.1	10.2	13.3	0.0	0.0	8.6	1.2	5.5	1.3	5.5	4.24
11	MV North-West Insurance	94.4	0.0	0.0	0.0	0.0	0.0	2.7	3.8	21.8	2.7	1.0	74.2	3.0	0.3	1.2	5.0	14.8	194.8	144.0	5.4	1.2	5.0	1.3	5.5	3.77
12	MM Refuge House	75.3	14.4	10.0	0.0	0.0	0.0	7.9	4.8	14.9	0.0	2.0	39.2	1.6	3.8	0.9	0.9	8.4	47.9	31.7	12.4	1.2	5.5	1.3	5.5	4.56
13	MM Hereford-Worcester	88.3	7.9	2.7	0.0	0.0	1.2	9.7	2.3	9.9	0.1	1.0	44.1	0.4	0.2	0.8	7.5	5.3	13.0	7.3	1.7	1.2	5.5	1.3	5.5	4.53
14	AC One Bridewell Street	51.4	0.0	0.0	0.0	0.0	1.5	12.5	2.5	15.8	1.9	0.8	31.1	3.0	1.1	0.5	1.1	7.9	1.6	1.9	4.8	1.4	6.0	1.3	5.5	5.29
15	NV Hempstead House	69.2	0.0	0.0	0.0	0.0	0.0	1.8	1.8	0.6	6.9	0.6	49.3	0.5	0.9	2.4	2.3	10.7	9.5	4.0	3.8	1.4	6.0	1.3	5.5	5.01
16	NV Cornbrook House	69.5	7.2	0.0	0.0	0.0	0.0	1.1	2.2	3.9	0.0	1.1	45.8	0.3	5.0	3.9	3.9	5.8	0.0	0.0	5.2	1.4	6.0	1.3	5.5	5.06
17	NV Heslington Hall	175.5	5.1	0.0	0.0	0.0	2.8	0.0	1.6	0.3	3.9	0.7	16.3	0.0	1.3	7.1	0.0	2.9	0.0	0.0	1.0	1.2	6.5	1.3	5.5	4.04
18	NV Policy Studies Inst	163.6	0.0	0.0	0.0	0.0	0.0	0.0	1.1	5.8	1.9	0.4	16.2	0.3	0.1	0.0	0.7	1.3	0.0	0.0	1.1	1.4	6.5	1.3	5.5	5.84
19	MM NFUM+Avon Group	103.1	11.7	9.5	12.8	0.0	0.0	2.2	2.5	4.0	1.0	2.0	19.7	1.0	1.6	9.3	3.1	9.1	64.2	33.8	8.8	1.2	5.0	1.3	5.5	4.00
20	NV S.Staffs Water Co	90.1	16.2	0.0	0.0	0.0	3.1	0.0	3.5	2.6	0.0	2.8	18.5	2.8	2.5	0.9	0.0	10.6	0.0	0.0	7.9	1.4	6.5	1.3	5.5	5.01
21	NV BRE LEO-Electric	0.0	0.0	0.0	0.0	44.1	0.5	0.0	0.1	0.4	4.9	0.5	12.4	0.0	0.7	10.2	0.0	5.6	0.0	0.0	1.9	6.0	6.0	5.5	5.5	5.36
22	NV Magnus House	0.0	0.0	0.0	0.0	40.2	0.3	0.0	0.0	0.3	2.4	0.1	14.4	1.0	1.6	1.5	2.1	6.4	0.0	0.0	1.5	6.0	6.0	5.5	5.5	7.22
23	MM BRE LEO-Original	109.0	2.8	0.0	0.0	0.0	0.0	0.0	1.1	5.2	2.2	0.5	4.7	0.0	2.0	7.7	0.0	1.2	0.0	0.0	1.0	1.4	6.5	1.3	5.5	6.00
24																						*TOTALS PER NETT SQ M:*				
25	**TABLE 6.1B**										TOTALS CORRECTED TO 2462 DEGREE DAYS										BS	*CORRECTED TO 2462 DD*				*BS*
26	**AGGREGATED AND**	TOTALS:				BLDG ONLY:					TOTALS:				BLDG ONLY:						£/m2	*ALL*		*BUILDING*		*£/m2*
27	**CORRECTED DATA**	Fossil		Both	F +	Fossil		Both	F +		Fossil		Both	F +	Fossil		Both	F +	%	kg/m2	Round	*SOURCES*		*ONLY*		*Round*
28	BUILDING NAME		Electricity		3.5E		Electricity		3.5E	*DDs*		Electric		3.5E		Electricity		3.5E	Bldg	CO2	cost	*F+E*	*F+3.5E*	*F+E*	*F+3.5E*	*cost*
29	AC Westminster CAV	243	227	471	1039	236	174	410	844	*2190*	270	227	498	1066	263	174	437	871	82%	197	12.97	*804*	*1723*	*706*	*1408*	*20.97*
30	AC City Atrium VAV	69	405	474	1486	69	207	276	794	*1961*	86	405	491	1503	86	207	294	811	54%	189	12.52	*656*	*2007*	*392*	*1083*	*16.71*
31	AC Victoria VAV	166	205	371	884	166	165	331	744	*2173*	187	205	393	905	187	165	352	765	84%	174	11.51	*587*	*1354*	*527*	*1144*	*17.21*
32	AC Quadrant House	62	162	224	630	56	126	182	498	*1963*	75	165	240	651	69	128	197	519	80%	121	7.96	*327*	*888*	*269*	*707*	*10.86*
33	MV North-West Insurance	94	475	569	1756	94	110	204	478	*2239*	104	475	579	1766	104	110	213	488	28%	112	7.38	*773*	*2358*	*285*	*651*	*9.85*
34	MM Refuge House	100	176	276	717	90	74	164	349	*2183*	109	176	286	727	99	74	173	359	49%	81	5.37	*392*	*998*	*238*	*493*	*7.37*
35	MM Hereford-Worcester	99	104	203	464	96	69	165	337	*2433*	100	104	204	465	97	69	166	338	73%	76	5.05	*260*	*591*	*211*	*429*	*6.41*
36	AC One Bridewell Street	51	88	139	360	51	70	122	297	*1799*	70	89	159	381	70	71	141	318	84%	73	4.81	*219*	*524*	*194*	*437*	*6.61*
37	NV Hempstead House	69	95	164	403	69	63	132	288	*2038*	84	95	179	417	84	63	146	302	73%	69	4.53	*207*	*484*	*169*	*351*	*5.25*
38	NV Cornbrook House	77	78	155	351	77	60	136	285	*2243*	83	78	162	358	83	60	143	292	82%	66	4.36	*182*	*403*	*161*	*329*	*4.92*
39	NV Heslington Hall	181	38	219	313	181	27	208	275	*2553*	174	38	212	307	174	27	201	268	87%	*68*	3.74	*328*	*474*	*311*	*415*	*5.78*
40	NV Policy Studies Inst	164	29	193	265	164	26	189	254	*1966*	*164*	*29*	*193*	*266*	*164*	*26*	*190*	*254*	96%	54	3.55	*294*	*405*	*289*	*388*	*5.42*
41	MM NFUM+Avon Group	137	162	299	705	115	34	149	234	*2363*	141	162	304	709	119	34	153	238	34%	52	3.42	*396*	*924*	*199*	*310*	*4.45*
42	NV S.Staffs Water Co	106	55	161	299	106	36	142	231	*2452*	107	55	162	300	107	36	142	232	77%	51	3.35	*261*	*483*	*229*	*374*	*5.41*
43	NV BRE LEO-Electric	0	81	81	284	0	64	64	222	*2115*	0	89	89	310	0	71	71	248	80%	59	3.90	*123*	*431*	*99*	*345*	*5.42*
44	NV Magnus House	0	72	72	252	0	60	60	211	*1597*	0	94	94	329	0	82	82	288	88%	69	4.53	*128*	*446*	*112*	*391*	*6.15*
45	MM BRE LEO-Original	112	26	138	202	112	16	128	167	*2104*	130	26	156	220	130	16	146	185	84%	39	2.56	*217*	*306*	*203*	*258*	*3.56*
46																										
47	CO2 Ratios assumed are taken from BREEAM 1/90					kg/kWh:		Electricity		0.832	Gas	0.198	Oil	0.302												
48	*Heslington Hall's Oil:gas ratio is*		*62%*			*kg/kWh:*		*Dual fuel*		*0.26*																
49	Rounded costs are		1.30	p/kWh for fossil			5.50	p/kWh for electricity					*PSI's heating has not been DD corrected as the case study year's consumption proved to be high.*													

6.2 Annual consumptions of fossil fuel and electricity

6.2.1 Figure 6.1 (using data from columns K, L, P & Q in the lower half of Table 6.1) shows annual delivered fossil and electricity consumptions both for normal building services and for other uses. Heating fuel consumption is corrected to the 2462 degree-day base. The buildings towards the top of the diagram have the traditional pattern of energy use in which fossil fuel for heating (electric heating in *Magnus House and BRE LEO Electric)* tends to dominate building services energy use: towards the bottom more diverse patterns tend to emerge, with "other" uses sometimes significant and occasionally dominant.

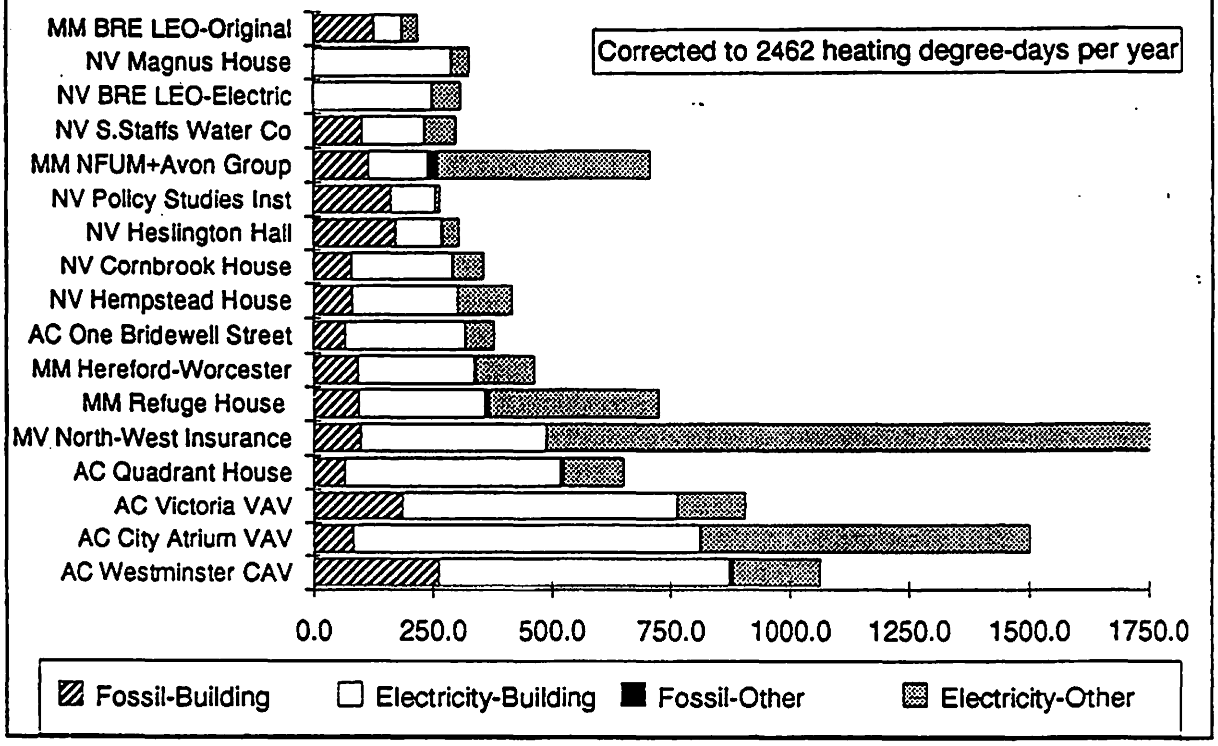
FIGURE 6.1 ANNUAL ENERGY USE (kWh per square metre TA)
delivered fossil fuel + delivered electricity consumption



6.2.2 Figure 6.2, using the F+3.5E index, shows how electricity dominates in nearly all the buildings, and plots of energy cost and of carbon dioxide emissions look qualitatively very similar. This is nothing new: the same situation was identified in BRE's review of energy and maintenance costs of offices in the late 1960s (reference 28). However, previous perceptions and the rapid increase in heating costs following the 1973 oil crisis seem to have set people thinking that heating was by far the most important component of energy costs, a view which seems to persist to this day.

6.2.3 Because the raw data in Table 6.1 (and through this chapter) was first sorted by F+3.5E for normal building uses only, the order of the offices in figure 6.2 is more-or-less that of the bars for "building" energy consumption. Including degree-day correction makes the heating fuel consumptions of *BRE LEO Electric* and particularly *Magnus House* alter their positions.

FIGURE 6.2 ANNUAL ENERGY USE (kWh per square metre TA)
delivered fossil fuel + 3.5 x delivered electricity consumption



6.3 Ranking orders of annual energy consumption

6.3.1 As discussed in Chapter 2, comparisons of energy use between one building and another are often flawed by inconsistencies between what is included, floor area data, etc.. Even with the more consistent measurements for the Case Studies, the order varies significantly depending on what is being looked at, as shown in table 6.1, Ranking orders for some of the indices are shown in Table 6.2. The following variations are particularly interesting:

- Its low fossil fuel consumption makes *1 Bridewell Street* look very good on a delivered energy basis (particularly for an air-conditioned building), but the electricity weighting and a fairly low nett:treated floor area ratio somewhat undermines this.
- *Hempstead House and Cornbrook House* are similarly affected by the electricity weighting but recover some of their position when nett floor areas are considered.
- The low electrical consumptions (though with relatively high fossil use) at *Heslington Hall, PSI, SSWC and BRE LEO Original* improve their ranking when the electrical weighting is included, though this is counterbalanced by poor nett-to-treated areas in all but *LEO* (see figure 5.2).
- *NFU's* position varies substantially depending how one looks at it, with a high level of "other" energy consumption and a reasonable level of "normal" building services energy consumption. Usually the two are more positively correlated.
- The EED offices: *BRE LEO Electric and Magnus House* slip down once the on-costs of electricity generation are included.

6.3.2 As a matter of principle, we do not think it is a good idea to concentrate for long on the overall energy consumption and rank of an individual office building - be it the total or for building services only, it is better to look at the individual components. The published Case Studies are all fairly good of their kind, and their good and bad points are equally instructive.

Table 6.2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	TABLE 6.2														
2	RANKING ORDER OF OFFICES														
3															
4		*Delivered energy per unit treated floor area:*									*Per unit nett floor area:*				
5	*Rounded costs are*	FOR STUDY YEAR				DEGREE-DAY CORRECTED:					DEGREE-DAY CORRECTED:				
6	*1.3p/kWh for fossil fuel*	AS SURVEYED:				*(2462 degree-days)*				Round	*(2462 degree-days)*				Round
7	*5.5 p/kWh for electricity*	Whole building:		Services only:		Whole building:		Services only:		cost,or	Whole building:		Services only:		cost,or
8	*See Table 6.1B*	F+E	F+3.5E	F+E	F+3.5E	F+E	F+3.5E	F+E	F+3.5E	CO2	F+E	F+3.5E	F+E	F+3.5E	CO2
9	AC Westminster CAV	15	15	17	17	16	15	17	17	17	17	15	17	17	17
10	AC City Atrium VAV	16	16	15	16	15	16	16	16	16	15	16	15	15	15
11	AC Victoria VAV	14	14	16	15	14	14	15	15	15	14	14	16	16	16
12	AC Quadrant House	11	11	11	14	11	11	12	14	14	10	11	11	14	14
13	MV North-West Insurance	17	17	13	13	17	17	14	13	13	16	17	12	13	13
14	MM Refuge House	12	13	9	12	12	13	10	12	12	12	13	10	12	12
15	MM Hereford-Worcester	9	10	10	11	9	10	9	11	11	7	10	8	10	10
16	AC One Bridewell Street	3	8	3	10	4	8	4	10	10	6	9	5	11	11
17	NV Hempstead House	7	9	5	9	7	9	6	9	9	4	8	4	5	4
18	NV Cornbrook House	5	7	6	8	6	7	5	8	6	3	2	3	4	3
19	NV Heslington Hall	10	6	14	7	10	4	13	6	7	11	6	14	9	8
20	NV Policy Studies Inst	8	3	12	6	8	2	11	5	4	9	3	13	7	7
21	MM NFUM-Avon Group	13	12	8	5	13	12	8	3	3	13	12	6	2	2
22	NV S.Staffs Water Co	6	5	7	4	5	3	3	2	2	8	7	9	6	5
23	NV BRE LEO-EED Refurb	2	4	2	3	1	5	1	4	5	1	4	1	3	6
24	NV Magnus House	1	2	1	2	2	6	2	7	8	2	5	2	8	9
25	MM BRE LEO-Gas EEDS	4	1	4	1	3	1	7	1	1	5	1	7	1	1

6.4 Breakdown of annual energy consumption into end uses

6.4.1 Figures 6.3 and 6.4 summarise the degree-day corrected delivered energy consumption and the F+3.5E figures in ten combined categories as used in previous publications (references 29 and 30). An early talk (reference 31) gave preliminary figures in seven categories for a rather different set of buildings, at a stage when only preliminary surveys had been done and floor areas had not usually been re-measured.

6.4.2 Heating is usually the largest single item of delivered energy consumption. However, lighting often approaches it and computer rooms (together with their air-conditioning) can exceed it: in terms of primary energy, energy costs and environmental impact these can be much more significant, as figure 6.4 shows. In the air-conditioned buildings, electricity consumption by fans, refrigeration and pumps (normally in that order) is also important . Here again nothing much has changed from 20 years ago (reference 28). Domestic hot water and lifts tend to be a relatively small component, as is catering except where there are staff restaurants, which also increase the hot water consumption. General office and telecommunications equipment are usually small but significant, though only really substantial at *City Atrium*, with long hours of use and high levels of IT including dealing rooms and associated communications equipment.

6.4.3 The following sections consider the main groups of energy use in more detail:

6.5 Heating.
6.6 Hot water
6.7 Cooling, fans, pumps and controls.
6.8 Lighting.
6.9 Computer rooms and their air-conditioning.
6.10 Office and telecommunications equipment.
6.11 Catering and vending.
6.12 Lifts and other uses.

FIGURE 6.3 ANNUAL ENERGY USE (kWh per sq metre TA)
delivered fossil fuel + delivered electricity consumption

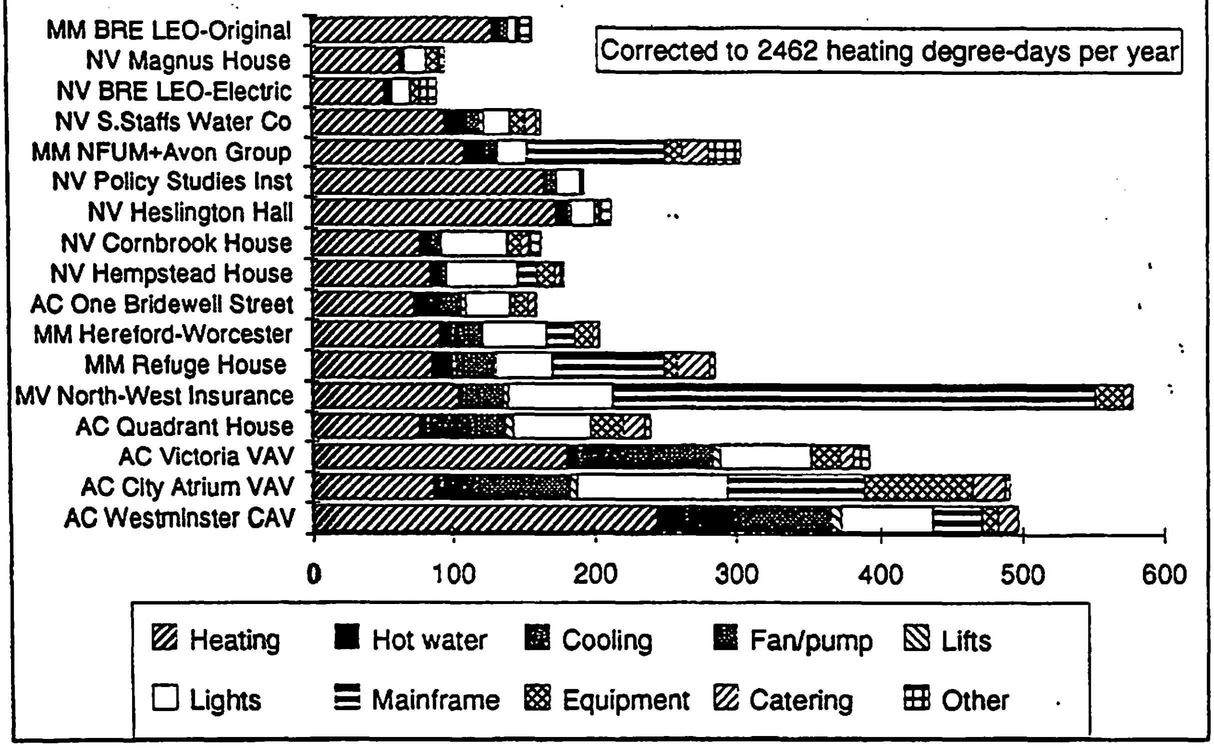
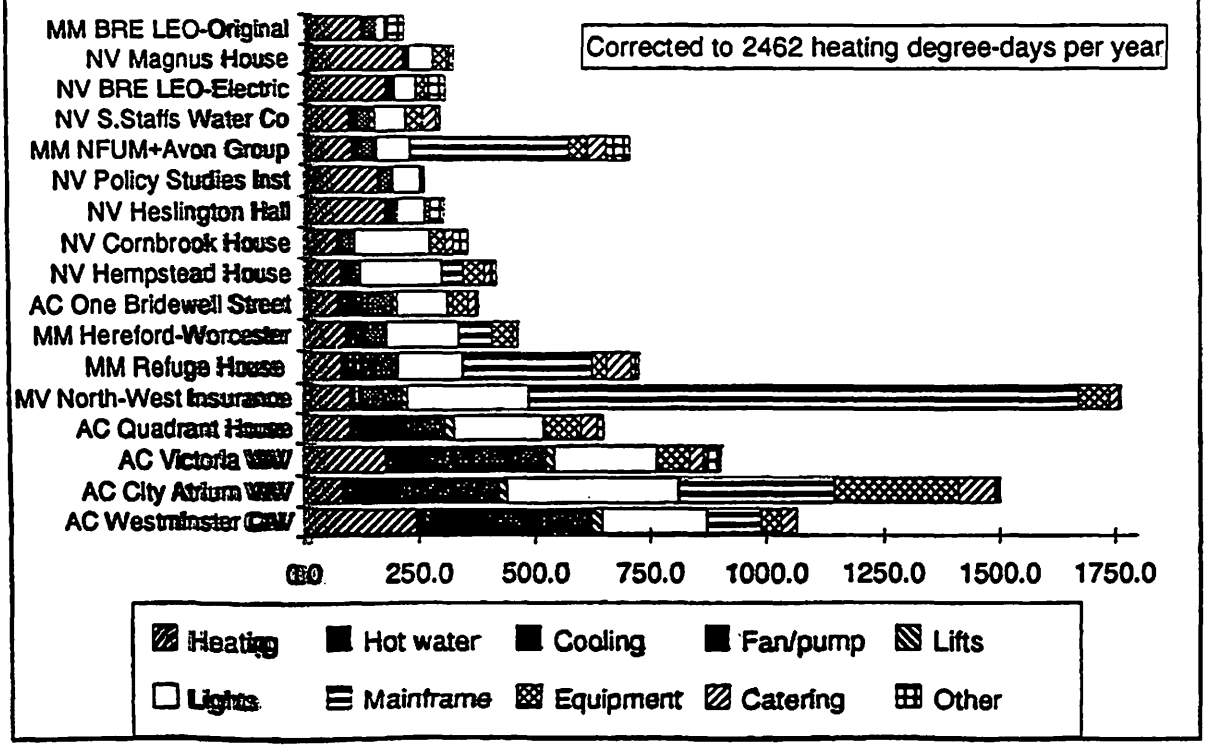


FIGURE 6.4 ANNUAL ENERGY USE (kWh per sq metre TA)
delivered fossil fuel + 3.5 x delivered electricity consumption



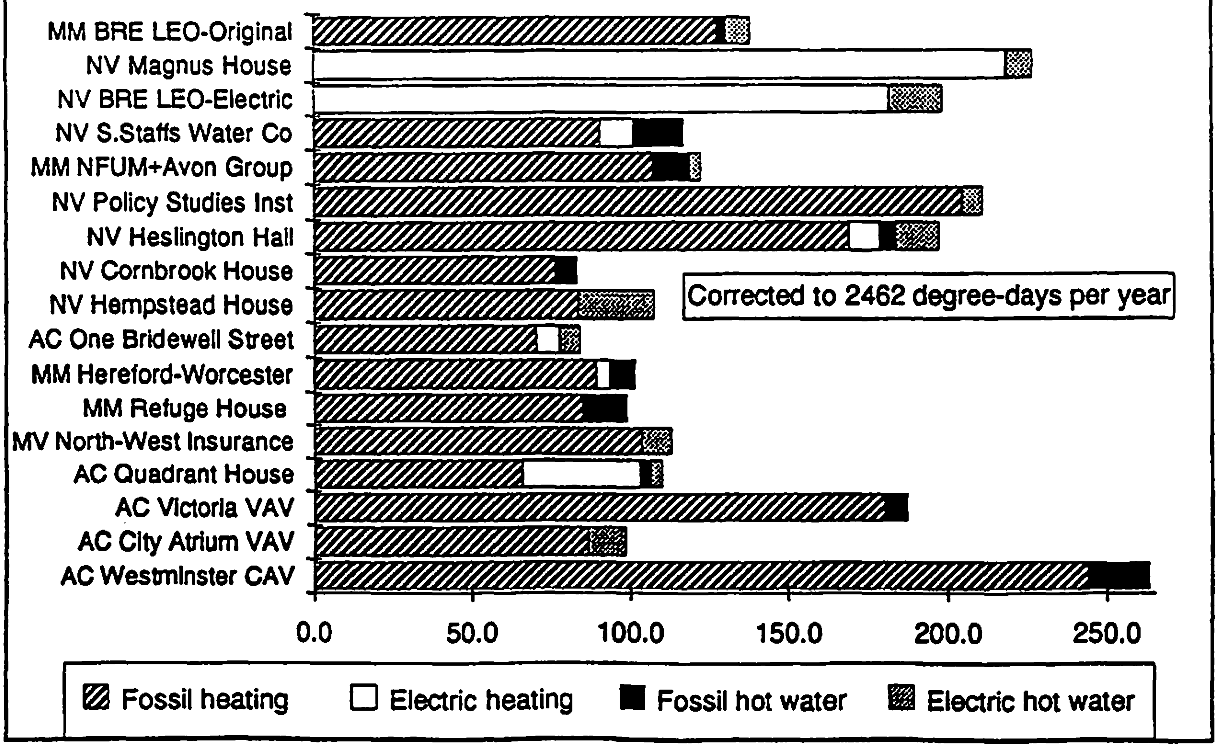
6.5 Heating

6.5.1 Figure 6.3 shows that most of the offices use between 70 and 110 kWh/m^2 for heating: about half the average levels reviewed in Section 2. The main exceptions are:

- The older refurbished *Heslington Hall and PSI*, with no wall insulation, older boiler plant, and at *Heslington Hall*, a management decision to maximise oil burning to minimise fuel costs, in spite of using the older, less-efficient plant. Before York University's energy-saving measures, *Heslington Hall* used nearly 2.5 times as much heating fuel.
- *BRE LEO Original*, which suffered from a number of (common) drawbacks, as discussed in reference 3, and initially had extremely low internal heat gains.
- The air-conditioned offices at *Victoria* and *Westminster*, which had a rather high energy consumption in relation to their use and were ultimately rejected as Case Studies.

6.5.2 Figure 6.5, using F+3.5E, brings the two EED buildings - *Magnus House* and the refurbished *BRE LEO Electric* - forward from the lowest towards the highest end of the scale. Tariff structures make their heating energy costs even higher, as discussed in Chapter 7. So while EED offers simplicity, low maintenance and good individual control in an electrically-heated office, in spite of high fabric insulation levels, heating energy costs and the associated primary energy consumption and environmental impact are still quite large.

FIGURE 6.5 HEATING AND HOT WATER (kWh/sq m TFA)
Annual fossil fuel + 3.5 x delivered electricity consumption



Corrected to 2462 degree-days per year

6.5.3 The following points are also of interest:

- Heating consumption is disappointingly high at *SSWC* in relation to the effort put into the low-energy passive solar design of this building. The main reason is that although the measures were largely successful in reducing the *demand* for heating, the heat was supplied uneconomically owing to the physical design of the system, the excessive complexity of the controls, and the use of the boiler plant for computer room reheat. This is discussed in more detail in the Case Study and Reference 4. Such misfits are not uncommon in our experience. The electric heating at *SSWC* is an electric heater battery in the ventilation plant for the management kitchen and adjacent dining room. This plant was expected to run for scheduled meals only two or three times a month, but is in fact used daily to ventilate the kitchen, which is also used for preparing hot drinks. For this purpose a small fan only would have sufficed: the full, high-volume supply-extract ventilation system with supply air tempering is vastly oversized but the only one available.

- *NFU's* heating consumption also appears rather high in relation to its insulation levels etc. The reasons for this include a deliberately heavyweight construction to reduce summertime temperatures while increasing heating costs owing to higher mean temperatures outside occupancy periods; the boiler plant which could have been more efficient had it been gas-fired rather than the multi-fuel scheme necessary at the time of design (when gas was available in limited quantities only); mechanical ventilation which increases the heating requirement and extends the heating season, and low internal gains from lighting.

- As mentioned in the Case Study, if *PSI* had had new boilers and better-located controls which could have been more readily adjusted to occupants' and conference needs, its heating fuel consumption could have been substantially reduced.

- The electric heating at *Heslington Hall* is by individual portable units (fitted with tamper-proof high limit thermostats) which are issued for weekend use and for a few cold rooms which previously called the tune for the whole central heating system.

- It is surprising that *Cornbrook House*, with its high insulation levels, small low-emissivity windows, and condensing boilers, uses only 10% less gas than the less well-insulated and conventionally-heated *Hempstead House*, which has a similar occupancy pattern and internal gain levels. The reasons lie in control and operation: *Hempstead* has effective zone controls, good management and tenant over-rides while *Cornbrook's* control system is more obscure and not managed directly by the occupants.

- *One Bridewell Street* has a very low heating consumption for an air-conditioned building. A major reason is its excellent management using BEMS information to the full to optimise the performance of a fairly conventional heating and VAV air-conditioning system in the offices. The atrium here is also well-managed to operate with minimum energy waste. The electrical component of the heating includes an air curtain (installed after occupation) and some tubular heaters in ancillary spaces.

- *Hereford & Worcester* performs very well for an open-planned office of its date, particularly in relation to the fully air-conditioned building it could easily have been. Good management has made the best of the intrinsic features, with consumption two-thirds as high as when the building was first completed. The Council Chamber and related areas have low occupancy hours and benefit from suitable zoning and effective programming.

- *North-West Insurance* and *Quadrant House*, although not dramatically low consumers, both show major reductions, with gas consumption (for heating and hot water) 30-40% of the levels of a few years before. *Quadrant House* used good management, with

Contract Energy Management (CEM) and a new BEMS with a good site engineer to operate the plant effectively and avoid the central air-handling plant and perimeter heat pumps fighting each other. *North West* used computer heat recovery to provide much of the heating for a relatively poorly-insulated building with elderly boiler plant.

- The relatively high consumption at *Victoria* (for a Case Study though not for a prestige air-conditioned building - it was one of the lowest energy consumers put forward by maintenance contractors) appeared to be a consequence of management and control. In this multi-tenanted building it was difficult to tune system operation to the needs of the individual tenants, and so operating hours were extended and BEMS features not fully utilised. A kink in the degree-day plot also suggested that the VAV plant's main dampers (which should have been controlled to maximise energy-saving through recirculation or free-cooling as appropriate, subject to CO_2- based air quality control), actually admitted excess fresh air in cold weather. A recent BSRIA study (reference 33) also confirms that even the simplest damper controls seldom work as intended.

- The consumption at *City Atrium* is good for an air-conditioned building but higher than theoretically necessary given the compact building form and high internal gains. The compensated perimeter mullion heating runs continuously to avoid any complaints during out-of-hours use.

- In spite of a well-publicised energy-saving programme, the heating consumption at *Westminster* is only about average for an air-conditioned office. Although the boilers have been replaced, the air-conditioning (perimeter induction plus constant-volume core system) and its controls are much as they were when the building was first completed in 1975, so system operation and management cannot be optimised. For example, heating and cooling plant run year-round, and one floor, used extensively outside normal working hours requires many systems throughout the whole building to remain on as well, though independent plant was under consideration at the time of our survey.

6.5.4 HEATING - CONCLUSIONS

6.5.4.1 From the case studies, one can confidently say that annual heating energy consumptions of 100 kWh or less per m^2 of treated area are feasible and demonstrated in a wide range of 1980s offices with different occupancy and use patterns and servicing systems: it could perhaps be a realistic maximum cut-off level for the performance in use of new office construction. Nothing more is required than Building Regulations insulation, double-glazing, and reasonably well-designed, controlled and managed central plant. However, in future, concern for indoor air quality may bring a requirement for more fresh air, which could greatly increase ventilation heat loads unless some form of heat recovery is incorporated: this in turn could also increase expensive "parasitic" electrical consumption by fans, pumps, controls and imperfect operation.

6.5.4.2 High insulation, more sophisticated plant, and passive solar features seemed to give disappointing results unless the problems of engineering, controls and management were very carefully addressed at the same time. Indeed, some buildings initially reviewed and subsequently rejected had more elaborate systems which were sometimes exacting energy penalties by either not operating as designed or otherwise increasing electrical requirements, cutting rapidly into the money value of saving relatively low-cost heat.

6.5.4.3 High insulation and good central and local control was effective in the EED buildings *Magnus House* and *BRE LEO Electric,* giving annual heating consumptions of 50-60 kWh/m^2 in buildings with low internal gains. Although the figures are creditable, and should be lower still in high-gain situations, the fuel (though not the capital and maintenance) energy costs for boiler/radiator systems in conventionally-insulated double-glazed buildings are significantly lower, and the associated carbon dioxide emissions approximately halved.

6.6 Hot Water

6.6.1 Figures 6.3, 6.4 and 6.5 shows that hot water is a fairly small part of the energy or F+3.5E requirements of the Case Study buildings, and generally lower than suggested by studies and targets some years ago. For example, in 1976 PSA (reference 34) stated a target level of 24 kWh/m^2 of occupied area (and excluding consumption by staff restaurants). Note that the accuracy of our figures is limited, being based for the most part on best estimates (usually cross-referred to monthly and sub-meter readings and in some cases to independent assessment and monitoring work). Hot water estimates are one of the weaker areas and small differences between individual buildings are not necessarily significant. A standard procedure for allocating energy to hot water in systems which use common boilers may well be worth developing: often consultants overestimate it by allocating the summer baseload to hot water for the whole year.

6.6.2 Studies by the Electricity Council and British Gas (for example reference 22) showed that central hot water systems in offices were often over-sized and inefficiently operated, and it appears that the Case Study offices have benefited from this understanding. While CIBSE Building Energy Code Part 2(a) values for HWS consumption tend to be too low, Reference 21 suggested a more practical basis: figures for a typical single-riser 2500 m^2 office building are reproduced in Table 6.3 below, with F+3.5E index figures added.

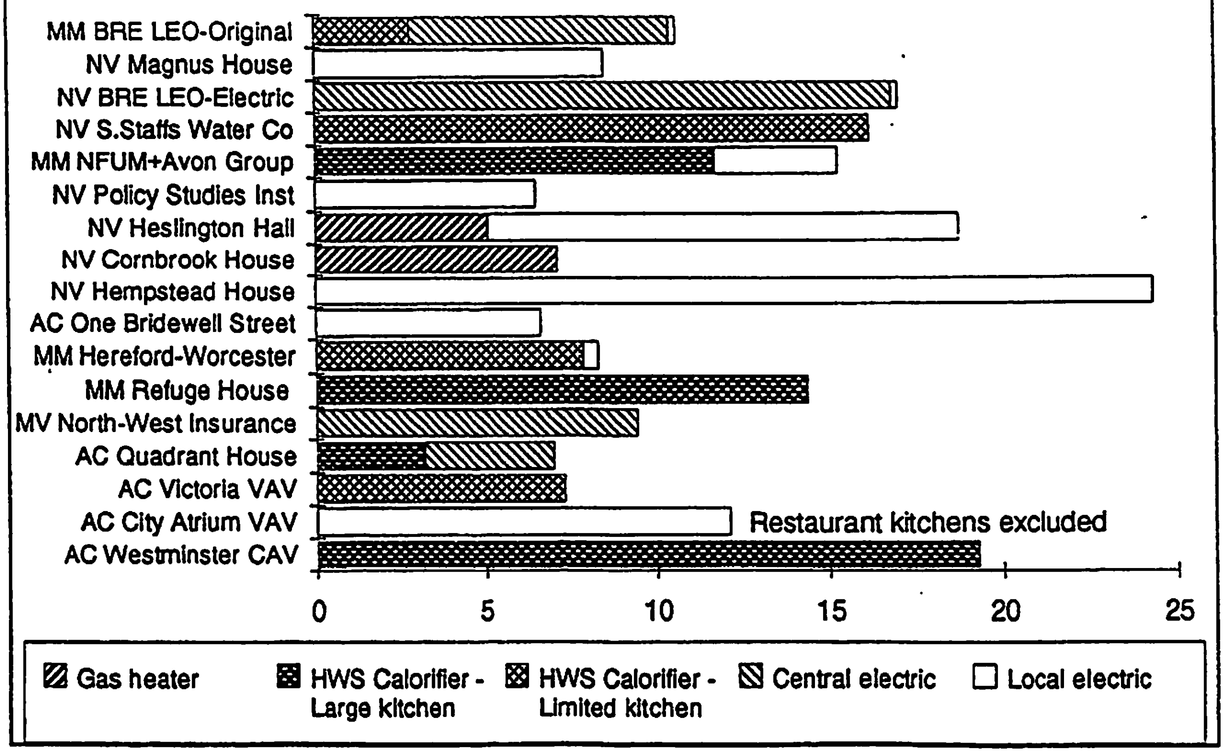
TABLE 6.3 - Hot Water Use (kWh/m^2 per annum)

	Spray taps Delivered	*Bib taps Delivered*	*Spray taps F+3.5E*	*Bib taps F+3.5E*
Local electric direct	*3.8*	*5.4*	*13.4*	*18.8*
Local electric off-peak	*4.0*	*5.6*	*14.1*	*19.5*
Central gas	*8.3*	*10.7*	*8.3*	*10.7*

A restaurant, serving lunches to about half the staff, typically doubles this requirement, excluding any local water temperature boosting which the dishwashers require.

6.6.3 Figure 6.6 shows F+3.5E requirements by system type. The amount of catering is also indicated in the shadings for "HWS calorifier": where there were large kitchens the hot water was usually heated by the main boilers. The exception, *City Atrium,* has four independently-metered catering kitchens including local electric hot water, which we have not recorded separately here. *PSI's* main kitchen does not count, being used largely for serving and seldom for cooking or even washing-up.

FIGURE 6.6 DOMESTIC HOT WATER (kWh/sq m treated area)
Annual fossil fuel + 3.5 x delivered electricity consumption



6.6.4 ELECTRIC HOT WATER SYSTEMS

6.6.4.1 The local electric systems for toilets at *City Atrium* are around the expected levels from Table 6.3, with *Magnus House, PSI and One Bridewell Street* well below:

- *Magnus House* was not very densely occupied at the time of the survey.
- *PSI* also has a low occupancy rate, tight time switch control, and kitchen heaters which are often off.
- *One Bridewell Street's* facilities manager has made full use of BEMS monitoring and control to minimise electrical consumption (and cost).

6.6.4.2 Consumption at *Heslington Hall* and *Hempstead House* is relatively high:

- *Heslington Hall* has elderly 1960s systems which are due for replacement.
- *Hempstead House* has a large number of heaters, and the standing losses all add up. In hindsight, a more compact arrangement with fewer heaters would have been possible.

6.6.4.3 The instantaneous local heaters at *BRE LEO* are extremely economical, having no standing losses and being seldom used. This is partly a behavioural issue - they are less convenient to use than ordinary taps, so people only use them if they really *need* hot water. And why not?

6.6.4.4 The central immersion heater at the refurbished *BRE LEO Electric* has a compact distribution system, with electrical use near the guidelines for a local unit. However, the system is not economically designed or operated at present, being the HWS calorifier with the standby immersion heater on permanently: this both gives room for improvement and puts the lower consumptions elsewhere into perspective. *BRE LEO Original* used electric immersion heating in summer only, as at *Quadrant House,* where it is now under BEMS control.

6.6.4.5 *North-West Insurance* also has relatively low consumption, this time by using a heat pump to upgrade waste heat from the computer's power supply, and replacing the former oversized and poorly-controlled boiler/calorifier system which was extremely inefficient for this purpose in summer. Gas consumption fell by some 45 kWh/m^2 after the change-over, predominantly by having the boilers off over the summer period. After taking account of usage, the energy cost of running the heat pump was very similar to that for the self-contained gas-fired water heaters at *Cornbrook House* and *Heslington Hall.*

6.6.5 GAS-FIRED HOT WATER

6.6.5.1 Both *Heslington Hall* and *Cornbrook House* have self-contained water heaters and use rather less energy per square metre than the guideline levels, both having BEMS time-control and *Heslington Hall's* not serving the entire building.

6.6.5.2 The other systems have central calorifiers heated by the main boilers. Of those not supplying large kitchens, *Victoria's* is rather below the guideline, perhaps not surprisingly because the building is larger and the distribution quite compact. *Hereford & Worcester's* consumption is very good, given that the system has local calorifiers heated by site primary mains, and includes a modest kitchen. An important reason is good management, with a single one-hour summer recovery period (see paragraph 5.4.3.2). The high consumption at *SSWC* (in spite of spray taps), arises from an extended distribution system and over-reliance upon an over-specified BEMS which has not fulfilled its promise. (NOTE: the initial EPA estimates (reference 4) were nearly twice our figure, but they included primary system standing losses outside normal operation hours which, in our opinion, were more justly assigned to the computer room).

6.6.5.3 The large kitchens at *NFU, Refuge House* and *Westminster* inevitably increase HWS consumption. The increasing order of consumption is not unexpected:

- In the lowest, *NFU,* although the system also supplies the swimming-pool's showers, the catering load is rather smaller and remote toilets also have electric heaters (probably mistakenly, as they are not all that remote). There was also a preheat contribution from the swimming-pool heat recovery system, although this was small for the Case Study period (see 5.4.3.1).
- *Refuge's* kitchens are generally more liberally operated than those at *NFU.*
- The systems and controls at *Westminster* are older, with no BEMS.

6.6.5.4 Energy consumption for hot water at *Quadrant House* is surprisingly low in view of its intensively-used kitchens. The following reasons suggest themselves:

- A compact distribution system in a very large building, with a single core.
- A relatively small kitchen with a higher load factor, serving throughout the day, with less of a lunchtime peak and a higher proportion of cold meals and snacks.
- Careful, responsive energy management of the building generally.

6.6.6 HOT WATER - CONCLUSIONS

6.6.6.1 Hot water supply in most of the Case Study buildings is reasonably efficient, avoiding much of the waste identified in earlier studies though frequently offering further scope for improvement. Where there were high catering loads, the main heating boilers, if properly managed, also proved reasonably economical for hot water, in contrast with older systems where the boilers used to keep themselves warm all the time in summer, HWS demand or not.

6.6.6.2 While electrical systems tended to use less delivered energy, their F+3.5E was often at least as high as for the gas-fired systems. None of the systems were designed to maximise the use of off-peak rates - many of the case studies did not have off-peak tariffs in any event. However, at *NFU, One Bridewell Street* and *Quadrant House,* BEMS time control ensured that all units were fully charged at the end of the overnight low-rate period and were not heated unnecessarily at the end of the day.

6.6.6.3 For basins, instantaneous electric systems, found here only in part of *BRE LEO,* appeared to offer great economies, using an order of magnitude less energy than storage-based systems with ordinary taps, probably because the instantaneous systems are less convenient to operate. This suggests that the real need for hot water for hand-washing is often marginal.

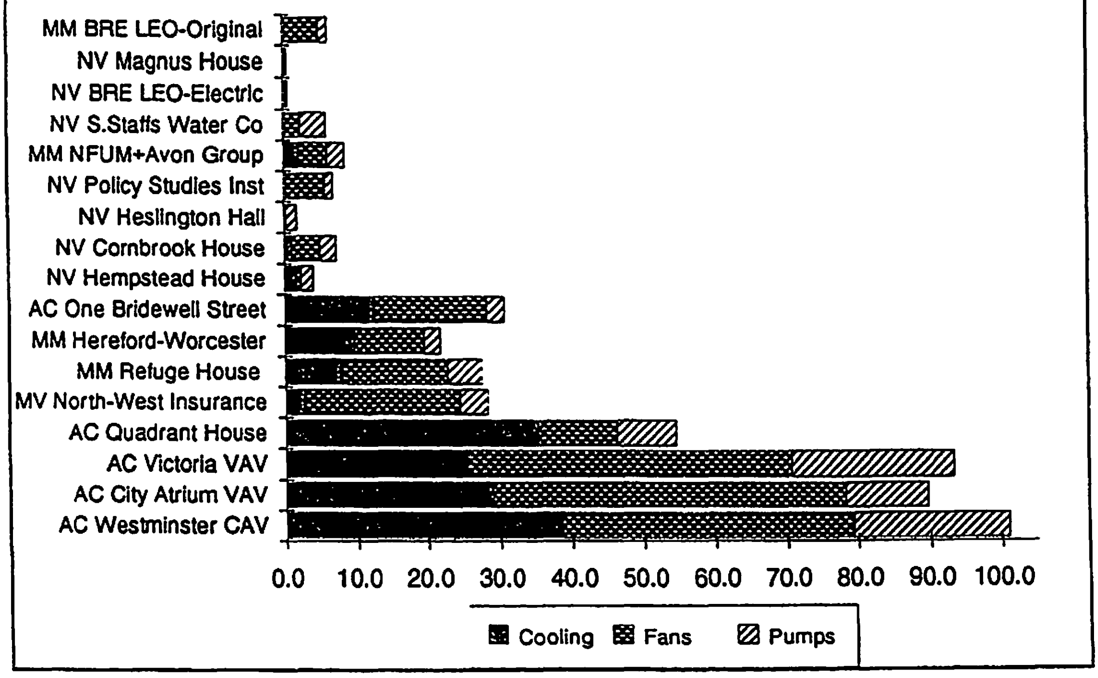
6.6.6.4 Spray taps at *NFU* and *SSWC* presumably contributed to water and energy saving but did not seem to give any noticeable economies in relation to the other buildings, probably because more of the avoidable waste was in the standing losses.

6.7 Cooling, fans, and pumps

6.7.1 Figures 6.3 and 6.4 shows the great variation in energy use by cooling (= refrigeration + heat rejection), fans and pumps, and a close correlation of high consumption in these categories with high consumption overall. Figure 6.7 shows the results on an expanded scale. The figures exclude systems for computer rooms, machine rooms, telephone exchanges and car parks, which were recorded separately.

6.7.2 For the three categories combined, air-conditioned offices tend to use the most, naturally-ventilated the least, with mixed-mode and mechanically-ventilated usually somewhere in between, though *One Bridewell Street* - the lowest-energy centrally air-conditioned building we have identified to date - is in the same league as the mixed-mode *Refuge House* and the partly mechanically-ventilated *North-West Insurance.*

FIGURE 6.7 COOLING, PUMPS AND FANS
Annual electricity consumption (kWh/sq m treated floor area)



6.7.3 NATURALLY AND MECHANICALLY-VENTILATED BUILDINGS

6.7.3.1 Heating and hot water pumps in the naturally-ventilated buildings use relatively little energy, typically 1 or 2 kWh/m^2, depending on detailed design and the hours of operation, which were particularly long at *SSWC* where the constant-temperature circuit ran continuously.

6.7.3.2 The naturally-ventilated buildings usually have small amounts of mechanical ventilation too:

- Toilet extract fans at *BRE LEO* and *Magnus House.*
- Toilet supply and extract ventilation, including extract from coffee kitchens and cleaners' rooms at *Cornbrook House.*
- Toilet supply and extract ventilation with cross-flow heat recovery at *SSWC.*
- Conference and meeting room ventilation at *Cornbrook, Hempstead* and *PSI.*
- Atrium and internal room ventilation at PSI.

There is often scope for further savings from tighter time programming generally, and using on-demand control in meeting rooms and other intermittently-occupied areas, with local interval timers for example.

6.7.3.3 Pump and particularly fan energy consumption at *North-West Insurance* is much higher, with F+3.5E similar to the heating. 85% of the fan consumption is attributable to the induction system in the 1971 building - archive, toilet and management kitchen/dining ventilation accounts for the rest. The 1971 system now runs 24 hours per day - in spite of normal flexitime occupancy by most of the staff - for two main reasons:

- Secondary glazing added some years ago made the windows very difficult to operate for summer cooling, and so the plant was instead run overnight to remove excess heat. While cooling by night ventilation can be an energy-efficient alternative to chilling, it is best done on-demand and with lower pressure drops than induction systems require.
- More recently, heat recovery from the computer room's chilled water system was added, with tepid water from the condenser circuit preheating the ventilation supply. This low-power input does not have sufficient capacity for early morning start-up and so the ventilation plant runs overnight instead.

Our estimates suggested that the additional electrical costs of extra hours of fan and pump operation reduced the money value of the gas savings from heat recovery by 40%, reducing the cost-effectiveness of the scheme. Further energy would have been required had the fans been upgraded to maintain the air volumes at their original level.

6.7.3.4 The small amounts of cooling at *Cornbrook House* and *Hempstead House* are for small packaged units used on-demand in hot weather only in equipment and meeting rooms. The units are not particularly efficient, but the low hours of use makes them practical and economic. *North-West Insurance* uses more for data processing offices, which are cooled by an extension to the computer's chilled water system, plus direct-expansion packages in more remote areas.

6.7.4 AIR-CONDITIONED BUILDINGS: PUMPS

6.7.4.1 Pump energy use is usually the smallest of the three items but rises substantially in fully air-conditioned buildings, typically to 10 kWh/m^2 or more (except at *1 Bridewell Street,* where the systems are very tightly managed). Since chilled and condenser water systems operate at lower temperature differentials than heating systems, they require larger water volumes and pressure drops for the same duty. The larger pumps, sized for peak cooling loads, often run at full capacity whenever cooling is required, however little (see footnote). There are several reasons for this:

- Cooling loads are often imposed by internal, not climatic, heat gains and so a low load overall does not stop certain parts of the building requiring full power. With the traditional 3-port valve constant-volume control arrangement, this can only be assured at full flow, and even 2-port systems often have constant pressure shunt bypass valves rather than pressure control and variable volume pumping.
- Chillers can sometimes be very sensitive to variable hydraulic conditions, and lock out if flow rates vary. This is easily remedied by having primary/secondary circuits where each chiller has a pump set of its own and flow through each chiller is independent of building demand. Sadly, in many systems a single pump set does both primary and secondary duties and then the system usually stays at constant, maximum flow whatever the load.
- Generally, less thought seems to be expended on the energy-efficient control of chilled water systems than of heating systems. For example, in some buildings visited (not case studies) the heating had optimum start/stop and zone controls, while the chillers and associated pumps and valves were entirely manually switched.

The lessons are to consider hydraulics and controls much more carefully, review the scope for variable-volume pumping (no Case Study had it) and to provide for regular out-of-hours uses independently as far as possible.

6.7.5 AIR-CONDITIONED BUILDINGS - FANS

6.7.5.1 Fans generally use much more energy than pumps, except in *Quadrant House*, which has a fresh-air system only: local heating, cooling and air-circulation is largely dealt with by the perimeter heat pumps in each room. Generally air/water systems such as fan-coils tend to use less energy overall than all-air systems such as VAV: the reduction in fan energy consumption with the former being greater than the increase in refrigeration requirements owing to the reduced opportunity for "free" cooling by outside air.

6.7.5.2 *Victoria, City Atrium* and *Westminster* all have consumptions in the 40-50 kWh/m^2 range, the first two for variable air volume (VAV) systems and the third for constant air volume (CAV) core and induction perimeter systems.

- Of the three systems, *City Atrium's* is the most efficient, having to deal with the heaviest loads for two shifts a day, and running for typically 15 hours on weekdays. Weekend requirements here are largely in equipment areas which have their own supplementary cooling; light occupancy elsewhere does not normally need the central VAV plant to run.
- *Westminster* has a less intensive occupancy but nevertheless all systems run for 14 hours on a typical day - and frequently on Saturdays - owing to the inflexible design and control discussed earlier.
- *Victoria* runs for shorter hours still, typically 12.5 hours a day, weekdays only. Here outside normal working hours some energy can potentially be saved by closing dampers to unoccupied floors and throttling-back the main fans accordingly. However, the monitored VAV fan energy consumption here was high and the zoning was not used to the full. The intensively-planted atrium also had to be ventilated continuously, accounting for over 10% of total fan energy consumption. The requirements of planting in atria often seem to increase HVAC and lighting requirements disproportionately - and probably unnecessarily - and some design guidance could well be useful.

6.7.5.3 The relatively high energy consumptions of the VAV systems at *City Atrium, Victoria* and elsewhere was initially surprising. VAV's energy-saving proponents often quote the fan laws "half the flow = one-eighth of the power", but our monitoring suggested that average VAV fan energy consumption was typically 70-80% of peak and similar to many constant-volume systems. Discussions suggest that our findings are not uncommon. Reasons for the lack of improvement include higher design pressures with VAV systems (especially to operate system-powered terminal devices), and controls which maintain constant pressure (or nearly so) with decreasing volume, making the behaviour more-or-less linear from a rather higher base. In bad cases where design or installation faults had led to insufficient pressures at the end of the line, fan power was increased at the commissioning stage, sometimes making energy consumption very high indeed! Building energy use predictions, which often focus on heating and cooling loads in any event, commonly seem to underestimate fan power and running hours.

6.7.5.3 However, at *1 Bridewell Street,* we did find a VAV system with a low fan energy consumption of 15.8 kWh/m^2 treated. This combined relatively low typical operating pressures (450 Pa supply, 100 Pa extract), good control including variable-speed motors, and excellent management which reduced typical daily operating hours to 10 and load factors to 40% of peak: this demonstrated again that low-energy engineering and management skills applied to largely-conventional systems can give better results than add-on technology.

6.7.5.4 The air-water system at *Quadrant House* has the lowest fan power as a result of the much smaller - minimum fresh air - air volumes, lower pressure drops, and shorter operating hours

(11 per day). Here inevitably, and in spite of careful optimisation of the supply-air temperature, the cooling capacity of the air is limited and the room heat pumps have to counter additional fabric and internal gains. This brings us on to cooling generally.

6.7.6 AIR-CONDITIONED BUILDINGS - COOLING

6.7.6.1 Cooling energy consumption (here defined as mechanical refrigeration plus heat rejection but not including pumps or cooling of machine rooms) is similar in the four largest buildings.

- Again *City Atrium* does best in relation to its more intensive use and high level of internal heat gain. This is largely because the ventilation plant is well-managed by BEMS to maximise the potential for "free" cooling by outside air without refrigeration.
- *Victoria* has a similar system - this time with CO_2 air-quality control as well - and should have done better. However, as already discussed for the heating, the controls for the fresh-recirculation air dampers were not behaving themselves, introducing too little fresh air in mild weather and too much in winter.
- *Westminster's* energy consumption is higher as the potential for free-cooling is limited, the system and its controls are older, and the chillers are operated year-round. (In the VAV buildings, the chillers are often switched-off sometime in October and do not come on until March). Refrigeration energy use was reportedly higher, and summertime peak cooling loads above the available capacity, before window film was applied. However, the window film was not an unmixed blessing, as it increased lighting energy consumption.
- At *Quadrant House* about 75% of the cooling energy is attributable to the perimeter heat pumps, 15% to the chiller for the primary fresh air, and the rest to local systems (particularly for the dining rooms and ancillary areas) and the cooling towers. The heat pump's coefficient of performance is relatively low, increasing energy consumption for cooling. Solar gains are also fairly high here owing to the relatively shallow plan and windows which are shaded internally only. Nevertheless, the overall combination of fans, pumps and chillers is relatively economical both for an air-conditioned building and in relation to the situation before the new BEMS and CEM contract.

6.7.6.2 Of the fully air-conditioned buildings, however, *One Bridewell Street* has by far the lowest cooling energy consumption. There are three main reasons for this:

i Careful design of the building, with modest window areas, much of the solar gains to the atrium simply ventilated out, and careful detailing of the envelope, with thermal mass in the inner concrete leaf, plus insulation and white ventilated rainscreen cladding outside.
ii Low heat gains from the well-controlled and energy-efficient lighting and from the VAV fans themselves.
iii Good management, obtaining comfort conditions *(the building rated best in a recent user survey by BRE)* with the chillers often not brought on until the afternoon in the summer and not at all for half the year.

This excellent result, however, has been partly achievable because the office has a fairly homogeneous occupancy pattern, with no major pockets of heat gain which might have required supply-air temperatures to be lowered.

6.7.7 MIXED-MODE BUILDINGS - COOLING, FANS and PUMPS

6.7.7.1 "Mixed mode" buildings have both openable windows and mechanical ventilation or air-conditioning, operated either as background or as emergency systems. These potentially offer higher levels of environmental performance than natural-ventilation alone, but with lower capital and energy costs and more user choice than sealed, fully air-conditioned buildings, and these days a "greener" image. Figure 6.7 confirms that they are indeed in the middle ground as far as fan, pump and cooling energy is concerned.

6.7.7.2 *BRE LEO Original* is the simplest of the four mixed-mode Case Study buildings: a naturally-ventilated cellular building with a minimum fresh-air system and heat recovery by thermal wheel. The mechanical ventilation was intended to save energy by avoiding wasteful window-opening in winter, when the windows were locked shut until occupants protested. Monitoring (reference 20) however showed that fan consumption, although fairly low (as figure 6.7 confirms), cost as much as the recovered heat was worth. The system also introduced further parasitic losses to the heating - through frost protection requirements, extra pipe losses, and so on, and during malfunctions. With increasing heat gains from office equipment (at least at present) and more concern for indoor air quality, there is now renewed interest in systems like this which offer controlled ventilation and heat removal, better summertime comfort by overnight cooling with fabric heat storage, and assisted at times by a low-powered heat pump which could also be economic for overnight wintertime heating. BRE are currently evaluating a number of options on site at *LEO*, but to date the results have not been very encouraging for this relatively simple, highly cellular, well-shaded and orientated building.

6.7.7.3 *Refuge House* is at the other end of the scale, with natural ventilation, background mechanical ventilation, and underfloor fan-coil air-conditioning, all available to choice. Good operational flexibility is obtained with each fan-coil unit capable of being separately controlled and managed through the BEMS and local group controllers. Energy consumption for cooling, fans and pumps also puts *Refuge* very much in the half-way house, offering good savings in relation to most air-conditioned buildings, although at first sight only marginal in comparison with *One Bridewell Street.* However, while at *Bridewell* the main office fans and fan-coil units account for 10 kWh/m^2, at *Refuge* the figure is 6.1 kWh/m^2, the balance being attributable to ancillary areas, and particularly the kitchen/restaurant system, which alone uses nearly as much as all the office fresh air plant. Pump consumption is modest because - at least for the year of the survey - wintertime chilled water circulation was not normally required. Cooling energy is also low owing to the short cooling season and cooling demands which are only localised except in very hot weather, and are met by evaporative "free" cooling without refrigeration when it gets colder.

6.7.7.4 In the middle are *Hereford & Worcester* - somewhat below *Refuge* in all aspects except refrigeration - and *NFU,* with a consumption pattern closer to the naturally-ventilated buildings.

- *Hereford & Worcester* is designed primarily as mechanically-ventilated, with comfort cooling and natural ventilation as somewhat limited options. With modular plant for each of the linked "pavilions", pressure drops are low and systems can be precisely managed to meet local needs, including only occasional use in the Council Chamber etc., so fan energy consumption is modest. Pump power is also reasonable, with systems split into primary site mains (MPHW for heating) and local, independently-pumped spurs for the pavilions, again managed according to actual need. The relatively low energy consumption for chilling is nevertheless quite high in relation to demand, owing to low load factors on the distribution system.
- *NFU* is a more traditional, high-ceilinged, cross-ventilated concept with background mechanical ventilation designed for a low-velocity 4 air changes per hour for high summer use, but normally running at only half this level, requiring very little fan power, as for the offices at *Refuge*. Some other areas: particularly the kitchen, restaurant, conference rooms, training rooms, print room and workshop have more powerful systems, but the areas concerned are relatively small and the local plant runs only for short hours under BEMS or local control. The chiller, which supplies chilled water on-demand only to the conference room, training rooms, general management suite, private dining rooms and board room systems is separately metered and consumes only 2.1 kWh/m^2 per year, with total treated floor area as the denominator, or some 12 kWh/m^2 for the areas concerned.

6.7.8 COOLING, FANS AND PUMPS - CONCLUSIONS

6.7.8.1 A major difference between the energy "fingerprints" of office buildings is the consumption of cooling, fans and pumps, with typically an order of magnitude change between naturally-ventilated (with fairly trivial consumption levels) and air-conditioned ones, where annual figures of 70 kWh/m^2 and more are normal and fan consumption can be particularly high.

6.7.8.2 High energy consumption often appears to be associated less with a specific type of system as with excessive running hours, unnecessarily high fan power and pressure drops, poorly thought-out zoning, or inappropriately designed, operated, or maintained controls. These problems are well-known to managers and energy consultants but are not often considered fully in predictive models. Straightforward engineering for high thermodynamic efficiencies, low pressure drops, matching systems to likely operational patterns, and controlling and managing them accordingly, may offer greater scope for practical energy-saving than seductive but ultimately often poorly-understood new technologies.

6.7.8.3 For offices, most people see a straight choice between natural ventilation and full air-conditioning, and in the 1980s have been more likely to choose the latter for a number of reasons including concerns about the quality of the external environment and heat gains from office equipment. However, this decision can bring with it a leap in energy consumption and, it seems, adverse user reaction against sealed, highly serviced buildings with insufficient individual control. We would prefer to regard the two types of building as two ends of a scale which also has many intermediate steps. The "mixed mode" offices reviewed suggest that there is indeed a middle way, and - at least for some organisations on some sites - can offer more pleasant, more cost-effective, lower-energy and potentially more future-proof buildings.

6.8 Lighting

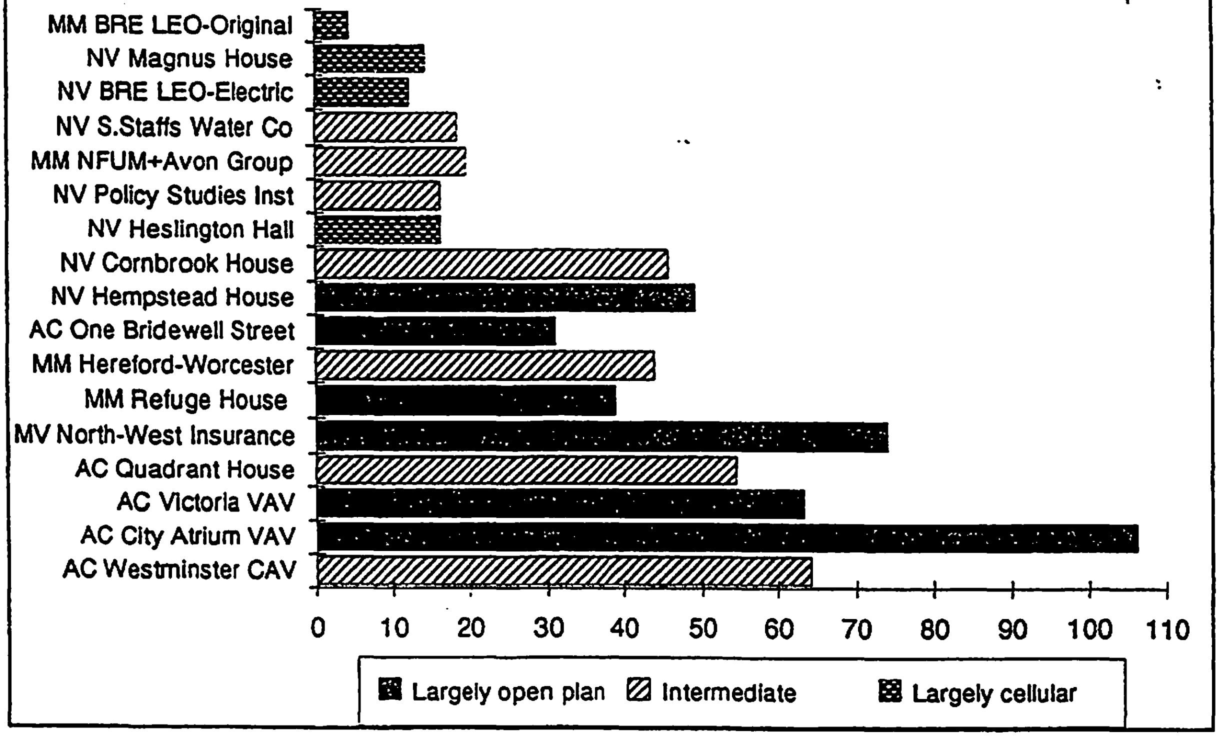


FIGURE 6.8 LIGHTING IN DIFFERENT OFFICE TYPES
Annual electricity consumption (kWh/sq m treated floor area)

6.8.1 Lighting energy use also varies greatly between buildings, though by less than cooling, pumps and fans. It depends on the installed lighting load (in W/m^2), the hours of use, the availability of daylight, and the likelihood of daylight being used. As earlier BRE studies have shown (eg: Reference 35), the primary influences on the operation of lighting are user behaviour and office type. If "first in" switches the lights on (if they perceive the office to be too dark) and "last out" switches them off again, then the bigger the space concerned the longer the running hours.

6.8.2 Figure 6.8 therefore differentiates annual lighting consumption by three different office types.

- *Largely Open Plan.* Here most people are in group spaces which span from window-wall to window-wall or core. Some cellular offices may be included but they seldom have good daylight, and quite often not even individual light switches.
- *Largely Cellular.* Here most people are in individual one or two-person offices, where a switch by the door is often a very effective means of lighting control.
- *Intermediate.* This category covers both offices with group spaces (containing perhaps 3-15 people, usually in a perimeter strip) and those with more of a mixture of open plan and well-daylit cellular offices.

Figure 6.8 confirms that in the Case Studies, the cellular office buildings all had the lowest levels of lighting energy consumption, the open-planned the highest, and the intermediate ones seemingly a double-humped distribution, with a cluster only a little above the cellular offices and another just below the open-planned ones. Individual consumptions in the three groups are discussed below.

6.8.3 LIGHTING IN LARGELY CELLULAR OFFICES

6.8.3.1 *BRE LEO Original* is anomalous, having very low occupancy during the initial monitoring period. The automatic lighting controls also caused adverse user reaction and were abandoned. *LEO's* performance under present conditions is more representative of well-daylit cellular offices with a sensible switching pattern. The lights here are now ten years old: with newer fittings consumption would be lower, particularly if high-frequency control gear was used. *(However, more efficient would not be as cost-effective here as in open plan offices, where running hours would normally be longer and savings could also be made by reducing air-conditioning loads, and possibly even the need for air-conditioning at all).*

6.8.3.2 *Magnus House* already uses high-frequency fittings, and has lower occupancy and shorter average lighting hours than the refurbished *BRE LEO Electric.* However, lighting uses more energy owing to a higher installed load (17 W/m^2 at *Magnus* versus 14 at *LEO* in the offices themselves -*LEO's* corridor lighting is also lower-powered). The main reasons are:

i) At 700 lux, *Magnus's* office illuminance level is twice *LEO's,* rather high for cellular offices, and more than the occupants seem to want.
ii) At *Magnus* there is only one switch for each room, in contravention of good energy-efficient practice, so the lights by the windows comes on at the same time as the inner ones.

6.8.3.3 Low lighting consumption is not restricted to modern offices: the refurbished *Heslington Hall* has good daylight, a 350 lux standard, and uses a similar amount per square metre, although admittedly it has a rather poorer nett:treated floor area ratio (see figure 5.2). Consumption is also reduced by having very low-energy lighting in corridors and ancillary areas, while the less efficient and more decorative lighting in function rooms has relatively short hours of use.

6.8.3.4 Lighting consumption in the cellular office Case Studies may not be very different from that in many other simple cellular office buildings with modest illuminance standards, reasonable daylighting and simple, effective switching arrangements, for example similar levels are stated in PSA's targets (see Appendices D and E). With good local switching, a 300-500 lux illuminance standard, and low-energy lighting of ancillary areas, annual lighting energy use of 10-15 kWh/m^2 or less seems feasible in most cellular office buildings.

6.8.4 LIGHTING IN LARGELY OPEN-PLANNED OFFICES

6.8.4.1 In open-planned offices, a reasonable working assumption is that, unless careful steps are taken to limit their use, most lights will not only be on all day, but for a period before and after for cleaning, stragglers etc. Average annual running hours can easily jump from around 1000 or less in cellular offices to typically 2500-3500. Energy consumption can increase still more as in the past design illuminance levels in open offices have often been higher, though this is less common today when, to suit VDU users, 300-500 lux tends to be specified instead of 750. For the Case Studies, (excluding the anomalously high *City Atrium* and *North-West Insurance* and the anomalously low *LEO Original)* the ratio of average annual energy use open:cellular is 4.2:1.

6.8.4.2 Full load annual running hours of the main office lighting are approximately 2750 at *Hempstead,* 2300 at *Bridewell,* 2000 at *Refuge,* 3100 at *North-West,* 2900 at *Victoria* and a massive 5500 at *City Atrium.* (NOTE: the figures for *Victoria* exclude 10 kWh/m^2 of atrium which ran 24 hrs/day to encourage plant growth). The lower hours at *Refuge and Bridewell* are a result of their electronic lighting controls, which actually achieved more of their potential at *Bridewell* even though there is little useful daylight. *Hempstead* and *Victoria's* controls were largely ineffective, owing to human factors problems and metal halide lamp starting delays at *Hempstead* which also affected *Refuge.* (NOTE: *Hempstead* has now replaced the MBI lamps on two floors with batteries of short fluorescent tubes (see para 5.3.3.10), which start instantly and allow the controls to be used more fully. If applied throughout the building, lighting energy use here could well drop to 25-30 kWh/m^2).

6.8.4.3 The very high running hours at *City Atrium* is partly attributable to its financial trading function, where there is widespread two-shift working on weekdays, plus Sunday night (for the Far Eastern Market) and overnight on Fridays. Weekends are also busy in places with furniture moves, refits, cable alterations, testing etc. The number of people working well outside normal office hours is nevertheless relatively small (perhaps 10-15% of total), but widely dispersed throughout much of the building. Because the lights are switched in large groups, with no automatic and few local controls, large areas of the office are often lit for only a few people.

6.8.5 LIGHTING IN INTERMEDIATE OFFICES

6.8.5.1 Intermediate offices are perhaps the most interesting because their energy consumption spans the range between open and cellular, although the average for the Case Studies (3.1 x cellular excluding the unpublished *Westminster)* is much closer to the open-plan level. However, some of the offices which have lighting energy consumption close to cellular have organisational and spatial characteristics closer to the open-plan and vice versa, offering hope for closing the divide.

6.8.5.2 At the top end of consumption, *Westminster* - although many of its lights had been refurbished with high-efficiency lamps and reflectors - suffered the open-plan problem of excessive running hours (3500-4000) owing to poor switching, in large groups from positions in the corridors and not the the individual rooms. Lighting use here was also reported to have increased markedly when film was applied to the windows to reduce solar gain *(this seems to be a common finding with tinted or reflective glass: even where illuminance levels are quantitatively sufficient, the outside world looks gloomier and people seem much more likely to have lights on). Quadrant House* originally had similar space planning and switching arrangements, but with a lower installed load (17 versus 20 W/m^2). They first fitted automatic controls with local over-rides (see Section 5.5.3), and brought average hours down by 35% to 2250 for a similar weekday occupancy pattern. *(Westminster,* however, has greater occupancy on Saturday mornings). Although lighting consumption at *Quadrant* is still quite high, it was more suitable than

Westminster for a Case Study owing to its more economical HVAC systems. *Quadrant* is now also considering improved reflectors, which would allow the installed lighting load to be approximately halved, here again reducing consumption to the 25-30 kWh/m^2 level.

6.8.5.3 The offices at *Hereford and Worcester* are predominantly open-planned, but are classified in the intermediate category because the council accommodation and ancillary areas reduce the intensity of use of parts of the building. The design dates from the early 1970s and the installed lighting load of 32 W/m^2 - although reasonable for the time - is by far the highest of any published Case Study *(NOTE: however, we recently discovered a similar installed power level in a well-publicised low-energy office completed in 1990!)* Although not implemented at the time of the Case Study, the lights are being upgraded from twin to single tubes with high-efficiency reflectors, promising a reduction in installed power to 15 W/m^2, and annual consumption again to the 25-30 kWh/m^2 level - possibly less if lighting in other parts of the building is also upgraded. Automatic photoelectric and time controls at *Hereford and Worcester* reduce mean annual running hours to about 2000, still somewhat disappointing in view of its use pattern and the daylight available. Although advanced for its time, by today's standards, the control system has over-large switching groups and cannot be used to the full (see paragraph 5.5.3.4).

6.8.5.4 In *Cornbrook House,* with a fairly shallow plan and quite a lot of cellular space, daylight might well have been effectively utilised. However, the designers expected that the lights would be on all day and so designed small windows for view, heat retention and low solar gain, but giving too little daylight to be viable on their own. While local switching allows lights in unoccupied empty offices to be turned-off, otherwise the office has been taken, perhaps unnecessarily, from the low towards the high end of the range. A minimum-energy cost design might well have paid more attention to lighting, whose annual energy costs are 2.5 times as high as the heating's.

6.8.5.5 The three main floors of *PSI* are largely cellular, and with a fairly low intensity of occupation use little more lighting energy than *BRE LEO Original.* This frugality is counter-balanced by the largely open-planned tenanted first floor (where lights are on throughout the working day except in the few cellular spaces) and the conference rooms (where the fairly high-energy tungsten-halogen lighting is fortunately well-managed with relatively short hours of use).

6.8.5.6 Finally *SSWC* and *NFU,* both offices where the designers aimed for good natural light and glare-free wintertime solar gains in open-planned office areas. Although neither lighting nor controls has been a 100% success (see sections 5.3 and 5.5), both buildings give an impression of good, even daylight. Lighting energy consumption in the open-planned areas has come down towards cellular office levels, with full-load running hours around 1000 and 1500 respectively. (NOTE: *NFU's* overall lighting energy consumption per square metre is not much higher than *SSWC's* because the ancillary areas at *NFU* are generally more economically lit and for shorter hours). Both offices were designed some 10 years ago, and with today's knowledge and technology - light sources, control gear and reflectors more efficient and controls more precise and user-friendly - lower consumption levels would be possible.

6.8.6 CONCLUSIONS ON LIGHTING

6.8.6.1 Annual lighting energy consumption is determined by the product of the installed power density (in W/m^2) and the hours of use. Both figures tend to be higher in open-planned than in cellular offices, giving a ratio of annual energy consumption typically of 3 or 4:1.

6.8.6.2 Modern lamps, reflectors and control gear can give major reductions in installed lighting power levels. For example, the open offices at *Hereford & Worcester* - a low-energy scheme for the mid-1970s - were designed to 600 lux and used 32 W/m^2, or 5.3 W/m^2 per 100 lux, including control gear losses. At the time, 50 W/m^2 and more was not uncommon in open-planned offices, including the EEDS-monitored automatic control retrofit projects at Bradford and Portsmouth (References 36 and 37), whose high loads also made them ineligible as Case

Studies. A Case Study at Woolgate House (Reference 39), with its telephone-controlled installation was not possible as the office was not suitable in some other respects.

6.8.6.3 The general office areas in the Case Study buildings completed or refurbished in the early-to mid-1980s usually have design illuminance levels of 300-700 lux and typically consume between 3 and 4 W/m^2 per 100 lux. The most recent installations, at *One Bridewell Street* and *Magnus House*, with high-frequency electronic ballasts, use around 2.5 W/m^2 per 100 lux, and the twin-to-single tube conversions with high-efficiency reflectors at *Hereford & Worcester* and *Westminster* perform similarly. Some recent EMILAS award winners (for example PHH at Swindon) are below 2 W/m^2 per 100 lux. An installed load target of 2.5 W/m^2 per 100 lux therefore seems feasible for many new installations, though to meet CIBSE's new Lighting Guide LG3 (Reference 38) standards for areas with VDUs may require rather more power if the lighting is also to be attractive. As an advisory standard, we suggest that office lighting should not use more than 3 W/m^2 per 100 lux, or a maximum of 15 W/m^2 assuming that horizontal illuminance levels above 500 lux will seldom be required today owing to VDU requirements. Lower-efficiency lower-illuminance systems such as uplighting would also be permissible within the 15 W/m^2 figure. In cellular offices with good daylight, 350 lux and 10 W/m^2 would often be appropriate: the PSA suggests 9 W/m^2.

6.8.6.4 Lighting outside the general office areas often uses more energy than people think: it tends to be less efficient and to run for longer hours in places, either from necessity (as for internal corridors) or from neglect. This contrast is particularly great at *SSWC*, for example, where the energy consultants had clearly advised on workspace lighting only. But one still regularly sees overlit corridors, tungsten lighting in WCs, poor lighting controls, and batteries of tungsten and tungsten-halogen lamps in reception, lobby, conference and dining areas, where frequently efficient background lighting with a few incandescent "accent" lights at critical points would give a similar decorative effect and much lower energy and maintenance costs. High maintenance requirements of tungsten and tungsten-halogen lighting were mentioned frequently during our surveys (as were the high lamp costs, variable colour, and slow warm-up for high-intensity discharge lighting): these points seemed more important to occupiers than energy costs.

6.8.6.5 In some of the Case Studies - particularly *NFU* and *SSWC*, automatic lighting controls have successfully reduced lighting energy consumption, confirming and possibly exceeding the expectations set in Reference 40. However, although performing well against other comparable buildings, management and users saw further scope for improvement: through more user-friendly control and disconnection of the wasteful "safety" lights at *SSWC*, and finer-grained directly-addressable controls at *NFU*. The newer system at *Bridewell*, though less effective generally owing to the limited amount of daylight, was better-liked, particularly the infra-red controls which allowed partitions to be installed and rearranged at will with no wiring changes. However the manager here has also worked hard to obtain user acceptance.

6.8.6.6 Automatic lighting controls in other Case Study offices (and some alternatives which were surveyed but not chosen) fell well short of design expectations, reinforcing what seems to be a common theme: the mere presence of a system does not guarantee its effective use. Most of the difficulties related to simple human factors such as inconveniently-located controls, annoying start-up delays, incompatibility of system design with building management, and zoning too coarse for diverse requirements. Perhaps the main change since the studies and demonstrations in the early 1980s has been the VDU, which means that daylight is not always the blessing it used to be - particularly in open-planned offices - and some people will need to have their blinds down even when daylight is deemed to be excellent.

6.9 Computer rooms and their air-conditioning

6.9.1 ENERGY CONSUMPTION PATTERNS

6.9.1.1 Mainframe computers and their air-conditioning can be very substantial energy users, particularly in insurance and financial services head offices as far as the Case Studies are concerned. In related work, we have also found similar high energy use in some computer companies (not surprisingly) and in retailing headquarters. In spite of (or perhaps because of) the growth in decentralised processing power, computer suites still seem to be growing in size and in power requirement, and all three insurance installations have at least doubled over five years or less.

6.9.1.2 Figures 6.3 and 6.4 show the annual energy use in the computer room divided by the treated floor area of the building *as a whole.* Annual electricity consumption in relation to the treated area of the computer room itself ranged from 400 kWh/m^2 at *Hereford & Worcester* - a modest installation, in a large room, operated for two shifts, weekdays only - to over 5000 kWh/m^2 at *Refuge*, for a more recent, densely-packed continuously-running installation with operators, printers etc. outside the machine room. Typical year-round average cooling loads were 200-250 W/m^2, rising to 350 W/m^2 at *Refuge* for the Case Study period. Peak loads were probably only about 20% higher. *Refuge's* computer installation has recently been altered and extended: an increase of 50% in cooling load was expected, although it now seems that only a fraction of this has materialised in practice and that manufacturers' information on loads may have been high.

6.9.1.3 The proportion of the building's electricity consumption that can be used in computer rooms often comes as a surprise to building managers, though not always to their engineering staff. People intuitively seem to relate energy consumption to the physical size or electrical loading of a particular item and do not take into account the hours of use. But things left on continuously may easily run for three to ten times as long annually as other items of office equipment and building services plant.

6.9.2 ENERGY CONSUMED BY COMPUTER ROOM AIR-CONDITIONING

6.9.2.1 Within the totals, it was not always easy to separate computer and air-conditioning energy use (although Table 6.1 contains some estimates): the two are therefore shown together in Figures 6.3 and 6.4. Although sub-meters were fitted in some installations, they seldom told the whole story. For example, the original computer and air-conditioning systems at *NFU* were individually metered but some later additions were not, and at *North-West Insurance* a single meter covered supplies to both the computer suites and their air-conditioning. On average, computer air-conditioning in the Case Study buildings - including consumption by compressors, fans, pumps, humidity control and heat rejection systems - tends to require about 2 kWh to remove 3 kWh of computer room heat gain.

6.9.2.3 In looking for Case Studies we also found a number of installations where the air-conditioning was using more energy than the computer equipment itself, and the associated lighting - some using up to an estimated three times as much! These systems tended to be badly-controlled, with units poorly sequenced and sometimes fighting each other, for example simultaneously or cyclically humidifying and dehumidifying and having high fan energy requirements with too many units running all the time. Other wasteful systems (again sometimes found even in recently-completed buildings) use the same chilled water system to meet computer cooling needs (usually continuous year-round) and space cooling needs (which may occur for only 1000 or so hours per year). These systems usually had low efficiencies and high parasitic losses.

6.9.2.4 Worryingly, several of the wasteful systems seen incorporated "free cooling", using run-around coils to outside air in cold weather, and intended to save energy by reducing refrigeration requirements! In some of these the "parasitic" losses of increased fan and pumping power through the extra indoor and outdoor coils undermined the refrigeration energy savings. In two others, the refrigeration heat was rejected to the run-around circuit either as an economy measure or for heat recovery purposes, but this had two ill-effects:

i) When any compressors were in operation, the run-around circuit's water temperatures (both flow and return) increased, reducing the amount of free cooling available and making further steps of refrigeration more likely.

ii) The efficiency of refrigeration year-round was being lowered by higher condensing temperatures and additional parasitic losses in the run-around circuit and air-blast coolers.

6.9.2.5 It may well be worth doing a monitored investigation into the on-site efficiencies of computer air-conditioning systems and the scope for making worthwhile energy-saving. The rewards may be quite high, with many savings possible from good engineering, control and management of simple systems than from add-on technologies.

6.9.3 COMPUTER HEAT RECOVERY

6.9.3.1 Virtually all the energy consumed in a computer room emerges as waste heat, and in the four largest consumers the annual amount of heat rejected from the computer suite is numerically sufficient to meet the entire building's heating needs. From an engineering point of view, this is not so easy as much of the heat is not available when needed, with computers rejecting it continuously and space heating being a much more variable and seasonal load.

6.9.3.2 At NFU the computer heats the swimming pool load very economically. This is an excellent - though somewhat rare - arrangement: a pool requires heat 24 hours a day and the slow-responding system with no precise limits on temperature avoids any wasteful short-cycling of plant. At North-West Insurance, a more elaborate system meets space heating needs but at some considerable cost in both capital expenditure and parasitic losses (see paragraph 6.7.3.3) while the heat recovery and its associated fans are operated continuously during the heating season.

6.9.3.3 Maintenance staff are somewhat unhappy about computer heat recovery as it could increase the complexity and likelihood of failure of computer air-conditioning, where reliability is paramount. In principle more use could be made of very simple systems (eg: condenser air to fresh air preheat), where there is no physical connection between the computer and building systems apart from a self-balancing open plenum chamber, an approach sometimes used with refrigeration in supermarkets, where priorities are similar. Unfortunately, we found no systems of this kind in offices suitable for Case Studies.

6.9.3.4 There would seem to be more scope for simple heat recovery in offices with mainframes. However, with improvements in communications and less need for physical access to machine rooms (which are increasingly operated in darkness with peripherals requiring regular attention in a separate room), some computer suites are now moving out of expensive head office space into dedicated centres elsewhere, where land is cheaper and physical security more easily enforced. This happened at *City Atrium* shortly after our study period and some insurance companies we have spoken to recently are considering similar moves. In these dedicated installations, there may be little use for the waste heat and efficient cooling would be more important.

6.9.4 COMPUTER FREE COOLING

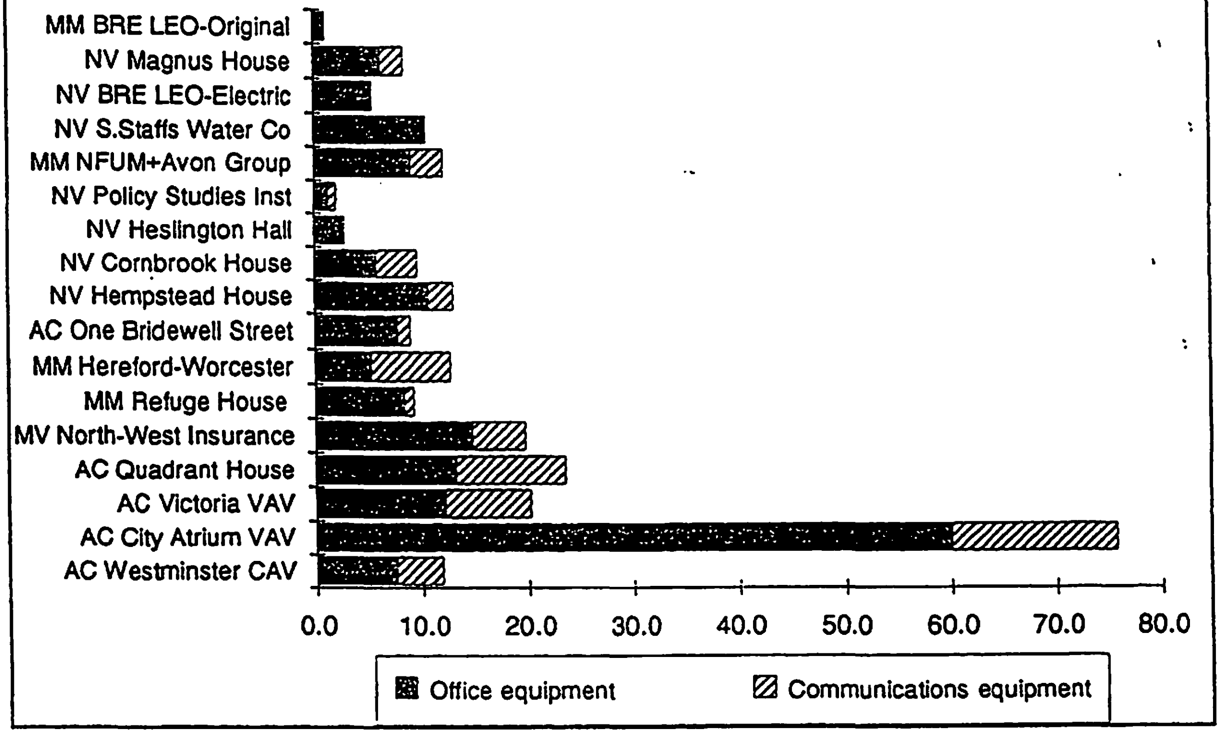
6.9.4.1 "Free" cooling of computers by outside air directly is seldom practicable owing to the high costs of additional filtration and humidity control. Run-around coils are limited in capacity and sometimes questionable in performance and cost-effectiveness as outlined in 6.9.2.4. Direct evaporative cooling through the cooling towers directly can be more effective, using either a plate heat exchanger or "Strainercycle" (Reference 41) to protect the chilled water circuit from contaminants, and effective for wet bulb temperatures below about 12°C, ie: for most of the winter and overnight as well. However, cooling towers are unpopular these days with fears of *legionella*, although in the free cooling mode itself their temperature is usually too low for propagation. A more recent innovation - "Thermosyphon" (Reference 42) has a refrigeration machine with a dry, compressor-free gravity refrigerant evaporation/condensation cycle for cold weather. All systems are better suited to large computer installations and we could find no appropriate Case Study example of Strainercycle or Thermosyphon in an office. *Refuge* originally employed plate heat exchangers, but before the maintenance staff were able to make full use of them they were set aside to make way for more refrigeration capacity.

6.9.5 CONCLUSIONS ON COMPUTER ROOMS

6.9.5.1 The amount of electricity used in computer rooms often comes as a surprise to building owners. Often it is not clear whether the computer itself is using electricity efficiently: maybe it could power itself and its air-conditioning down automatically at times of idleness - a fairly simple engineering problem but a feature customers do not yet ask for. Air-conditioning systems also frequently seem to be running uneconomically. More research and information on the subject could be very valuable, both on the performance and scope for upgrading of real systems in use, and on future ways of making computers and their air-conditioning more energy efficient.

6.10 **Office and telecommunications equipment**

FIGURE 6.9 OFFICE AND COMMUNICATIONS EQUIPMENT
Annual electricity consumption (kWh/sq m treated floor area)



6.10.1 Figure 6.9 shows the estimated annual energy use for:

- *Office Equipment.* Largely personal computers, terminals, printers, file servers, network controllers and photocopiers - within the general offices themselves. Equipment in dedicated rooms (eg: computer rooms and printing departments) is recorded separately.
- *Communications equipment.* This includes main telephone switching systems, modems, computer communications systems, dealing room systems etc., including their dedicated ventilation and air-conditioning systems where appropriate, which are neither in the general office space nor in mainframe computer rooms.

Communications is recorded separately because it is sometimes significant and sometimes non-existent (for example at *LEO*, *SSWC* and *Heslington Hall* the switching systems are in different buildings) and if included with other office equipment it can give a falsely high impression of cooling loads in the general office.

6.10.2 It should be noted that, as always, the energy use is divided by the treated areas of the buildings as a whole and does not represent the consumption in the spaces concerned. For instance, there is little or no office equipment in most receptions, main circulation and ancillary areas, conference rooms, kitchen and dining areas, atria, filing areas and many senior management offices, and the figures for equipment in dedicated rooms are separately recorded. Typically "normal" office space occupies only about 40-60% of the treated area, and to estimate the local levels of energy consumption and heat output, the quoted figures should be roughly doubled. Density of occupancy by people and machinery and hours of use also varies locally, sometimes over a wide range. Environmental engineers have not yet come fully to terms with the resulting statistical nature of heat gains (as electrical engineers do in their concepts of diversity) and can tend to design for the worst case, leading sometimes to unnecessary and over-sized air-conditioning systems. Reference 46 outlines an alternative approach, as does Energy Consumption Guide 35.

6.10.3 ENERGY CONSUMPTION BY COMMUNICATIONS EQUIPMENT

6.10.3.1 Annual energy use by communications can be unexpectedly high because most of the equipment stays on continuously. Not surprisingly, consumption is greatest at *City Atrium* where it includes the support equipment for the dealing rooms and related international communications. *Quadrant House* and *Hereford and Worcester* are high for a different reason: they both have energy-intensive first-generation electronic telephone exchanges which date from the mid-1970s, and are more on a par with mainframe computers, as is their air-conditioning. The more recent technology at *Victoria*, *Westminster* and *North-West Insurance* is nevertheless more energy-intensive than the late 1980s systems as to a lesser extent is *NFUs*. The figures include a small dealing room system at *Victoria* and network communications to branch offices at *Westminster*, *North-West* and *Cornbrook* (*NFU's* network communications are in the computer suite).

6.10.3.2 Of the remaining offices, the newer systems at *Refuge House* and *1 Bridewell Street* represent the more energy-efficient new technology for the larger office building and *PSI* for the smaller one. *Magnus House* and *Hempstead House* use more energy because they contain additional exchanges to meet tenants' needs, with *Hempstead's* (now removed) also serving some remote buildings. *Cornbrook House* includes modem communications to associated offices and a central computer facility.

6.10.3.3 While electronic telephone switching is becoming less energy-intensive, often requiring little or no air-conditioning, computer networks and their associated communications are proliferating. This is a worrying trend as far as energy efficiency is concerned, as not only is the communications equipment left on permanently, but networked office equipment connected to it is often left on as well to receive messages, which can multiply annual hours of use by factors of four and more. There is a need for equipment which goes automatically into progressively lower-energy standby modes the longer it remains on but unused. The technology is not new: such systems are already used to some extent in photocopiers and more intensively in laptop computers to avoid flattening the batteries unnecessarily, but to date there seems to have been little consumer demand for it elsewhere, although this is now changing.

6.10.4 ENERGY CONSUMPTION BY OFFICE EQUIPMENT

6.10.4.1 In the Case Studies, annual energy consumption by office equipment (installed outside dedicated equipment rooms) divides itself into four groups, which we will call low (less than 7 kWh/m^2 of the whole building per year), average (7-15 kWh/m^2 per year) and high (over 15 kWh/m^2 per year). In the following paragraphs the individual offices will be reviewed in these categories . They are classified partly by number of occupants per screen (PC, terminal, or display): although these are by no means the sole energy users, they are a useful index of IT intensity.

6.10.4.2 Low energy consumers: less than 7 kWh/m^2 of total treated floor area per year

At the lower end one finds the public sector and the more cellular offices, perhaps because:

i) Public sector offices tend to have lower IT levels than the private sector and more rigid operating hours. Intensive IT operations are often concentrated in data processing centres.
ii) The public sector offices in the Case Studies all have central computing facilities, and so have a greater ratio of terminals (with relatively low energy demands) to PCs, which use more. They also have central printing facilities for high volume copying.
iii) As with the lighting, occupants of cellular offices are perhaps more likely to switch on equipment only when they need it and to switch it off when they go away.
iv) Cellular offices are probably associated with managerial functions which tend to make less use of IT.
v) Open-planned offices can be more densely occupied and are more likely to contain batteries of information processing functions.

Typically these offices have one screen or less per three persons.

For the individual offices in the low category, in order of increasing equipment energy use:

- *BRE LEO's* low consumption originally relates to data from 1982: the refurbished office is much more characteristic of today's levels.
- *PSI* has a low intensity of use in relation to commercial offices. Their researchers are often doing other things and only switch on their equipment when they need it.
- *Heslington Hall* is surprisingly low, although it has one screen per 2 persons. This results from a low occupation density and a predominance of terminals.
- *Hereford and Worcester* is probably quite characteristic of a council office.
- *Cornbrook House* makes extensive use through terminals of central computing facilities elsewhere, with communications equipment in separate rooms and separately classified. Some staff are frequently out on site and only use office machines intermittently. The Case Study was for the year to September 1988: visiting in late 1989 the IT use had risen sufficiently to take it into the "average" category.
- *Magnus House* has a relatively low occupancy level and again with some staff regularly out on site.

6.10.4.3 Average energy consumers: between 7 and 15 kWh/m^2 per year

These offices tend to have between one and two screens for every three occupants. Again, in order of increasing consumption:

- The accountants and consultants at *Westminster* use their PCs and terminals (1:3 occupants) only intermittently. The nett:treated area ratio is also poor in this building.

- *One Bridewell Street*, also accountants, has two PCs for every three occupants, but these include newer and lower energy equipment.
- Both insurance companies, *Refuge* and *NFU* combine intensive data entry and data processing functions with lower IT professional functions. Most of the routine work uses terminals onto the mainframe, and the number of PCs and local printers is limited. Both offices also have extensive areas of non-office use, which depresses the average figure.
- *SSWC* has only one screen per three persons, but here the consumption is boosted by some computer programmers (long hours of use), mailing and cheque-sorting equipment (for the water bills) and network controllers in the offices which run 24 hours. In the other offices these are usually in separate rooms and classified differently.
- Nearly half *Hempstead House's* consumption is attributable to two minicomputer systems in the general office space which run continuously.
- *Victoria* has approximately one screen per occupant, though weighted upwards by a dealing room for one of the tenants.
- The magazine publishing at *Quadrant House* is largely PC-based, with two systems for every three occupants.
- *North-west Insurance* also has two screens for every three occupants, predominantly terminals and word processing systems, but of a rather high-energy variety and including some permanently-running communications controllers within the general offices.

6.10.4.4 High energy consumers: over 15 kWh/m^2 per year

Only one office - *City Atrium* - falls into this category, and that dramatically so, being the archetypical financial trading office with long hours of use, comprehensive electronic information systems, and dealing rooms. The dealers themselves have five or six screens each and most other people one or two. Nevertheless, equipment gains here and in most other offices are considerably lower than the levels clients and letting agents were often suggesting in the mid- to late- 1980s, typically 100-150 W/m^2 for dealing rooms and 50W/m^2 and more elsewhere. Our findings initially appeared to be heresy but the more people we spoke to the more we found were also querying the figures, as electrical maximum demands in recently completed offices often failed to approach the estimated - and often hard won - availability levels.

Office equipment at *City Atrium* is typically 5100 hours per year (average hours = total annual consumption/total average running load). With general offices accounting for about 50% of treated floor area, this equates to a mean cooling load over the 5100 hours of 60 kW (see cell R8 of Table 6.1) x 2/5100 = 23.5 W/m^2 and a peak level of say 30 W/m^2. This order of magnitude was confirmed by measuring the power consumption of two typical dealer desks, which at their highest density are installed one position per 4.5 square metres, including local circulation:

- Older desks, vintage 1985-86, with 11 screens per two persons
  260 watts per person.
- Newer desks, vintage 1988-89, with 6 screens per person
  170 watts per person.

This gave equipment gains of 60 and 40 W/m^2 respectively in the most densely occupied areas. The dealer desks themselves (excluding their backup equipment in computer and communications rooms) accounted for 25% of the building's estimated annual energy use by office equipment.

6.10.5 HEAT OUTPUTS FROM OFFICE EQUIPMENT

6.10.5.1 In the course of the Case Studies, we found that people frequently estimated equipment energy requirements not by measurement, but from nameplate data, which was often too high, creating a greater need for air-conditioning on paper than often materialised in practice. Similarly, growth rates in equipment energy requirements, although rapid, have not always been as high as predicted because newer equipment of the same type uses less energy for the same or better result, though additional equipment and higher specifications still tend to increase load densities. For example PCs can replace terminals, workstations replace PCs, laser printers replace matrix printers, large colour screens replace small monochrome ones, and - perhaps worst of all - equipment become networked and never get switched off. Although further growth is likely to occur as IT makes increasing inroads, equipment power demands may well level off (see reference 44) and could even fall as technologies advance (reference 45), potentially reducing the demand for air-conditioning.

6.10.5.2 In our surveys, we started making spot measurements of instantaneous power consumption of new pieces of equipment we encountered, and which clients allowed us to disconnect. Appendix B gives some figures. The data includes periods of high and low density operation, but not any times where the equipment was either completely off or in such a deep state of standby that it could not start immediately. There are wide variations, but as a general rule, and for a normal "basket" of office equipment, general running loads in normal use are one-third or less of nameplate levels (see figure 6.10). The main exceptions are fax machines and laser printers (around 15-20% of nameplate in our sample) and electronic typewriters and dedicated word processors (around 50%).

FIGURE 6.10 Office Equipment Power Consumption

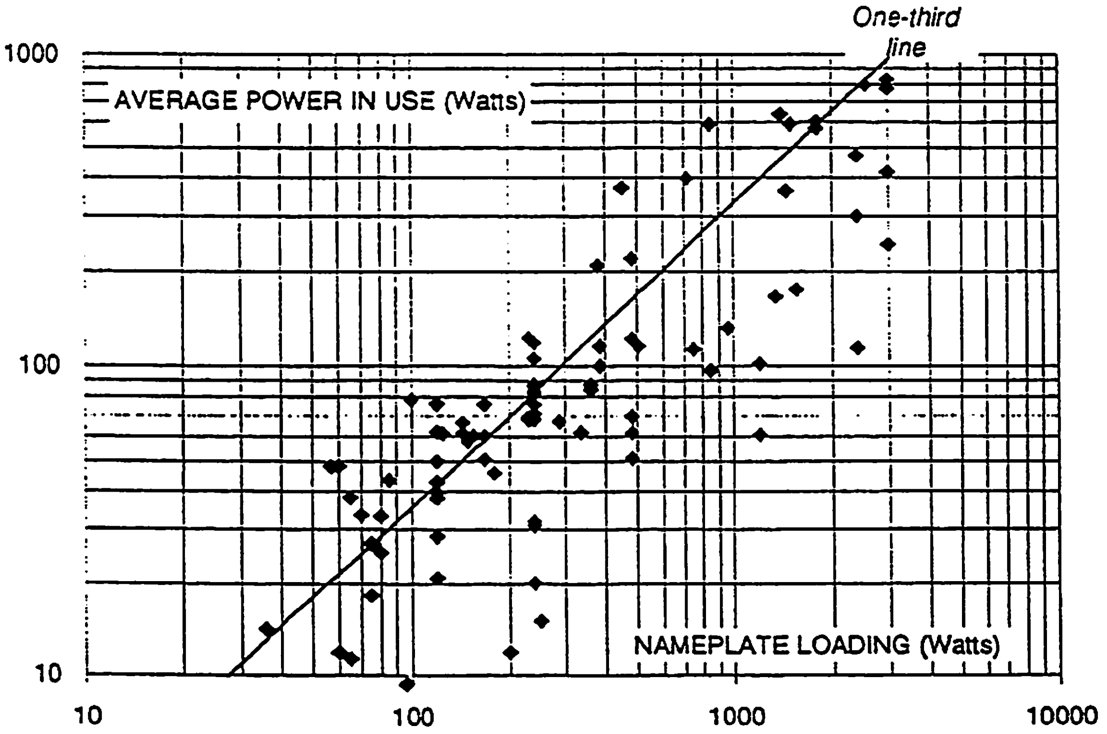


TABLE 6.4: SOME RULE OF THUMB EQUIPMENT POWER LEVELS (Watts)

ITEM	*REFERENCE 43*			*THIS STUDY: TYPICAL WHEN ON*			
	Min	*Max*	*Design*	*Min*	*Max*	*Normal*	*Comment*
VDU TERMINALS OR PC SCREENS (Normal size - big screens use more)							
Old mono VDU	50	200	140	50	120	100	
New mono VDU	25	50	40	30	40	35	
Colour VDU	-	-	-	70	90	80	*Newish*
DOT MATRIX PRINTERS							
Flat out	75	200	125	35	160	100	
Normal duty cycle	-	-	-	10	110	30	
HIGH RESOLUTION PRINTERS							
Thermal	200	800	400	-	-	-	
Laser	-	-	-	135	735	400	*Flat out*
	-	-	-	100	140	140	*Normal*
PCs INCLUDING VDU, HARD DISC, FLOPPY DISC (not 386, 486, workstation units)							
Monochrome	500	750	700	50	170	120	
TYPEWRITER							
Electric	100	220	150	-	-	-	
Electronic	56	100	90	40	75	50	*Flat out*
	-	-	-	20	45	30	*Normal*
PHOTOCOPIERS (excludes print room versions)							
Personal	-	-	-	60	160	150	*5% print*
Small	850	2000	1500	110	300	250	*10% print*
Large	2000	3500	3000	600	600	600	*30% print*
SMALL THERMAL FAX							
Flat out	50	500	150	20	75	40	
Typical rate	-	-	-	15	30	25	

6.10.5.3 Table 6.4 summarises some rule-of-thumb consumption levels, together with figures from Reference 43. Differences between the two arise partly from differences in methodology and partly because the equipment we were measuring was newer. Reference 43 gives peak figures (which would be used for electrical distribution circuiting),which are then diversified down according to occupation density etc. For our energy calculations, we prefer to diversify the figures first for the normal performance characteristics of the individual piece of equipment and subsequently for its observed daily hours of use in the particular building. The biggest discrepancy between the two sources occurs with PCs and faxes, where Reference 43's maximum and design figures are very high and must represent now very elderly equipment. For photocopiers, the large differences between connected loads and average running loads result because the heater elements - which are usually the highest-consuming component - only operate continuously on warm-up and cycle on and off thereafter and the lamps (the next highest element) operate only for parts of the copying cycle.

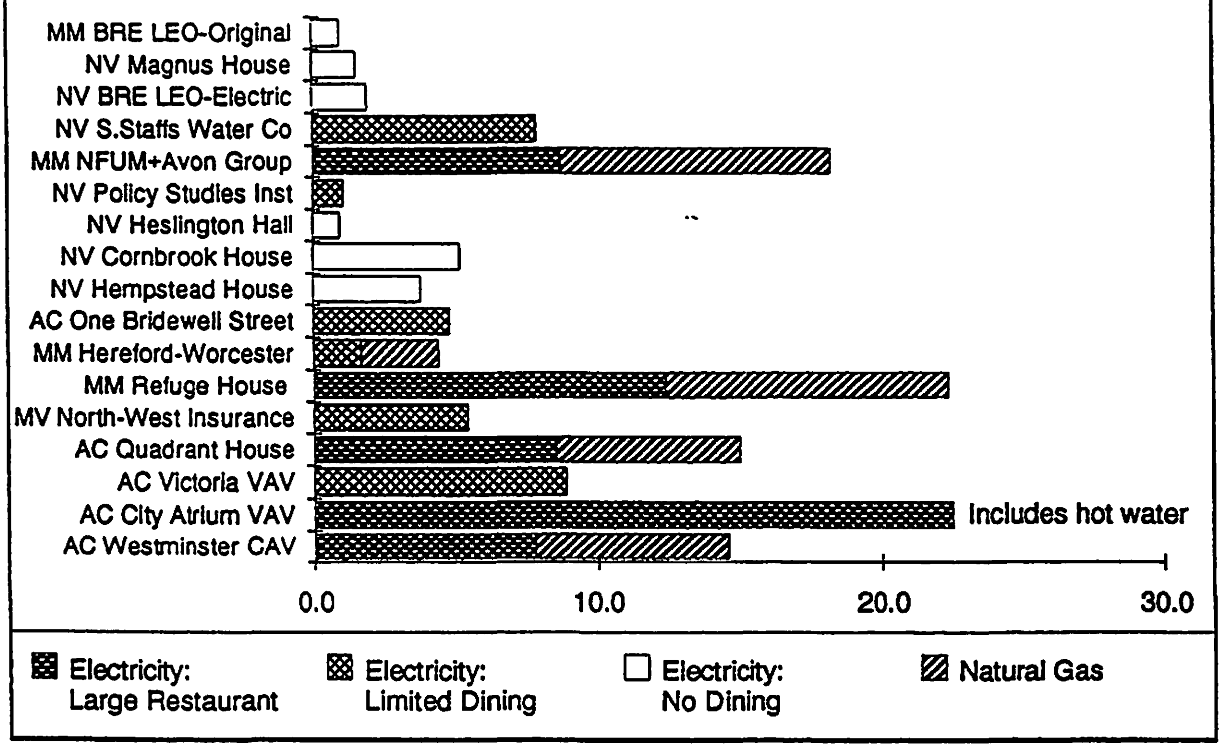
6.10.5.4 Table 6.5 gives some simplified figures for a hypothetical 200 square metre area of office with a range of occupation densities and IT-use intensities. The usage hours are averaged over all the equipment, while in practice they would be different for different items: they vary according to the patterns observed in the Case Study offices: generally the more IT there is the longer it is on, giving a geometric increase in energy consumption. It also seems that computer and engineering staff are much more likely to leave equipment on overnight (with major increases in energy consumption) than are general office staff. The results are expressed in terms of W/m^2 and kWh/m^2 per year for the areas concerned, and kWh/m^2 per year for the treated area of the office as a whole, assuming some simple ratio of office-equipment containing space to total office space. Incidentally, the figures are very similar to those suggested by W Southwood of Ove Arup Partnership verbally in 1988 - 50 W/m^2 in dealing rooms, 15 W/m2 in high-IT offices (1 screen per person) and 8 W/m^2 in general offices (1 screen/ 3 persons). Only the High-IT, mixed base (PCs and Terminals) and the Dealing room examples are above the 15-20 W/m^2 for one shift (say 3000 hours per year maximum) threshold for air-conditioning. The question for the future is, as IT grows, whether most buildings can continue to remain below the threshold, by using such techniques as energy-efficient selection of office equipment, management to minimise running hours, and removal of unwanted heat-producing equipment from the office area and unwanted heat gains at source. (*NOTE: Since completion of the Case Studies, the presence and energy use of electronic office equipment tends to have risen significantly, particularly in the low and medium energy consumers*).

TABLE 6.5

TABLE 6.5								
OCCUPANCIES AND LOAD DENSITIES IN A 200 SQUARE METRE WORKSPACE								
Typical examples excluding communications equipment etc in separate rooms								
			OFFICE INFORMATION TECHNOLOGY LEVEL:					**Dealing**
			Low	**Average:**		**High:**		**Room:**
				Largely terminals	**Largely PCs**	**Largely terminals**	**Largely PCs**	**Largely terminals**
ROOM CHARACTERISTICS:								
Number of occupants			15	22	22	25	25	40
Density m2/person in space concerned			13.3	9.1	9.1	8.0	8.0	5.0
Density m2/person of overall treated area			19.0	15.2	15.2	13.3	13.3	10.0
Screens per person			0.33	0.50	0.50	1.00	1.40	5.50
EQUIPMENT CHARACTERISTICS:								
Watts average running per item >>								
PC/WP systems:	Colour	170	1	1	5	2	5	
	Mono	120	4	1	6	1	10	20
Terminals	Colour	80		9		7		
	Mono	35				15	20	200
Printers	Impact	30	4	1	1		2	
	Laser: individual	140	1	1	3	1	2	
	Laser: shared	400				2	2	
Typewriters	Electronic	50	2	2	1	1	1	
Copiers	Small	250		0.2	0.2	1	1	
TOTALS								
Watts equipment gain			1,010	1,330	2,120	2,785	4,190	9,400
W/m2 equipment gain			5.1	6.7	10.6	13.9	21.0	47.0
Average in use hours/year			1500	2000	2000	3000	3500	5500
kWh/m2/year in area concerned			7.6	13.3	21.2	41.8	73.3	258.5
Office:treated area			70%	60%	60%	60%	60%	50%
kWh/m2 of overall treated area			5.3	8.0	12.7	25.1	44.0	129.3
SIMILAR CASE STUDY			Magnus	Refuge	Quadrant	NFU's DP	City Atrium	City Atrium
			BRE LEO			Office	Accounts	Dealing
Air Conditioning Present?			No	On demand	Yes	No	Standard	Boosted
A/C necessary for IT alone?			No	No	No	Possibly	Probably	Definitely

6.11 Catering and Vending

FIGURE 6.11 CATERING AND VENDING
Annual energy consumption (kWh/sq m treated floor area)



6.11.1 Figures 6.3 and 6.4 show that catering (including hot drinks) accounts for a small but significant part of the energy use and cost in some offices, and figure 6.11 above shows the information on a larger scale, and with some indication of the facilities provided. Essentially,

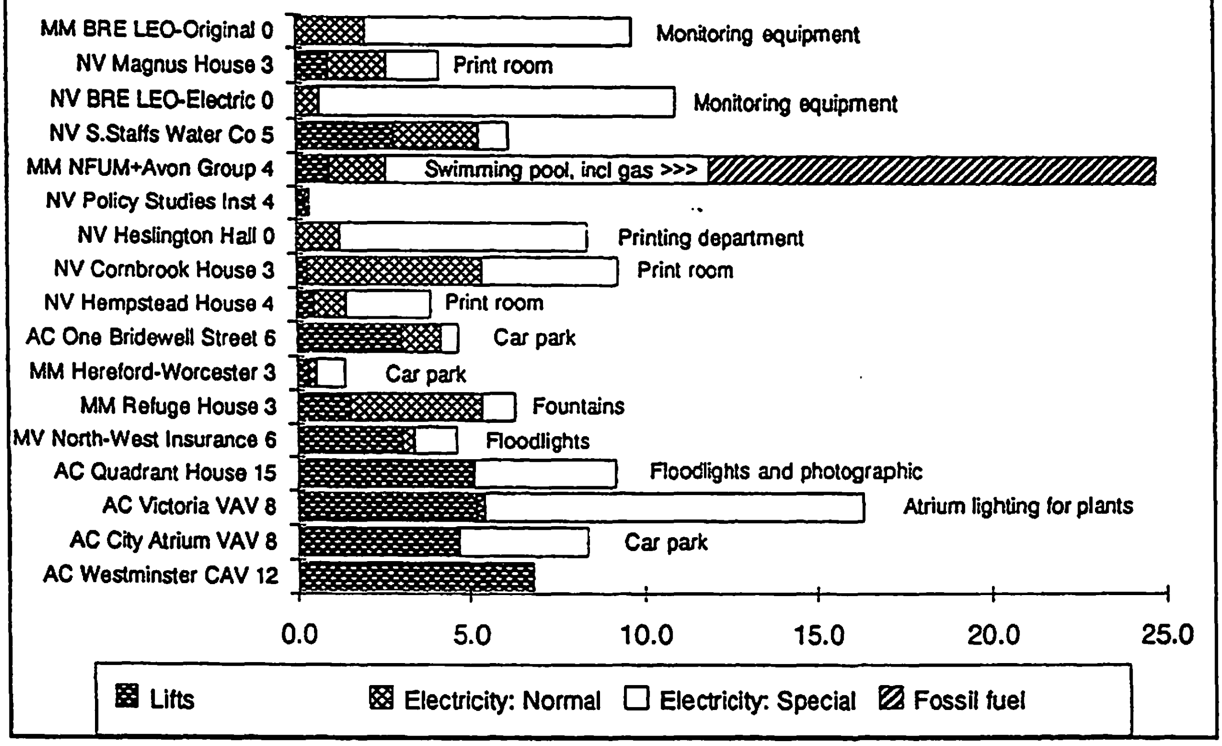
- Offices with catering kitchens and restaurants tend to use 15 kWh/m^2 per annum or more, split about equally between gas and electricity.
- Offices with sinks, kettles and the odd refrigerator and manual coffee-maker or hot water boiler use typically 1 to 2 kWh/m^2.
- The rest fell typically between 4 and 8 kWh/m^2. Those at the low end had vending machines only while those higher up had small catering kitchens for management or private dining.

6.11.2 Energy consumption by vending machines was surprisingly high, partly because they tend to stay on continuously. Several organisations (eg: *NFU*) had tried to switch them off overnight but had trouble with the ingredients congealing. *Refuge* did not have the same problems and things seem to vary with suppliers of machines and ingredients. Typical units monitored consume between 15 and 20 kWh per 24 hour day on average, the higher figures from machines which serve chilled drinks as well as hot ones, and have brightly lit display panels. With typically one machine per 1000-2000 m^2, continuously operating equipment uses between 3 and 7 kWh/m^2 per annum, or about half that by desk-top office equipment in offices with average IT levels. A greater awareness of this, plus selection of machines with lower standing losses and capable of being time-switched, would not only reduce energy waste but also internal heat gains and the need for air-conditioning.

6.11.3 The energy consumptions of catering kitchens at *NFU, Refuge* and *City Atrium* were available from sub-meters, the rest had to be determined by apportionment. No detailed work was done on the energy efficiency of the different operations, but in relation to norms in Reference 26, *NFU* seemed about average, *Refuge* rather poor and *Quadrant* rather good, probably because it has a better load factor (serving meals throughout the day rather than just at lunchtime) and with more cold meals and snacks. Kitchen equipment still seems to be operated rather wastefully with catering contractors usually receiving energy supplies "free" from their clients. Sub-metering and re-charging could create greater incentives to conserve.

6.12 Lifts and other energy uses

FIGURE 6.12 LIFTS AND OTHER USES
Annual energy consumption (kWh/sq m treated floor area)



6.12.1 Figure 6.12 shows the annual consumption for lifts and other uses: all electricity except for gas in *NFU's* swimming pool. "Normal" uses are predominantly external lighting, laboratory equipment at *LEO* and occasionally used humidifiers at *1 Bridewell Street* and *North-West Insurance* (0.6 and 0.4 kWh/m^2 per annum respectively). The main "special" use for each building is shown on the chart: primarily car park ventilation, print rooms with dye-line and photographic equipment, fountains and floodlighting, plus additional monitoring and control equipment at *LEO*, the swimming pool at *NFU*, and intense atrium lighting at *Victoria* to encourage plant growth.

6.12.2 The figures to the right of the names in figure 6.12 show the effective number of floors served by the lifts, excluding roof and basement plant rooms etc. to which there is very little traffic. *Quadrant House*, a pair of linked 11 and 21 story blocks, has been given only 15 effective floors. Lift energy consumption more or less follows floor-to-floor height with some interesting anomalies:

- Relatively high consumption at *Magnus House* because there is no central stair. People arriving at the building and using the busier centrally located rooms all therefore use the lift.

- Relatively high consumption at *SSWC* owing to the hydraulic lift, intrinsically a higher energy device as it is not counterbalanced.
- Very low consumption at *Hereford & Worcester* (and to a lesser extent at *NFU* and *Refuge*), where most of the main circulation occurs on the upper ground floor and most journeys are by stair between adjacent floors only.
- Relatively high consumption at *North-West Insurance*, where the installation is elderly, with motor/generator sets which continue to spin for extended intervals between lift calls.
- Relatively low consumption for the height of *Quadrant*, where the nature of the organisation generates little inter-floor traffic.
- Relatively high consumption at *Victoria*, where the offices start at second floor level, with initial access by lifts which also give a scenic trip through the atrium.
- Relatively low consumption in relation to the intensity of use at *City Atrium*, which uses modern electronically controlled machinery.

All lift consumption is estimated, except at *Hereford & Worcester* which has a lift sub-meter and *NFU*, *Hempstead House* and *City Atrium* where lifts share sub-meters with other plant. More detailed monitoring of lift consumption was discussed with BRECSU, but eventually did not proceed.

SECTION 7

ENERGY COSTS FOR THE CASE STUDY BUILDINGS

7 ENERGY COSTS FOR THE CASE STUDY BUILDINGS

7.1 Introduction

7.1.1 As mentioned in Section 4.6, the main focus of the Case Studies was on energy consumption not costs, which are rather variable, depending among other things upon date, magnitude of demand, supply authority, tariff, load factor and electrical demand pattern. Towards the end we began to look into costs in more detail, and this was particularly important for the EED buildings *BRE LEO Electric* and *Magnus*, where electrical maximum demand and availability charges accounted for an important part of the average costs per unit. The tariff model developed has since been applied to data from several other buildings, but not comprehensively across all the Case Studies. Some patterns have emerged which are discussed here and may be sufficient for most purposes.

7.2 Unit costs actually paid

7.2.1 Figure 7.1 shows the cost per delivered kWh for fossil fuel and for electricity over the 12 month Case Study periods. The number after the building name is the tariff year (normally April to March) in which the greater part of the energy consumption occurred. An "E" after the date indicates estimated figures for buildings which were not individually billed, but were on a larger site with a single supply point and its own internal electrical distribution system. Points of particular interest on the individual figures are outlined below.

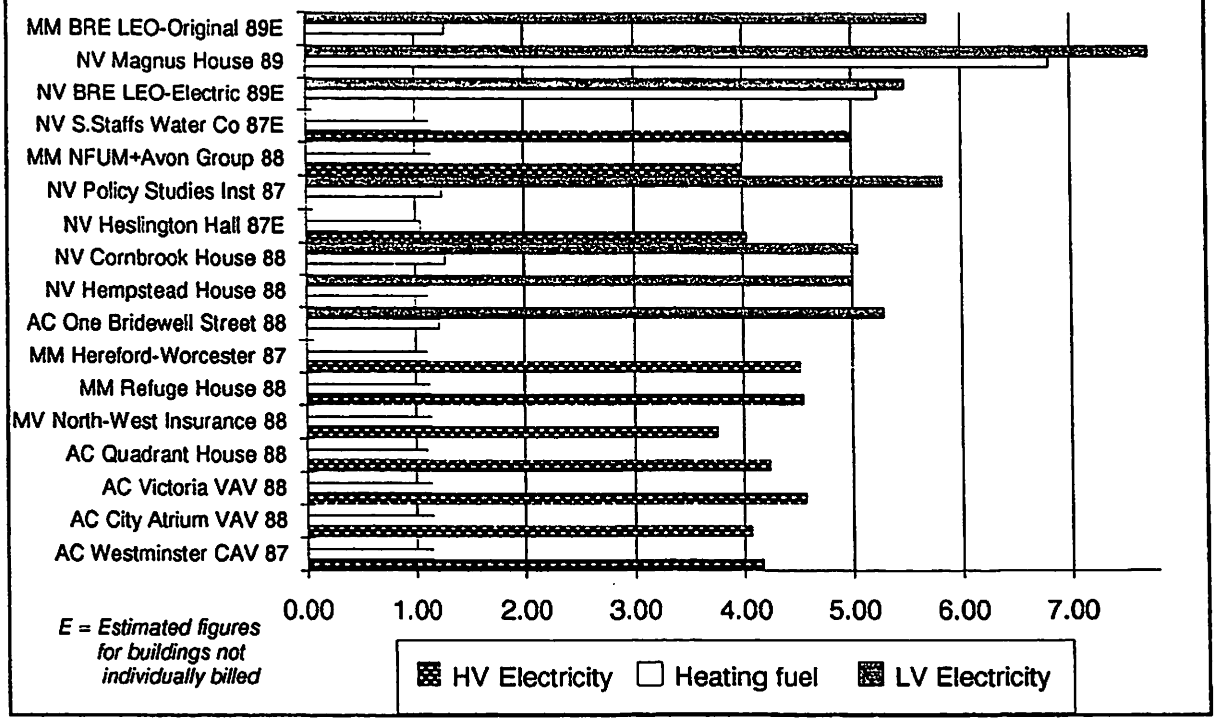


FIGURE 7.1 FUEL COSTS PER DELIVERED UNIT
Pence/kWh paid in Case Study year

7.2.2 HEATING FUEL COSTS

The cost of heating fuel, normally natural gas, was fairly constant at around 1.2 p/kWh. The main anomalies are:

- Extremely high unit costs, 6.8 and 5.25 pence/unit respectively, for EED heating at *Magnus House* and the *BRE LEO Electric*. These relate predominantly to the maximum demand and availability charges associated with the electric heating. *Magnus'* figure reflects not only South-West Electricity's tariff structure but also that the year concerned was very mild, reducing unit consumption considerably but with little or no effect on availability and maximum demand levels and charges.
- *BRE LEO* and *Magnus House* have relatively high charges because their consumption, particularly for lighting, is significantly higher in the winter months November-February, where maximum demand charges are applied. *Magnus'* are particularly high owing both to the demand pattern, the SWEB tariff, and inflation - the figures being for one year later than most of the others.
- With the highest unit charges in spite of the earlier 1987 data, *PSI* is the only Case Study building on a general purpose unit-based tariff without maximum demand charges. The unit charges on this tariff normally look expensive, but with *PSI's* low load factor, with minimal night-time and low summer consumption, a comparison suggested the tariff was appropriate.
- For the size of building, *One Bridewell Street's* relatively high charges are partly attributable to the good management which has reduced load factors. At the time, it also did not have the power factor correction equipment which was fitted in all the other large offices.

7.2.3 ELECTRICITY COSTS

7.2.3.1 Electrical unit costs are more variable, but fall into two main groups: the larger buildings with their own substations and supplied at high voltage paying on average around 4.25 pence per unit; and the smaller buildings are supplied at low-voltage and pay between 5 and 6 pence per unit. The differences originate not only in the tariffs themselves but in the larger absolute levels of consumption and usually better load factors for the larger offices. High voltage consumers also bear the costs of their transformer losses etc., typically quoted at around 1% at rated output but which could easily average 2% or more with a typical annual office load profile. In the Case Studies, the losses were not identified separately but distributed over the end-uses, which raises the electrical consumption in the larger buildings slightly in relation to the smaller ones.

7.2.3.2 *BRE LEO, SSWC and Heslington Hall*, are anomalous, being relatively small buildings - which would normally get low voltage supplies - on large sites which are metered at high voltage. While *BRE LEO's* annual costs were calculated as if it was individually supplied by Eastern Electricity, *SSWC* and *Heslington Hall* were initially given average rates per kWh paid by the site as a whole.

7.2.3.3 The pattern of unit costs for the other buildings on low-voltage supplies is explained as follows:

- *Hempstead House* and *Cornbrook House* have lower charges owing to greater hours of use of electric lighting, which spreads maximum demand and availability charges over a larger number of units, and night-time demands from computer and communications equipment, vending machines, external lighting and signs.

- *LEO* and *Magnus House* have relatively high charges because their consumption, particularly for lighting, is significantly higher in the winter months November-February, where maximum demand charges are applied. Magnus' are particularly high owing both to the demand pattern, the SWEB tariff, and inflation - the figures being for one year later than most of the others.

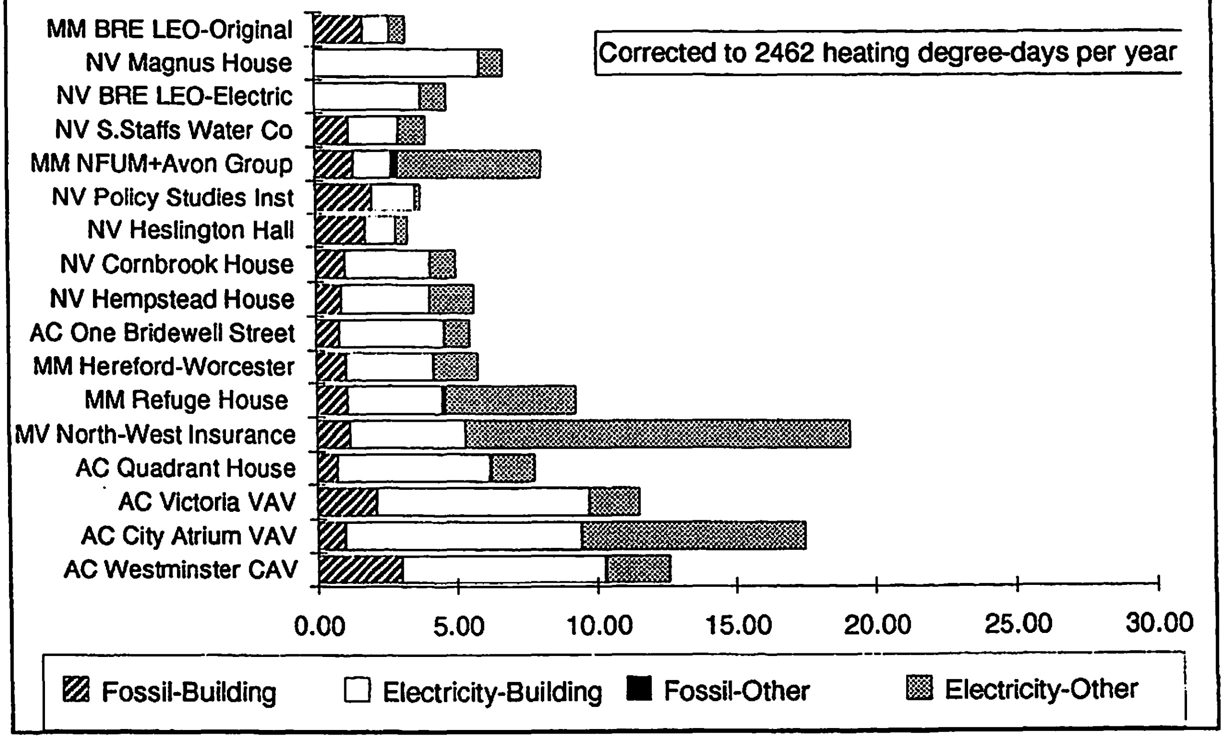
- *PSI*, with the highest unit charges in spite of the earlier 1987 data, is the only Case Study building on a general purpose unit-based tariff without maximum demand charges. The unit charges on this tariff normally look expensive, but with *PSI's* low load factor, with minimal night-time and low summer consumption, a comparison suggested the tariff was appropriate.

- For the size of building, *One Bridewell Street's* relatively high charges are partly attributable to the good management which reduced load factors. At the time, it also did not have the power factor correction equipment which was fitted in all the other large offices.

7.2.3.4 The pattern of unit costs for high voltage supplies very much reflects the load factors at the sites concerned, with the very large computer suite at *North-West Insurance*, the computer and swimming pool (and an economical day/night tariff) at *NFU*, and shiftwork and 24-hour IT systems at *City Atrium*. As mentioned above, *Heslington Hall* and *SSWC's* charges are averages for the site: their electrical demand pattern is in fact more similar to *BRE LEO Original* and *PSI*, and had they been free-standing they would have paid about 5.5 p/kWh on average.

7.2.3.5 Figure 7.2 shows the costs actually paid per square metre of treated area for fossil fuel and electricity, distributed into categories of "Building" (= normal building services) and "Other" in the ratio of annual energy for these purposes. The order of the dividing points between "Building" and "Other" follows very much the sequence of the F+3.5E index as shown in figure 2, with local charges owing to the date and tariff variations discussed above. These anomalies do not assist the side-by-side comparison of different buildings and so we sought ways of removing them, as described below.

FIGURE 7.2 ANNUAL ENERGY COSTS (£ per sq m TA)
Amounts actually paid during case study periods



7.3 Simplified 1990 fuel prices for cost comparisons

7.3.1 Tariff analyses really need to be done for the individual buildings and supply authorities concerned. However, in order to compare the energy costs of the case study buildings on a simple, standardised basis, we have estimated some representative figures, using 1990 tariffs obtained from British Gas and the Electricity Association.

7.3.2 ELECTRICAL TARIFFS

7.3.2.1 The Electricity Association initially suggested that Norweb's tariffs would be representative, but our first analyses gave fairly high figures in relation to the Case Study buildings' actual costs, and EA then suggested MEB's. For simplicity we used MEB's A1 tariff, which is available in both high and low voltage and standard and day/night tariff versions and therefore does not introduce anomalies of different charging philosophies.

7.3.2.1 Electrical tariffs suitable for most office buildings have several components :

1 Unit charges per kWh, which can be lower at night (usually 0030 to 0730 hours).

2 Maximum Demand (MD) charges per kW or kVA, for the maximum amount of electricity drawn in any 30-minute period during the month. Typical MD charges are around £6.50 per month in December and January, £2.50 per month in November and February, and zero at other times. Sometimes, MD charges are only levied on electricity consumed between 0800 and 2000 Monday to Friday, allowing off-peak electricity to be used for special purposes without incurring punitive demand charges.

3 Availability charges, per kW or kVA, for the "declared capacity" of supply. This must always be higher than any MD and is sometimes available only in steps, eg 2500, 3000, 3500 kVA. Costs are typically around £1.00 per month. For new buildings, the declared capacity initially requested prevails for the first five years. For offices, it is not unknown for this to exceed the actual peak MD by factors of two to four.

4 Monthly standing charges, typically around £25 for low-voltage and £75 for high-voltage supplies.

5 Reactive power charges if the power factor falls, usually below 0.9.

7.3.2.3 In round figures, standardised 1990 costs (p/kWh of electricity) for various types of office are :

A High voltage supply, high load factor, day/night MD tariff 5.0
This would apply to buildings with high out-of hours use, such as *City Atrium* and large, continuously-operating computer rooms etc as at *NFU*, and *North-West Insurance.*

B High voltage supply, average load factor, standard MD tariff 5.5
This applies to *Hereford & Worcester*, *Refuge House*, *Quadrant House* and *Victoria.*

C Low voltage supply, average load factor, standard MD tariff 6.0

This applies to *Cornbrook House*, *Hempstead House* and *One Bridewell Street*

D Low voltage supply, low load factor, electric heating, day/night MD tariff 6.0
The refurbished *BRE LEO Electric* and *Magnus House*

E Low voltage supply, low load factor, standard MD tariff 6.5
SSWC, *Heslington Hall* and *PSI.*

MD and standing charges account for typically 10-15% of the total costs in Group A, 15-20% in Groups B and C and 25-30% in Groups D and E.

7.3.2.4 These price levels above are in very similar steps to those actually paid during the Case Study years (see figure 7.1), but typically around 1 p/kWh higher after two years' inflation and not including the benefits of special tariffs on some of the sites. The greater increases for *SSWC* and *Heslington Hall* result from choosing the rates appropriate to buildings of this size and load profile being supplied individually. With electricity privatisation, the largest buildings on high voltage supplies would often have been able to obtain lower rates by negotiation. Rates A and B take some account of this, with the stated figures about 0.2 p/kWh below the calculated levels.

7.3.3 GAS TARIFFS

The tariffs given to us by British Gas include the infamous step which allowed consumers of around 25000 therms per year to save money by burning more gas. Typical 1990 costs for fixed price contracts, including standing charges and seasonal pricing factors, are around 1.2 p/kWh for large consumers and 1.4 p/kWh for small consumers, respectively well above and well below the 25000 therm level. *Heslington Hall*, which was near the dividing line but also benefited from dual fuel flexibility, has also been given the 1.2p rate.

FIGURE 7.3 ANNUAL ENERGY COSTS (1990 £ per sq m TA)
at standardised cost levels applied equally to all buildings

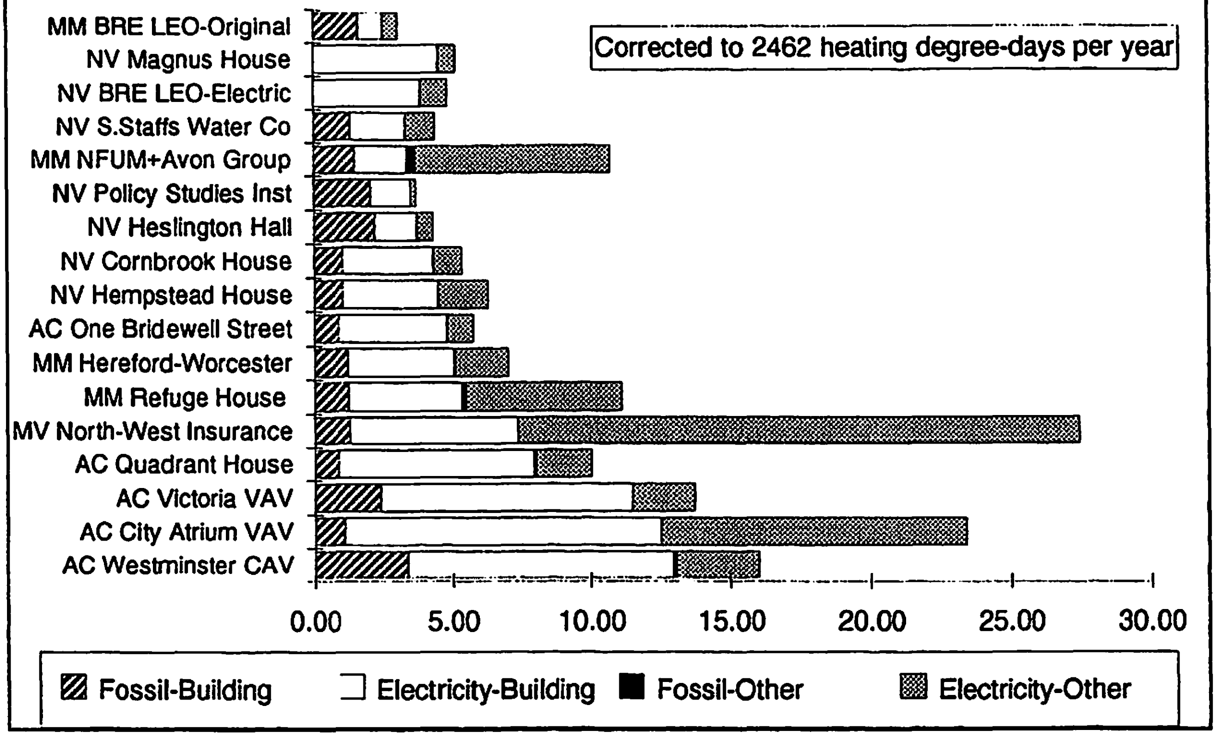
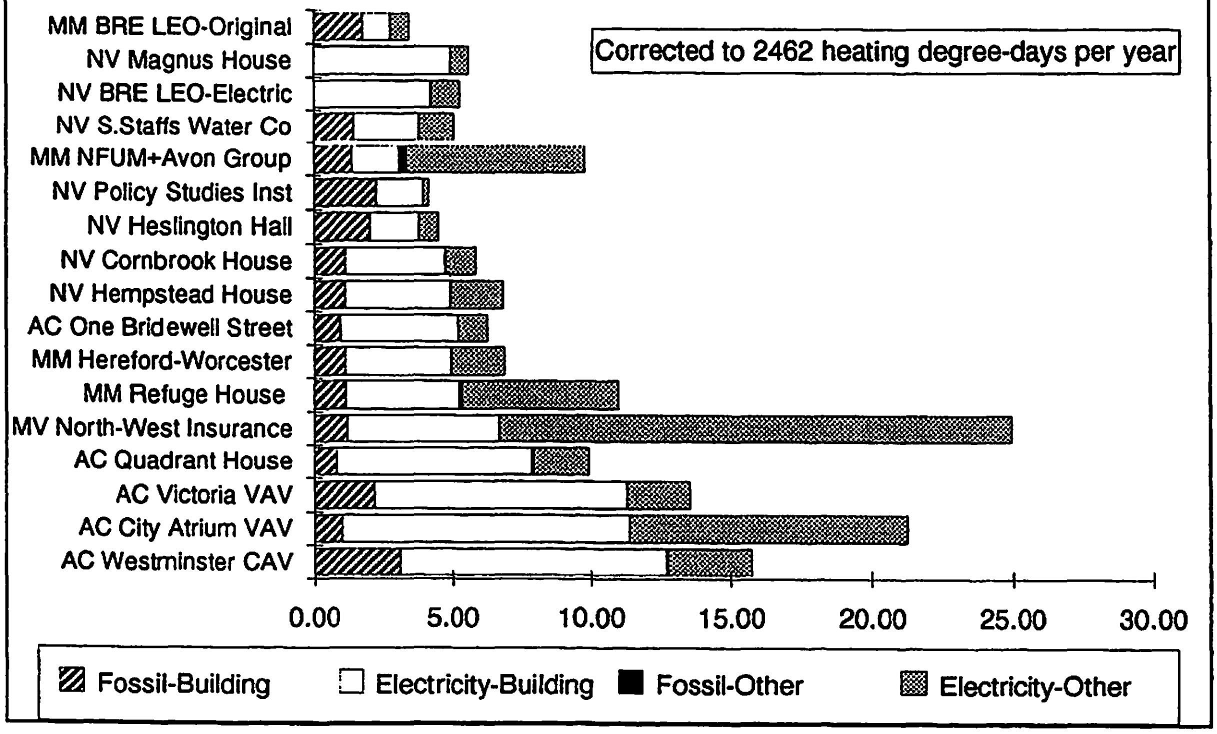


FIGURE 7.4 ANNUAL ENERGY COSTS (1990 £ per sq m TA)
at standardised cost levels related to building size and demand



7.4 Application of the simplified fuel prices

7.4.1 Figure 7.3 shows the buildings in order of simple, standard level unit costs (£/m^2 TA per year) of 5.5 p/kWh for all electricity, and 1.3 p/kWh for all gas. Figure 7.4 shows the same thing but using the incremental steps from section 7.3 above: this makes very few changes in ranking and gives a pattern closer to that of the actual energy costs in figure 2. *NFU* is anomalous, as the relatively high and constant computer room consumption depresses the average electrical unit price.

7.4.2 Table 7.1 shows that there is very little difference in ranking order, first discussed in Section 6.3, between the F+3.5E index used in Chapter 6 and the various costing assumptions discussed here. But for the anomaly of *Magnus House*, buildings seldom move more than one place away from their position under the F+3.5E rating. We therefore suggest that in published material, either F+3.5E or very simple energy costs are used, with footnotes on the effects of building size, method of electrical intake, and load factor on the amounts individuals will actually pay.

TABLE 7.1

RANKING ORDER OF OFFICES, COST VERSUS F+3.5E

Delivered energy per	ALL ENERGY CONSUMPTION:					NORMAL BUILDING SERVICES ONLY:				
unit treated floor area.	F+3.5E	Actual	1990 standardised costs:			F+3.5E	Actual	1990 standardised costs:		
Degree-day corrected.	Index	costs	Uniform	Variable		Index	costs	Uniform	Variable	
AC Westminster CAV	15	15	15	15		17	17	17	17	
AC City Atrium VAV	16	16	16	16		16	15	16	16	
AC Victoria VAV	14	14	14	14		15	16	15	15	
AC Quadrant House	11	11	11	12		14	14	14	14	
MV North-West Insurance	17	17	17	17		13	12	13	13	
MM Refuge House	13	13	13	13		12	10	12	12	
MM Hereford-Worcester	10	9	10	10		11	9	11	10	
AC One Bridewell Street	8	7	8	8		10	11	10	11	
NV Hempstead House	9	8	9	9		9	7	9	8	
NV Cornbrook House	7	6	7	7		8	8	7	7	
NV Heslington Hall	4	2	3	3		6	3	5	5	
NV Policy Studies Inst	2	3	2	2		5	5	4	4	
MM NFUM+Avon Group	12	12	12	11		3	2	3	2	
NV S.Staffs Water Co	3	4	4	4		2	4	2	3	
NV BRE LEO-Electric	5	5	5	5		4	6	6	6	
NV Magnus House	6	10	6	6		7	13	8	9	
MM BRE LEO-Original	1	1	1	1		1	1	1	1	

7.5 Electrical costs of individual items

7.5.1 The relevant unit costs do not only vary with building, but also with individual item. Figures can vary substantially according to use pattern, inflating the unit costs of items - like restaurant dishwashers and particularly humidifiers - which tend to be used for short periods at peak times, and reducing those - like comfort cooling chillers - which often do not run at all in the months where MD charges apply. Similarly, equipment which operates continuously, particularly computer rooms, communications and vending machines have low average unit costs, while things like lighting, fans and office equipment, - whose hours of operation are normally characteristic of the use of the building as a whole - are usually close to buildings' unit electricity cost levels.

7.5.2 The tariff model developed could be applied more widely. Although several analyses were done, it was not within the scope of the project to assign costs to individual items in consistent detail: within the overall totals the results are dependent on methodology and assumed demand patterns. For example, in EED buildings, MD tends to occur at switch-on in the early-morning, when only the heating and any overnight uses are on. Subsequently, the building warms-up and internal gains replace the heating. One could therefore say that all the MD charge should be apportioned between heating and overnight loads, with everything else fitting into the subsequent trough, which would make the electric heating look very expensive. The best way in this instance was to calculate charges on most appropriate tariffs for the building as a whole, with and without electric heating, and attribute the difference to the costs of the heating. A "fair" MD figure was then inserted for heating to give the same total costs on the tariff actually used, and the remainder re-assigned to other uses.

SECTION 8

PERFORMANCE YARDSTICKS FOR TYPICAL OFFICES

8 PERFORMANCE YARDSTICKS FOR TYPICAL OFFICES

8.1 Introduction

8.1.1 The Case Studies, although only a small sample, give real benchmarks of what can be achieved in practice. They also show the extent to which overall energy use and cost can vary between offices that are good of their individual kinds, at least in parts. We have also collected a large amount of background information on energy use in UK offices generally. This chapter suggests some practical guidelines for possible use in Best Practice programme literature: these employ rounded figures on energy consumption and cost in order to describe the situation straightforwardly. *(NOTE: This information has now been published in Energy Consumption Guide 19: Energy Efficiency in Offices: A technical guide for owners and single tenants, October 1991).*

8.2 Facts and fallacies

8.2.1 A number of fallacies are still at large, which need to be exposed. The most important of these are:

1 A high energy consumer is a poor and inefficient building. Not necessarily. The energy may be used legitimately, as in computer rooms. Special areas like this should be separately metered to provide the necessary management information: usually they aren't.

2 It is important to minimise delivered energy consumption of gas, oil and electricity. It is usually more important to minimise delivered energy costs and environmental impact. For most comparisons of buildings and priorities, a simple and practical way to take account of this is the 'F+3.5E' index. Ultimately, however, costs and benefits need to be related to the individual circumstances of the building and the fuels and tariffs concerned.

3 *Heating is the priority area.* In fact, this only applies for older buildings with poor insulation, plant, controls and management, and limited electricity use, eg: buildings with largely cellular offices, good natural lighting, and limited amounts of computer and catering equipment. (NOTE: Many public sector offices fall - or used to fall - into this category). In most other offices, electrical costs exceed heating costs.

4 *Yes, but growth in electricity consumption is inevitable with more information technology.* While rapid growth in desk-top IT is undeniable, the proportion of electricity use it accounts for can still be quite small. Large savings are often possible by attention to lighting, HVAC systems and controls (for computer and equipment rooms, as much as for general building services), and to the selection and use of the office equipment itself. Things which keep running for 24 hours per day (eg: computer rooms, vending machines, and communications equipment), need particular attention, and tendencies to leave electronic office equipment on overnight should be resisted unless this is functionally essential. *(NOTE: it was interesting that many high-technology computer and aerospace companies visited switched off supplies to all their desk-top equipment centrally overnight, for safety and security reasons).*

5 *Better insulation is the key to saving heat.* At one level, this is undoubtedly true. Good insulation and double-glazing has helped reduce the heating energy consumption of many of the Case Study offices to 100 kWh/m^2 or less, as against national stock averages of about twice this level, as reviewed in Chapter 2. However, progressing beyond current Building Regulations levels (with the double-glazing which is now commonplace in offices) can yield disappointing returns unless heating systems are well-designed, controlled and managed to avoid waste. It is important to see the

building as a complete thermal and human system and to balance one's attention between all the elements.

6 *In air-conditioned buildings, saving on refrigeration should be the priority.* In many air-conditioned offices, outside air provides much of the cooling and the main HVAC chillers run for 1000 hours per year or less. Annual fan energy consumption is often the more important. Refrigeration is a greater priority for continuously running systems, as in computer rooms, but here too it is also important to look at overall energy consumption, including fans, pumps and humidity controls, and not solely the refrigeration aspects.

7 *Technology is the key.* The case studies, and even more so many buildings rejected along the way, suggest that technological solutions can be over-rated, particularly those which require a sophisticated level of specification, installation, commissioning, management and maintenance skills, and those which are installed for energy saving purposes only, without giving other perceived benefits. It is a good idea to aim to use no more maintenance-intensive technology than absolutely necessary to meet client requirements and to do the job efficiently. Hence consider high-efficiency boilers before heat recovery systems; energy efficient lights before automatic lighting controls; shading by orientation, insulating windows before constructionally-difficult superinsulation; fixed and manually-controlled solar shading devices before automatic ones. Add-on technology also tends to consume small but significant amounts of electricity, which can cut into the expected savings - particularly in circumstances where the benefits are only seasonal while the electrical overhead may continue year-round.

8 Occupants mess up energy-saving strategies. The lowest-energy offices tend to make good use of natural light and ventilation under individual control, perhaps with some automatic or managerial assistance. Individual control also widens the envelope of personal tolerance, reducing people's dependency upon finely-tuned systems to deliver the goods and hence energy costs: and surveys indicate that greatest dissatisfaction occurs where no perceived local control is available. People also tend to be the best judges of what they need: systems should therefore be designed more for manual ON/ auto OFF or standby.

8.3 Major variables affecting energy use

8.3.1 A wide range of variables determines the energy use pattern of an office building. Of these, perhaps the most important are listed below. Climatic variables are also significant, though often less so than operational ones.

1 *The presence of a computer room.* This not only consumes its own energy, normally 24 hours a day, but brings people into the building outside normal hours. It also tends to be associated with more IT generally, though not necessarily extra energy consumption at the desk-top if "dumb" terminals are used instead of PCs.

2 *The presence of air-conditioning.* This not only consumes its own electricity (typically 70-100 kWh/m^2 or more for fans, pumps and refrigeration together), but can also be correlated with more IT, more artificial lighting, more intensive building use, and other energy-consuming features such as catering kitchens and lifts.

3 *Open versus cellular office planning.* Open-planned offices tend to have higher light levels, and have all the lights on for more than the working day unless daylight and lighting controls were very carefully considered.

4 *Date of construction.* Older buildings tend to use considerably more heat but often significantly less electricity. The higher cost of the latter often results in lower overall

energy costs than many recently completed offices, which often depend more on artificial lighting and mechanical ventilation.

5 *Level of management.* Management consultants have always claimed that energy-efficiency is as much if not more a management than a technical problem. This project bears this out: some of the older buildings had made dramatic savings largely through management measures, while in some newer ones the energy-efficiency potential had not been fully realised, sometimes because the systems were over-complicated and not user-friendly. As well as better management, buildings need to be designed to avoid putting unnecessary demands on the management itself. Electronic systems are only part of the solution: they can easily be too complicated, obscure or time-consuming themselves, particularly if they transfer to central management tasks (like perhaps switching-on ventilation in a meeting room), which could often be performed more easily and energy-efficiently by the users themselves, using interval timers for instance.

6 *Pattern of use.* A few offices are intensively-occupied outside normal hours. Most aren't, and to make standard corrections for hours of occupancy is in our experience more likely to conceal unnecessarily high hours of plant operation than to be a helpful normalising technique.

8.4 What targets should be set?

8.4.1 The number of variables present suggest that it would be preferable to set individual targets for each building, working through a decision-tree of questions about important features such as building size, location, construction, presence of computer suite, etc. This would be too complicated for most people to consider doing by hand: a PC disc-based version would be preferable. Possibilities are now under study by BRE.

8.4.2 Meanwhile, as a simple and direct way of putting the ideas and numbers across for publications in the Best Practice programme, we suggest using four distinct types, with simple graphic icons to represent them. The four proposed types are, in order of increasing energy costs:

TYPE 1 NATURALLY-VENTILATED CELLULAR

This is typical of the small, cellular offices, such as *BRE LEO* and *Magnus House*. Lighting is the largest single electricity user, and even this is fairly low.

TYPE 2 NATURALLY-VENTILATED OPEN

This is typical of the rather larger speculative office building. Its much higher lighting energy consumption differentiates it most from Type 1. These offices tend to have more mechanical ventilation, office equipment, vending machines etc., and so the figures have been increased accordingly.

TYPE 3 AIR-CONDITIONED

These buildings tend to be rather larger still, deeper plans, tinted glass etc., requiring yet more artificial lighting. However, the main increase is from the air-conditioning plant, with further contributions from office equipment, catering, and other uses such as lifts, external lighting and car park services. Two examples have been calculated: TYPE 3 with all-air (eg: VAV) air-conditioning and TYPE 3A with air-water (fan-coils etc.). However, the differences between the two seem to be too small to make them worth identifying as separate building types in guidance literature.

TYPE 4 PRESTIGE AIR-CONDITIONED

This is more of a Head Office type of building, with restaurant, computer room etc., and some consequent increase in hours of operation of building systems. On the other hand, these buildings are likely to be better managed than the others, so the increases for HVAC and lighting are relatively small.

8.4.3 ENERGY USE PROFILES OF TYPICAL OFFICES

8.4.3.1 Table 8.1A shows profiles of energy use (on the left) and cost (on the right) for a typical example of the four types of office in the existing building stock. Fossil-fuelled heating and hot water is assumed and the figures have been related to background material in our possession, from energy surveys etc. Rounded figures have been input into the table on the top left (cells A5 to F20) and then proportioned int the two tables below by the area ratios in rows 23 and 40 and the landlord/tenant split in column G.

8.4.3.2 To get the energy costs in the three right-hand tables, the energy figures in the three left-hand ones have been multiplied by the typical rounded fuel costs in rows 19 and 20, taken from Section 7.3. The totals (excluding office equipment etc. where appropriate) relate fairly consistently to the "average" of "fair" levels discussed in Chapter 2, and we suggest that these profiles could be regarded as characteristic of "typical" offices.

Table 8.1A

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**TABLE 8.1A**	**ENERGY USE AND COST PROFILES FOR TYPICAL OFFICES**											
2													
3		**BUILDING TYPE**					%		**BUILDING TYPE**				
4	**kWh/m2 gross**	1	2	3A	3	4	Land	**p/m2 gross**	1	2	3A	3	4
5	HEATING FUEL:						lord	HEATING FUEL:					
6	Heating and hot water	190	190	200	200	220	100%	Heating and hot water	266	266	240	240	264
7	Catering gas	0	0	0	0	12	0%	Catering gas	0	0	0	0	14
8	ELECTRICITY:							ELECTRICITY:					
9	Refrigeration	0	0	45	30	35	100%	Refrigeration	0	0	248	165	175
10	Fans, pumps, controls	3	6	30	55	60	100%	Fans, pumps, controls	20	36	165	303	300
11	Lights	25	50	60	60	70	25%	Lights	163	300	330	330	350
12	Office equipment	10	15	20	20	25	0%	Office equipment	65	90	110	110	125
13	Computer room	0	0	0	0	90	0%	Computer room	0	0	0	0	450
14	Catering electricity	3	5	7	7	12	0%	Catering electricity	20	30	39	39	60
15	Other	5	5	10	10	15	75%	Other	33	30	55	55	75
16	TOTALS	236	271	372	382	539		TOTALS	565	752	1186	1241	1813
17	Total Heating:	190	190	200	200	232		Total Heating:	266	266	240	240	278
18	Total Electricity:	46	81	172	182	307		Total Electricity:	299	486	946	1001	1535
19	*Typical fossil p/kWh*	*1.4*	*1.4*	*1.2*	*1.2*	*1.2*							
20	*Typical elec p/kWh*	*6.5*	*6.0*	*5.5*	*5.5*	*5.0*							
21													
22	**kWh/m2 treated**	1	2	3A	3	4		**p/m2 treated**	1	2	3A	3	4
23	Treated:gross area	95%	95%	90%	90%	85%		Treated:gross area	95%	95%	90%	90%	85%
24	HEATING FUEL:							HEATING FUEL:					
25	Heating and hot water	200	200	222	222	259		Heating and hot water	280	280	267	267	311
26	Catering gas	0	0	0	0	14		Catering gas	0	0	0	0	17
27	ELECTRICITY:							ELECTRICITY:					
28	Refrigeration	0	0	50	33	41		Refrigeration	0	0	275	183	206
29	Fans, pumps, controls	3	6	33	61	71		Fans, pumps, controls	21	38	183	336	353
30	Lights	26	53	67	67	82		Lights	171	316	367	367	412
31	Office equipment	11	16	22	22	29		Office equipment	68	95	122	122	147
32	Computer room	0	0	0	0	106		Computer room	0	0	0	0	529
33	Catering electricity	3	5	7	7	14		Catering electricity	21	32	43	43	71
34	Other	5	5	11	11	18		Other	34	32	61	61	88
35	TOTALS	248	285	413	424	634		TOTALS	596	793	1319	1380	2134
36	Total Heating:	200	200	222	222	273		Total Heating:	280	280	267	267	328
37	Total Electricity:	48	85	190	201	361		Total Electricity:	316	513	1052	1113	1807
38													
39	**kWh/m2 nett**	1	2	3A	3	4		**p/ft2 nett**	1	2	3A	3	4
40	Nett:treated area	80%	80%	80%	80%	80%		Nett:treated area	80%	80%	80%	80%	80%
41	HEATING FUEL:							HEATING FUEL:					
42	Heating and hot water	250	250	278	278	324		Heating and hot water	33	33	31	31	36
43	Catering gas	0	0	0	0	18		Catering gas	0	0	0	0	2
44	ELECTRICITY:							ELECTRICITY:					
45	Refrigeration	0	0	63	42	51		Refrigeration	0	0	32	21	24
46	Fans, pumps, controls	4	8	42	76	88		Fans, pumps, controls	2	4	21	39	41
47	Lights	33	66	83	83	103		Lights	20	37	43	43	48
48	Office equipment	13	20	28	28	37		Office equipment	8	11	14	14	17
49	Computer room	0	0	0	0	132		Computer room	0	0	0	0	61
50	Catering electricity	4	7	9	9	18		Catering electricity	2	4	5	5	8
51	Other	7	7	14	14	22		Other	4	4	7	7	10
52	TOTALS	311	357	516	530	793		TOTALS	69	92	153	160	248
53	Total Heating:	250	250	278	278	341		Total Heating:	33	33	31	31	38
54	Total Electricity:	61	107	238	252	451		Total Electricity:	37	59	122	129	210
55	*LANDLORD TOTALS*	*267*	*279*	*413*	*427*	*506*		*LANDLORD TOTALS*	*43*	*49*	*100*	*107*	*121*
56	*Landlord Fossil*	*250*	*250*	*278*	*278*	*324*		*Landlord Fossil*	*33*	*33*	*31*	*31*	*36*
57	*Landlord electricity*	*17*	*29*	*135*	*149*	*182*		*Landlord electricity*	*10*	*16*	*69*	*76*	*85*
58													
59	LANDLORD DELIV %:	86%	78%	80%	81%	64%		LANDLORD% COSTS	62%	53%	65%	67%	49%
60								Of fossil costs	100%	100%	100%	100%	95%
61								Of electricity costs	28%	27%	57%	59%	40%
62													
63													
64	*TYPE 1*	*Naturally-ventilated, cellular, small*						1 ft2 =	.0929	m2			
65	*TYPE 2*	*Naturally-ventilated, open plan, small*											
66	*TYPE 3A*	*Air/water air-conditioned, medium*											
67	*TYPE 3*	*All-air air-conditioned, medium*											
68	*TYPE 4*	*Air conditioned, including computer centre, canteen etc., large*											

8.4.4 ENERGY USE PROFILES OF GOOD PRACTICE OFFICES

8.4.4.1 Table 8.1B shows the same thing for an office to good current practice, where the figures are related to those attained or attainable by reference to the Case Studies, with some allowance for advances in lighting technology since many of these offices were designed and built, and for some growth in office equipment since the survey periods. The same fuel costs are also assumed, though strictly they would be likely to go up slightly, owing to the lower demands and often peakier electrical load profiles of lower-energy buildings.

8.4.4.2 Comparing the treated area table (in the centre left of Table 8.1B) with Table 6.1 (the Case Study data) we find:

Row 93	*Heating and Hot Water.* Most of the newer case study offices operate within the suggested levels, or could if they had no other alteration but high-efficiency gas boilers. Some offices with high internal gains are far lower, but research work at BRE LEO suggests that even in small offices with low internal gains the estimated levels are quite readily achievable.	
Row 94	*Catering Gas.* Some of the Head Offices use more than the targets but here savings could be made relatively easily by improved kitchen management.	
Row 96	*Refrigeration.*	
	Type 3	*1 Bridewell Street* is within the estimate.
	Type 3A	The estimate is perhaps rather tight, with *Quadrant House* using about 40% more in spite of its good management. However, the mixed-mode *Refuge* has fan-coils throughout and sails through easily, so we do not think the standard should be too lax.
	Type 4	*City Atrium* approaches this estimate, in spite of its long hours of use and high internal gains, so a more liberal estimate cannot be justified.
Row 97	*Fans, pumps & controls*	
	Types 1+2	Requirements vary, and the allowance is fairly arbitrary.
	Type 3	*1 Bridewell Street* meets this requirement, but considerable attention will be required to fan power and operation in the other offices to meet it. Low fan power does not seem to have been as much of an engineering priority as we feel it should be, and we therefore consider that a tight standard is justifiable.
	Type 3A	*Quadrant House* and *Refuge House* are within this estimate.
	Type 4	As for Type 3, the estimate is tight for all-air systems but not unreasonable in view of the achievement at *1 Bridewell Street*. *City Atrium* also approaches this level after allowing for its extended running hours.
Row 98	*Lighting*	
	Type 1	*BRE LEO* and *Magnus House* are already below this level. Although their intensity of occupation is relatively low, it would not be difficult in practice to reduce installed lighting power in these two offices by 30-40%, giving sufficient headroom.
	Type 2	Although the two most typical offices of the type: *Hempstead House* and *Cornbrook House* exceed this level, their lighting offers considerable scope for improvement. *NFU* and *SSWC*

		already perform well below this level, though their window and control systems are fairly elaborate.
	Type 3/3A	The standard is met at *1 Bridewell Street.*
	Type 4	Although tight, the standard could be met by applying a *1 Bridewell Street* approach to a prestige office, where high-frequency fittings and good controls should be affordable.
Row 99	*Office Equipment*	The same allowances are made as for the "typical" buildings.
Row 100	*Computer Room*	A reduction has been made for more efficient air-conditioning and lighting only.
Row 101	*Catering*	Improvements include kitchen management and selection of lower-energy vending machines, where appropriate.
Row 102	*Other*	20% savings are proposed from more efficient systems: outside lights, lifts, etc.

8.3.4.3 Table 8.2 below shows the percentage savings potential from moving from "typical" to "good practice for the various office types. Reductions from average levels of over 50% in fossil fuel consumption and 25-35% in electrical consumption are possible using existing technology and without resorting to advanced features, with total money savings around 30-40%. With current Building Regulations, much of the heating fuel savings will normally be achieved in any event, but the electrical side still offers good scope for savings.

8.3.4.4 Further savings are possible if all or part of the office can be moved down a type. For example, the mixed-mode offices at *NFU, Hereford & Worcester* and *Refuge* are in the Type 4 class but embody some features of Type 2 and 3 buildings, and their annual energy costs reflect this in some areas.

	A	B	C	D	E	F	G	H	I	J	K	L	M
137	TABLE 8.2	RATIOS OF GOOD PRACTICE TO AVERAGE OFFICES											
138													
139		BUILDING TYPE							BUILDING TYPE				
140	ENERGY USE	1	2	3A	3	4		ENERGY COSTS	1	2	3A	3	4
141	HEATING FUEL:							HEATING FUEL:					
142	Heating and hot water	47%	47%	45%	45%	48%		Heating and hot water	47%	47%	45%	45%	48%
143	Catering gas	-	-	-	-	58%		Catering gas	-	-	-	-	58%
144	ELECTRICITY:							ELECTRICITY:					
145	Refrigeration	-	-	56%	50%	57%		Refrigeration	-	-	56%	50%	57%
146	Fans, pumps, controls	83%	83%	67%	64%	67%		Fans, pumps, controls	83%	83%	67%	64%	67%
147	Lights	60%	60%	58%	58%	57%		Lights	60%	60%	58%	58%	57%
148	Office equipment	100%	100%	100%	100%	100%		Office equipment	100%	100%	100%	100%	100%
149	Computer room	-	-	-	-	83%		Computer room	-	-	-	-	83%
150	Catering electricity	83%	80%	86%	86%	83%		Catering electricity	83%	80%	86%	86%	83%
151	Other	80%	80%	80%	80%	80%		Other	80%	80%	80%	80%	80%
152	TOTALS	53%	55%	55%	55%	62%		TOTALS	61%	63%	62%	61%	69%
153	Total Heating:	47%	47%	45%	45%	48%		Total Heating:	47%	47%	45%	45%	48%
154	Total Electricity:	74%	72%	66%	65%	72%		Total Electricity:	74%	72%	66%	65%	72%
155	LANDLORD TOTALS	·48%	49%	49%	49%	52%		LANDLORD TOTALS	50%	51%	54%	53%	56%
156	Landlord Fossil	47%	47%	45%	45%	48%		Landlord Fossil	47%	47%	45%	45%	48%
157	Landlord electricity	58%	58%	57%	57%	60%		Landlord electricity	58%	58%	57%	57%	60%
158													
159	*TYPE 1*	*Naturally-ventilated, cellular, small*											
160	*TYPE 2*	*Naturally-ventilated, open plan, small*											
161	*TYPE 3A*	*Air/water air-conditioned, medium*											
162	*TYPE 3*	*All-air air-conditioned, medium*											
163	*TYPE 4*	*Air conditioned, including computer centre, canteen etc., large*											

Table 8.1B

	A	B	C	D	E	F	G	H	I	J	K	L	M
69	**TABLE 8.1B**	**ENERGY USE AND COST PROFILES FOR GOOD PRACTICE OFFICES**											
70													
71		**BUILDING TYPE**					%		**BUILDING TYPE**				
72	**kWh/m2 gross**	1	2	3A	3	4	*Land*	**p/m2 gross**	1	2	3A	3	4
73	HEATING FUEL:						*lord*	HEATING FUEL:					
74	Heating and hot water	90	90	90	90	105	*100%*	Heating and hot water	126	126	108	108	126
75	Catering gas	0	0	0	0	7	*0%*	Catering gas	0	0	0	0	8
76	ELECTRICITY:							ELECTRICITY:					
77	Refrigeration	0	0	25	15	20	*100%*	Refrigeration	0	0	138	83	100
78	Fans, pumps, controls	3	5	20	35	40	*100%*	Fans, pumps, controls	16	30	110	193	200
79	Lights	15	30	35	35	40	*20%*	Lights	98	180	193	193	200
80	Office equipment	10	15	20	20	25	*0%*	Office equipment	65	90	110	110	125
81	Computer room	0	0	0	0	75	*0%*	Computer room	0	0	0	0	375
82	Catering electricity	2.5	4	6	6	10	*0%*	Catering electricity	16	24	33	33	50
83	Other	4	4	8	8	12	*50%*	Other	26	24	44	44	60
84	TOTALS	124	148	204	209	334		TOTALS	347	474	735	763	1244
85	Total Heating:	90	90	90	90	112		Total Heating:	126	126	108	108	134
86	Total Electricity:	34	58	114	119	222		Total Electricity:	221	348	627	655	1110
87	*Typical fossil p/kWh*	*1.4*	*1.4*	*1.2*	*1.2*	*1.2*							
88	*Typical elec p/kWh*	*6.5*	*6.0*	*5.5*	*5.5*	*5.0*							
89													
90	**kWh/m2 treated**	1	2	3A	3	4		**p/m2 treated**	1	2	3A	3	4
91	Treated:gross area	95%	95%	90%	90%	85%		Treated:gross area	95%	95%	90%	90%	85%
92	HEATING FUEL:							HEATING FUEL:					
93	Heating and hot water	95	95	100	100	124		Heating and hot water	133	133	120	120	148
94	Catering gas	0	0	0	0	8		Catering gas	0	0	0	0	10
95	ELECTRICITY:							ELECTRICITY:					
96	Refrigeration	0	0	28	17	24		Refrigeration	0	0	153	92	118
97	Fans, pumps, controls	3	5	22	39	47		Fans, pumps, controls	17	32	122	214	235
98	Lights	16	32	39	39	47		Lights	103	189	214	214	235
99	Office equipment	11	16	22	22	29		Office equipment	68	95	122	122	147
100	Computer room	0	0	0	0	88		Computer room	0	0	0	0	441
101	Catering electricity	3	4	7	7	12		Catering electricity	17	25	37	37	59
102	Other	4	4	9	9	14		Other	27	25	49	49	71
103	TOTALS	131	156	227	232	393		TOTALS	365	499	817	847	1464
104	Total Heating:	95	95	100	100	132		Total Heating:	133	133	120	120	158
105	Total Electricity:	36	61	127	132	261		Total Electricity:	233	366	697	727	1306
106	*Total as % of typical*	*53%*	*55%*	*55%*	*55%*	*62%*		*Total as % of typical*	*61%*	*63%*	*62%*	*61%*	*69%*
107													
108	**kWh/m2 nett**	1	2	3A	3	4		**p/ft2 nett**					
109	Nett:treated area	80%	80%	80%	80%	80%		Nett:treated area	80%	80%	80%	80%	80%
110	HEATING FUEL:							HEATING FUEL:					
111	Heating and hot water	118	118	125	125	154		Heating and hot water	15	15	14	14	17
112	Catering gas	0	0	0	0	10		Catering gas	0	0	0	0	1
113	ELECTRICITY:							ELECTRICITY:					
114	Refrigeration	0	0	35	21	29		Refrigeration	0	0	18	11	14
115	Fans, pumps, controls	3	7	28	49	59		Fans, pumps, controls	2	4	14	25	27
116	Lights	20	39	49	49	59		Lights	12	22	25	25	27
117	Office equipment	13	20	28	28	37		Office equipment	8	11	14	14	17
118	Computer room	0	0	0	0	110		Computer room	0	0	0	0	51
119	Catering electricity	3	5	8	8	15		Catering electricity	2	3	4	4	7
120	Other	5	5	11	11	18		Other	3	3	6	6	8
121	TOTALS	163	195	283	290	491		TOTAL COSTS:	42	58	95	98	170
122	Total Heating:	118	118	125	125	165		Total Heating:	15	15	14	14	18
123	Total Electricity:	45	76	158	165	326		Total Electricity:	27	43	81	84	152
124	*LANDLORD TOTALS*	*128*	*136*	*203*	*210*	*263*		*LANDLORD TOTALS*	*21*	*25*	*54*	*57*	*68*
125	*Landlord Fossil*	*118*	*118*	*125*	*125*	*154*		*Landlord Fossil*	*15*	*15*	*14*	*14*	*17*
126	*Landlord electricity*	*10*	*17*	*78*	*85*	*109*		*Landlord electricity*	*6*	*10*	*40*	*43*	*51*
127													
128	LANDLORD DELIV %:	79%	70%	72%	72%	54%		LANDLORD% COSTS	50%	43%	57%	58%	40%
129								Of fossil costs	100%	100%	100%	100%	94%
130								Of electricity costs	22%	22%	49%	51%	33%
131													
132	*TYPE 1*	*Naturally-ventilated, cellular, small*						1 ft2 =	.0929	m2			
133	*TYPE 2*	*Naturally-ventilated, open plan, small*											
134	*TYPE 3A*	*Air/water air-conditioned, medium*											
135	*TYPE 3*	*All-air air-conditioned, medium*											
136	*TYPE 4*	*Air conditioned, including computer centre, canteen etc., large*											

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APPENDICES

APPENDIX A

TYPICAL PRELIMINARY QUESTIONNAIRE

ENERGY EFFICIENCY IN OFFICES:

Questionnaire 1 - Preliminary Information - Page 1 of 2 Completed by....................

Name of company: Date..............................

Name and address of office:

Contact name and address for correspondence:

BUILDING CONSTRUCTION AND USE

1 DATES: Construction............................ Last major alteration..............................
2 NUMBER OF FLOORS at and above ground level..
3 NUMBER OF FLOORS below ground level...
4 EXTERNAL WALL CONSTRUCTION *(please tick type)*: Masonry............................
Lightweight cladding......Concrete panels ....Other *(please state)*..............................
5 GLAZING (please tick): Single......Double....... High performance........Solar protected........
Tinted or reflective......Typical glazing percentage of external wall area ....
6 OCCUPANTS: Total number.......................Normal occupancy level........................
7 NORMAL OCCUPANCY AND CLEANING HOURS:
Weekday occupancy..................................Weekday cleaning...............................
Saturdays.......................Sundays............................Public holidays....................
Please state if any areas are used outside these times

FLOOR AREAS (IF AVAILABLE) *Tick the units used: square feet......../square metres........*

8 GROSS..........................NETT...................... *Please enclose floor plans if available*
9 APPROX. AREA OF BUILDING NOT DEVOTED TO NORMAL OFFICE ACTIVITIES:
Please mark with an asterisk (*) any areas below which are additional to the totals in 8 above.
Computer rooms..............................Dealing rooms ....
Kitchen/dining...................Recreation.....................Covered car parking ....
Large storage areas...............Other *(specify)*..
10 ESTIMATED % OF FLOOR AREA in 8 WITH: Heating and natural ventilation................ %
Heating & mechanical ventilation................%, Air conditioning...............................%
No heating & ventilation......................%, Mechanical ventilation only....................%

HEATING, VENTILATION AND AIR-CONDITIONING SYSTEMS

12 TYPE OF HEATING *(please tick)*: Hot water radiators..............or Convectors ....
Warm air.........Heat pump..........Electric..........Other *(specify)*..................................
13 HOT WATER SUPPLY *(please tick)*: From heating boiler.............Central electric ....
Local electric...........Central gas-fired..............Local gas fired..................................
Other *(specify)*........................If electric, estimate % of off-peak electricity used........... %
14 AIR CONDITIONING TYPE *(please tick)*: All air constant volume............VAV ....
Local air handlers...........Fan coil...............Induction............... Heat pump..........
Packaged units................Other *(specify)*..
15 IS THERE ANY LOCAL CONTROL BY OCCUPANTS? *Please note*............................
16 REFRIGERATION PLANT *(please tick)*: Centrifugal................ Screw.........................
Reciprocating..............Other *(specify)*.. None.........
17 HEAT REJECTION SYSTEM *(please tick)*: Air cooled......... Cooling tower....................
Evaporative condenser......................Is heat recovery included? YES..........NO............
Is free cooling included? YES, BY OUTSIDE AIR.....YES, OF CHILLED WATER..... NO...

ENERGY EFFICIENCY IN OFFICES:
Questionnaire 1 - Preliminary Information - Page 2 of 2

LIGHTING

17 LIGHTING USED IN GENERAL OFFICES *(please tick)*:
General lighting......................Background with local "task" lighting...........................
18 DESIGN ILLUMINANCE LEVEL (if known): Background............lux. Task............. lux
19 LIGHTING TYPE *(please tick)*: Ceiling-mounted fluorescent single tube...........................
Ceiling-mounted fluorescent multiple tube.........................Incandescent.....................
High intensity discharge uplighting............Other *(specify)*...
20 USE OF DAYLIGHT *(please tick)*: Good.........Fair..........Poor.........Virtually none........
21 LIGHT SWITCHING *(please tick)*: Switched by floor............Switched in blocks.............
By individual users..................Automatic controls *(please note details)*..........................
....
....

OTHER FEATURES

22 IS THERE AN ELECTRONIC BUILDING MANAGEMENT SYSTEM? YES.....NO.....
23 If YES, please tick its uses: plant switching................plant control.......................lightin
control...........alarms...........maintenance management............energy monitoring........
24 ARE THERE LIFTS OR ESCALATORS? How many lifts................escalators................
25 IS THERE A STANDBY GENERATOR? YES..........NO........
26 IS USE OF ELECTRONIC OFFICE EQUIPMENT high.........medium............low...........
27 *Please state number of personal computers or terminals per workstation*...........................
28 IF THERE IS A COMPUTER SUITE, PLEASE ESTIMATE THE PROPORTION OF ANNUAL ELECTRICAL CONSUMPTION IT USES (including its air-conditioning)........ %
29 *Are any other major pieces of energy-consuming equipment or systems not identified above? Please specify:*

30 *Are any other energy-saving systems not identified above? Please specify:*

ENERGY CONSUMPTION FOR A RECENT 12-MONTH PERIOD

31 *Please state period* *IF IN DIFFICULTY, PLEASE FILL IN TOTALS ONLY*
from...to..

Month	Natural Gas Therms	Oil grade .... Litres	Electricity Standard kWh	Electricity Off peak kWh	Other ?............... units............
1	....	....	....	....	....
2	....	....	....	....	....
3 or first qtr	....	....	....	....	....
4	....	....	....	....	....
5	....	....	....	....	....
6 or 2nd qtr	....	....	....	....	....
7	....	....	....	....	....
8	....	....	....	....	....
9 or 3rd qtr	....	....	....	....	....
10	....	....	....	....	....
11	....	....	....	....	....
12 or 4th qtr	....	....	....	....	....
TOTAL	....	....	....	....	....

Please append copies of fuel bills if possible. If a complete set, you need not repeat the details above.

OTHER FEATURES OF INTEREST
Please note any key items not covered above

Please return t
WILLIAM BORDASS ASSOCIATES
10 Princess Road London NW1 8J
Telephone and Facsimile 01-722 263

THANK YOU FOR YOUR HELP.

APPENDIX B

ENERGY CONSUMPTION OF SOME OFFICE EQUIPMENT: TABLES

ENERGY EFFICIENCY IN OFFICES:							Calculations based on currents assume													APPENDIX B
ELECTRICAL CONSUMPTION OF OFFICE EQUIPMENT							Voltage		240	Power factor			1.00	NOTE: some items have much lower PFs						PAGE 1
							(Where no currents are shown, true power has been measured directly by HCK Unihall meter)													
ITEM		MEASURED:		NAMEPLATE:			CALC	MEASURED IDLING:				MEASURED RUNNING:				TYPICAL USE			% of	COMMENTS
TYPE and MAKE	MODEL	At	Date	Amp	Watt	PH	WATTS	AMPS	WATTS	%	Function	AMPS	WATT	%	Functio	Idle	Run	Watt	Plate	
CATERING EQUIPMENT									317				2203						21%	SECTOR AVERAGE
Brewmaster coffee mkr	Diplomat 2	DL&E	Nov-88		2560	1	2560	0.70	168	7%	2 plates	9.40	2256	88%	Boiling	70%	30%	794	31%	Common boiler
Coffee maker (2 rings)	Check	PSI	Nov-88		3000	1	3000	0.25	60	2%	1 plate	5.20	1248	42%	Boiling	70%	30%	416	14%	One side running only
Wittenborg H vender	Floor mode	Laing	Nov-88		3000	1	3000	2.80	672	22%	Idling	11.00	2640	88%	Boiling	92%	8%	829	28%	+5% run pks idling
Wittenborg H&C vender	Floor mode	DL&E	Nov-88		3000	1	3000	2.60	624	21%	Idling	10.50	2520	84%	Boiling	92%	8%	776	26%	+5% run pks idling
Wittenborg H vender	Wall model	Laing	Nov-88		3000	1	3000	0.25	60	2%	Idling	9.80	2352	78%	Boiling	92%	8%	243	8%	+5% run pks idling
DYE-LINE MACHINES									1677				3385					1848	61%	SECTOR AVERAGE
Océ	230	Laing	Nov-88		5300	1	5300	10.00	2400	45%	Standby	19.50	4680	88%	Copying	90%	10%	2628	50%	Peak continuous print
Nig Banda	?	SVM	Jan-89		5300	1	5300	10.00	2400	45%	Standby	19.50	4600	87%	Copying	90%	10%	2620	49%	Peak continuous print
Harper	3-140	BKB	May-90	6		1	1440		232	16%	Standby		875	61%	Copying	90%	10%	296	21%	875 W hi speed
FAX									13				38					14	10%	SECTOR AVERAGE
Canon	510	DL&E	Nov-88		250	1	250	0.05	12	5%	Standby	0.30	72	29%	Receivi	95%	5%	15	6%	Average
Nefax	3EX	BRE	May-90	0.5		1	120		16	13%	Standby	0.30	24	20%	Copying	95%	5%	16	14%	Average
Panasonic	KX-F120	WBA	Jun-89		65	1	65		11	17%	Standby		17	26%	Receivi	95%	5%	11	17%	True power meas.
PERSONAL COMPUTERS									64				65					62	23%	SECTOR AVERAGE
Amstrad	PC1512DD	DL&E	Nov-88		57.2	1	57.2	0.20	48	84%	Waiting	0.21	50	88%	Booting	95%	5%	48	84%	2xFD, inc B/W screen
Amstrad portable	PPC 512	BRE	May-90				35		19	54%	Waiting		27	77%	Booting	95%	5%	19	55%	Power supp only 4.2W
Apple Mac Plus,2MB MacSnap Card		WBA	Nov-88		60	1	60	0.20	48	80%	Waiting	0.22	53	88%	Booting	95%	5%	48	80%	1xFD, inc B/W screen
Apple Mac SE30 5MB, Radius card		WBA	Nov-88	2		1	480	0.29	70	15%	Waiting	0.30	72	15%	Booting	95%	5%	70	15%	2xFD, 1xHD, own scn
Apple Mac SEHD,Radius driver card		WBA	May-90	2		1	480	0.29	51	11%	Waiting	0.30	62	13%	Disc/cal	95%	5%	52	11%	1xFD, 1xHD, own scn
Apple Mac	II cx	BRE	May-90		850	1	850		43	5%	Waiting	0.30	43	5%	Booting	95%	5%	43	5%	1xFD, 1xHD, no scn
Apricot XEN	i-X120	York U	Nov-88	1.5		1	360	0.35	84	23%	Waiting	0.37	89	25%	Booting	95%	5%	84	23%	1xFD, 1xHD, Inc VDU
BBC (chassis only)	Model B	BRE	May-90	0.5		1	120		18	15%	Waiting	0.37	18	15%	Booting	95%	5%	18	15%	No disc or VDU
BBC dual disc drive		BRE	May-90	0.5		1	120		17	14%	Waiting	0.37	17	14%	Waiting	95%	5%	17	14%	Not measured in flight
Compaq portable	LTE/286	WBA	Jun-90	0.5		1	120		16	13%	Waiting	0.37	18	15%	Booting	95%	5%	16	13%	Also slumber mode
Dell	PC200	SVM	Jan-89	1.5		1	360	0.36	86	24%	Waiting	0.44	106	29%	Booting	95%	5%	87	24%	1xFD, 1xHD, No VDU
DEC Rainbow	100	York U	Nov-88	1		1	240	0.35	84	35%	Waiting	0.35	84	35%	Booting	95%	5%	84	35%	1xFD, 1xHD, Inc VDU
DEC Vaxmate	PC500C3	Warburg	Jan-89		230	1	230	0.51	122	53%	Waiting	0.52	125	54%	Booting	95%	5%	123	53%	1xFD, 1xHD, Inc VDU
	NOTE: DEC Vaxmate draws 0.06 amps when OFF!!								123	Watts measured on similar model at BRE in May 1990										
IBM PC (original)		MSL	Jun-84		230	1	230	0.30	72	31%	Waiting	NOT MEASURED				95%	5%	68	30%	2xFD, no screen
IBM PC XT	PC3270	Laing	Nov-88	2.1		1	504	0.48	115	23%	Waiting	0.50	120	24%	Booting	95%	5%	115	23%	1xFD, 1xHD, No VDU
IBM PS/2	PS/2	Laing	Nov-88	0.75		1	180	0.19	46	25%	Waiting	0.20	48	27%	Booting	95%	5%	46	25%	1xFD, 1xHD, No VDU
IBM PS/2	8550	NFU	Jul-89	1.4		1	336		62	18%	Waiting		65	19%	Booting	95%	5%	62	18%	1xFD, 1xHD, No VDU
Olivetti M19	PS/2	DL&E	Nov-88		150	1	150	0.24	58	38%	Waiting	0.26	62	42%	Booting	95%	5%	58	39%	2xFD, inc grn screen
RM Nimbus Netwk Sta	PCI	RM	Jun-89		80	1	80		33	41%	Waiting		35	44%	Booting	95%	5%	33	41%	1xFD, no screen
RM Nimbus Prototype	PC2 specia	RM	Jun-89	0.5		1	120		50	42%	Waiting		50	42%	Running	95%	5%	50	42%	1xFD, 1xHD, no VDU
RM Nimbus higher pwr	AX-286/2	RM	Jun-89	1.6		1	384		100	26%	Waiting		100	26%	Booting	95%	5%	100	26%	1xFD, 1xHD, no VDU
Sirius		SVM	Jan-89	1.6		1	384	0.48	115	30%	Waiting	0.50	120	31%	Booting	95%	5%	115	30%	2xFD, inc grn screen

Table 1

ENERGY EFFICIENCY IN OFFICES:							Calculations based on currents assume													APPENDIX B
ELECTRICAL CONSUMPTION OF OFFICE EQUIPMENT							Voltage		240	Power factor			1.00	NOTE: some items have much lower PFs						PAGE 2
ITEM		MEASURED:		NAMEPLATE:			CALC	MEASURED IDLING:				MEASURED RUNNING:				TYPICAL USE				COMMENTS
TYPE and MAKE	MODEL	At	Date	Amp	Watt	PH	WATTS	AMPS	WATTS	%	Function	AMPS	WATTS	%	Function	Idle%	Run%	Watt		
PHOTOCOPIERS									216				1162					395	21%	SECTOR AVERAGE
Agfa Xl (desk top)	X1	Laing	Nov-88	5		1	1200	0.13	31	3%	Standby	2.60	624	52%	Copying	95%	5%	61	5%	Peak-50%, rest .95
Agfa X41 (high cap)	X41	Laing	Nov-88	10		1	2400	0.83	199	8%	Standby	6.50	1560	65%	Copying	80%	20%	471	20%	Peak continuous print
Canon(large)	NP8570	PSI	Nov-88	10		1	2400	1.00	240	10%	Standby	3.50	840	35%	Copying	90%	10%	300	13%	Copying peak ca 50%
Canon(small)	Check	PSI	Nov-88	10		1	2400	0.25	60	3%	Standby	2.50	600	25%	Copying	90%	10%	114	5%	Copying peak ca 50%
Canon (Personal)	PC25	WBA	Jun-89		1350	1	1350		100	7%	S'by inc jumps		1420	105%	Copying	95%	5%	166	12%	Copying peak ca 60%
Canon (Personal)	PC16 zoom	WBA	May-90		1200	1	1200		60	5%	S'by inc jumps		500	42%	Copying	95%	5%	82	7%	Abs peak 1264 W
Gevafax (high cap)	X3165	Laing	Nov-88		1800	1	1800	1.41	338	19%	Standby	8.00	1920	107%	Copying	85%	15%	576	32%	Peak-50%, rest 3 A
Harris 3M (small)	6010	Laing	Nov-88	6.5		1	1560	0.70	168	11%	Standby	1.20	288	18%	Copying	95%	5%	174	11%	Plus pulses to 4 A
Infotec (medium)	9015Z	BRE	May-90	6		1	1440		133	9%	Standby		600	42%	Copying	95%	10%	186	13%	Inc pulses to 1000 W
Minolta c/w sorter	EP415Z	Provinci	Dec-88		1450	1	1450	0.76	182	13%	Standby	4.50	1080	74%	Copying	80%	20%	362	25%	Ave, fluctns 2-6A
Xerox (curved platen)	3600	Laing	Nov-88		4000	1	4000	2.40	576	14%	Standby	11.00	2640	66%	Copying	70%	30%	1195	30%	Copy peak continuous
Xerox (table top)	2830	DL&E	Nov-88		1400	1	1400	2.00	480	34%	Standby	5.30	1272	91%	Copying	80%	20%	638	46%	Copy peak continuous
Xerox (floor w sorter)	1050	DL&E	Nov-88		1800	1	1800	0.72	173	10%	Standby	6.70	1608	89%	Copying	70%	30%	603	34%	Copy peak continuous
Xerox (floor w collator)	1045	DL&E	Nov-88		1500	1	1500	1.18	283	19%	Standby	5.50	1320	88%	Copying	70%	30%	594	40%	Copy peak continuous
PLOTTERS																			29%	SECTOR %
Calcomp	81	MSL	Jun-84	1		1	240	0.15	36	15%	Standby	0.42	101	42%	Plotting	50%	50%	68	29%	
PRINTERS - impact									42				76					45	24%	SECTOR AVERAGE
Acoustic hood	??	SVM	Jan-89	0.25		1	60	0.05	12	20%	Not labelled					99%	0%	12	20%	Fan only
Apple Imagewriter	Mark I	WBA	Nov-88	1		1	240	0.12	29	12%	Standby	0.25	60	25%	Printing	90%	10%	32	13%	Dot Matrix
Apple Imagewriter	Mark 2	WBA	Nov-88	1		1	240	0.08	19	8%	Standby	0.12	29	12%	Printing	90%	10%	20	8%	Dot Matrix
Apricot	Writer 2	York U	Nov-88	0.5		1	120	0.08	19	16%	Standby	0.15	36	30%	Printing	90%	10%	21	17%	Dot Matrix
Diabolo	630	DL&E	Nov-88	2		1	480	0.20	48	10%	Standby	0.33	79	17%	Printing	90%	10%	51	11%	Daisy wheel
Dictaphone	Daisy	SVM	Jan-89	1		1	240	0.31	74	31%	Standby	0.67	161	67%	Printing	90%	10%	83	35%	Daisy wheel
Epson	FX-100	York U	Nov-88	0.4		1	96	0.03	7	8%	Standby	0.12	29	30%	Printing	90%	10%	9	10%	Dot Matrix
Genicom (inc hood fan)	3210	Laing	Nov-88	1		1	240	0.35	84	35%	Standby	0.45	108	45%	Printing	90%	10%	86	36%	Dot Matrix
IBM Proprint XL	XL	Laing	Nov-88		120	1	120	0.15	36	30%	Standby	0.23	55	46%	Printing	90%	10%	38	32%	Dot Matrix
IBM	5219	MSL	Jun-84	1		1	240	0.42	101	42%	Standby	0.63	151	63%	Printing	90%	10%	106	44%	Dot Matrix
NEC Pinwriter	PS XL	DL&E	Nov-88		125	1	125	0.24	58	46%	Standby	0.40	96	77%	Printing	90%	10%	61	49%	Dot Matrix
Siemens		SVM	Jan-89	0.15		1	36	0.05	12	33%	Standby	0.14	34	93%	Printing	90%	10%	14	39%	Dot Matrix

Table 2

Table 3

ENERGY EFFICIENCY IN OFFICES:							Calculations based on currents assume													**APPENDIX B**
ELECTRICAL CONSUMPTION OF OFFICE EQUIPMENT							Voltage		240	Power factor		1.00	NOTE: some items have much lower PFs							**PAGE 3**
ITEM		**MEASURED:**		**NAMEPLATE:**			**CALC**	**MEASURED IDLING:**				**MEASURED RUNNING:**				**TYPICAL USE**				**COMMENTS**
TYPE and MAKE	MODEL	At	Date	Amp	Watt	PH	WATTS	AMPS	WATTS	%	Function	AMPS	WATTS	%	Function	Idle%	Run%	Watt		
PRINTERS - laser									82				431					117	12%	SECTOR AVERAGE
Apricot	Laser	York U	Nov-88	4		1	960	0.50	120	13%	Standby	1.00	240	25%	Printing	90%	10%	132	14%	Copying peak ca 50%
Apple	II NT	BRE	May-90	6		1	1440		70	5%	Standby		736	51%	Printing	90%	10%	137	9%	
DEC	LNO 3	BRE	May-90		700	1	700		90	13%	Standby		400	57%	Printing	90%	10%	121	17%	Inc copy peak 625 W
HP Laserjet	Series 2	DL&E	Nov-88		850	1	850	0.17	41	5%	Standby	2.50	600	71%	Printing	90%	10%	97	11%	Peak 40%, .45A rest.
IBM Persnl Pagemaker	Laser	Laing	Nov-88	5		1	1200	0.26	62	5%	Standby	1.90	456	38%	Printing	90%	10%	102	8%	Copying peak ca 50%
Wang	LPS/L158	Warburg	Jan-89		750	1	750	0.45	108	14%	Standby	0.65	156	21%	Printing	90%	10%	113	15%	Plus 2.6A pk ca 10%
TYPEWRITERS									26				51					31	37%	SECTOR AVERAGE
Adler	SE100S	SVM	Jan-89		70	1	70	0.07	17	24%	Idling	0.30	72	103%	Typing	70%	30%	33	48%	
Canon	AP200X	UoY	Nov-88		85	1	85	0.16	38	45%	Idling	0.23	55	65%	Typing	70%	30%	43	51%	
IBM	6750	Laing	Nov-88	0.5		1	120	0.15	36	30%	Idling	0.20	48	40%	Typing	70%	30%	40	33%	Used as PC printer
IBM Golfball	82	MSL	Jun-84		80	1	80	0.15	36	45%	Average					70%	30%	25	32%	Details not recorded
Olivetti	ET 115	WBA	Jun-89		75	1	75		21	28%	Idling		41	55%	Typing	70%	30%	27	36%	True power measured
Olivetti	ET 2500	Laing	Nov-88		75	1	75	0.04	10	13%	Idling	0.16	38	51%	Typing	70%	30%	18	24%	
TERMINALS									70									70	29%	SECTOR AVERAGE
Cato Monterey	MT200	Laing	Nov-88	2		1	480	0.26	62	13%						99%		62	13%	Colour display
Digital-old model	VT100	BRE	May-90		300	1	300		53	18%						99%		52	17%	Monochrome
Digital-newer model	VT220	BRE	May-90		65	1	65		36	55%						99%		36	55%	Monochrome
Digital-later model	VT320	BRE	May-90		50	1	50		29	58%						99%		29	57%	Monochrome
IBM	3179	Laing	Nov-88	0.7		1	168	0.32	77	46%						99%		76	45%	Colour display
IBM	5253	MSL	Jun-84	1		1	240	0.50	120	50%						99%		119	50%	Colour display
IBM	3192	NFU	Jul-89	1.2		1	288		68	24%	True power measured			New model		99%		67	23%	Colour display
IBM	3278	NFU	Jul-89	1		1	240		83	35%	True power measured			Triffid model		99%		82	34%	Green display
IBM	3279	NFU	Jul-89	2		1	480		123	26%	True power measured			Raked front		99%		122	25%	Green display
Microcolour	2200	Warburg	Jan-89	1		1	240	0.32	77	32%						99%		76	32%	Colour display
Microcolour	2250	Warburg	Jan-89	1		1	240	0.37	89	37%						99%		88	37%	Colour display
Televideo	B & W	York U	Nov-88	0.5		1	120	0.12	29	24%						99%		29	24%	Black & White
TELECOM SWITCHES																			82%	SECTOR %
BT	Regent	SVM	Jan-89		450	1	450	1.56	374	83%						99%		371	82%	Estimated

Table 4

ENERGY EFFICIENCY IN OFFICES:							Calculations based on currents assume													APPENDIX B
ELECTRICAL CONSUMPTION OF OFFICE EQUIPMENT							Voltage		240	Power factor			1.00	NOTE: some items have much lower PFs						PAGE 4
ITEM		MEASURED:		NAMEPLATE:			CALC	MEASURED IDLING:				MEASURED RUNNING:				TYPICAL USE				COMMENTS
TYPE and MAKE	MODEL	At	Date	Amp	Watt	PH	WATTS	AMPS	WATTS	%	Function	AMPS	WATTS	%	Function	Idle%	Run%	Watt		
VDUs for PCs									66									65	27%	SECTOR AVERAGE
IBM PC colour monitor	5272	Laing	Nov-88	0.6		1	144	0.28	67	47%						99%		67	46%	Colour
IBM PC colour monitor	Old style	Laing	Nov-88	0.95		1	228	0.29	70	31%						99%		69	30%	Colour
IBM PS/2 Colour display	8512	NFU	Jul-89	0.7		1	168		61	36%	True power measured					99%		60	36%	From one factory
IBM PS/2 Colour display	8512	NFU	Jul-89	0.7		1	168		51	30%	True power measured					99%		50	30%	From different factory
Microvitec	Cub	MSL	Jun-84	1		1	240	0.30	72	30%						99%		71	30%	Colour
Microvitec (RM badge)	14"	RM	Jun-89	0.5		1	120		63	53%	True power measured					99%		62	52%	64 W meas. at BRE
Mitsubishi	XC1440C	RM	Jun-89	0.5		1	120		77	64%	True power measured					99%		76	64%	Colour
Radius two page display 19"	B/W	WBA	Jun-89		100	1	100		79	79%	True power measured					99%		78	78%	A3 Black & White
Radius A4 portrait display		BRE	May-90	4.2		1	1008		55	5%	True power measured					99%		54	5%	A4 Black & White
Taxan	765E	SVM	Jan-89	0.6		1	144	0.26	62	43%						99%		62	43%	Green 13"
WORD PROCESSORS									215									215	50%	SECTOR AVERAGE
Dictaphone	Master	SVM	Jan-89	3		1	720	1.65	396	55%	Waiting	1.72	413	57%	Booting	90%	10%	398	55%	Master unit 2x8" FD
Dictaphone	Keyboard	SVM	Jan-89		200	1	200	0.05	12	6%						99%		12	6%	Up to 3 per master
Dictaphone	Gn Screen	SVM	Jan-89	1		1	240	0.13	31	13%						99%		31	13%	Up to 3 per master
ICL	V120	Provinci	Dec-88		380	1	380	0.85	204	54%	Waiting	1.05	252	66%	Printing	90%	10%	209	55%	Inc yellow scn+daisy
Jaquard	500	DL&E	Nov-88	2		1	480	0.90	216	45%	Waiting	1.05	252	53%	Booting	90%	10%	220	46%	2x 8"FD, inc grn VDU
Wang WP Screen	4230-A	Warburg	Jan-89	0.5		1	120	0.18	43	36%						99%		43	36%	
Wang WP master unit	65	Warburg	Jan-89		850	1	850	2.50	600	71%						99%		594	70%	Estimated only

APPENDIX C

FLOOR AREA DEFINITIONS

APPENDIX C

Floor area definitions: The measurement of office buildings

C1 INTRODUCTION

C1.1 When comparing building data, it is customary to use area as the common unit, for example, energy consumption is expressed as kWh/m^2 and energy cost as pence/ft^2. This apparently straightforward approach to normalising building data is, however, fraught with difficulty. There is no single clear, consistent and readily-available statement of the rules by which buildings should be measured for this purpose. As a result, energy consumption indicators are presented in a number of different ways.

C1.2 Although floor area is generally accepted as the preferred measure, there are differences in detail as to what "floor area" actually means. In simple terms:

- The construction industry - architects, engineers, quantity surveyors and contractors - uses total built area.
- The property industry - developers, landlords, tenants and general practice surveyors - uses lettable area, and
- The energy/building services industry prefers to use treated area.

An additional complication is that the property industry continues to use the imperial system while the other two use metric units. Conversions between them are often fairly roughly done.

C2 RICS DEFINITIONS OF BUILDING AREA

C2.1 The main source of guidelines on the measurement of buildings is the Code of Measuring Practice published by the Royal Institution of Chartered Surveyors (RICS) and the Incorporated Society of Valuers and Auctioneers (ISVA). This provides three principal floor area definitions: Gross External Area, Gross Internal Area, and Nett Internal Area. These are all defined in detail in the publication: the following notes briefly summarise the content of each.

C2.2 ***Gross External Area (GEA)*** describes office floor space for the purposes of the Town and Country Planning Act (1971). It is the area measured on each floor from the outside face of the external walls, ie: the complete footprint of the building. However, when calculating this area the following should be excluded: open balconies and fire escapes; atria; areas with a height of less than 1.50 m under roof slopes; open covered ways or minor canopies; open vehicle parking areas; and terraces and party walls beyond the centre line. Structural elements and spaces such as partitions, columns, lift wells, plant rooms and the like are excluded.

C2.3 ***Gross Internal Area (GIA)*** is measured on the same basis as GEA but between the inside faces of the external walls to all enclosed spaces fulfilling the functional requirements of the building, including all circulation areas, voids, staircases (measured flat on plan) and other non-office areas such as plant rooms, toilets and enclosed car parks.

C2.4 ***Nett Internal Area (NIA)*** refers to the gross internal building area less the building core area and other common areas. It is measured to the internal finish of external walls and excludes all auxiliary and ancillary spaces such as toilets, ducts, plant rooms, staircases, lift wells and major access circulation. NIA equates with the letting agents' nett lettable floor area.

C2.5 As indicated, GEA is generally used for planning and commercial rating purposes and is not referred to further in this paper. GIA is the measure generally used by the construction industry (but more often called gross floor area) and NIA (more commonly lettable area) is the property industry's preferred measure. We recommend that the RICS definitions are adopted.

C2.6 ***Treated Area (TA)*** is familiar to the building services industry and energy consultants, but in our work we have discovered that there is no consistent definition. For example, CIBSE publications sometimes include and sometimes exclude plant rooms from TA, and this can account for differences of up to 10% in quoted energy consumption figures. We propose that TA should be measured in a similar way to GIA but should exclude those areas which are not directly heated, are only occasionally occupied, and whose building services are normally limited only to rudimentary ventilation and lighting. For practical reasons, the plan areas of lift shafts and service ducts are included but plant rooms themselves are excluded. Ideally what little energy these areas do account for should be measured separately: in the Office Case Studies it has been recorded in the "others" category.

C3 RECOMMENDATIONS

It is recommended that the following floor area terms and definitions are generally adopted:

Gross Floor Area
Total building area measured inside external walls.
(As RICS/ISVA Gross Internal Area).

Nett Floor Area
Gross area, less common area and ancillary spaces. Agents' lettable floor area.
(As RICS/ISVA Nett Internal Area).

Treated Floor Area
Gross area less plant rooms and other areas (eg: stores) not directly or fully heated.
(Treated Area as discussed above).

APPENDICES D&E

REVIEW OF SOME OFFICE ENERGY CONSUMPTION RATINGS

APPENDIX D

Review of some existing theoretically-based office energy consumption ratings

D1 CIBSE BUILDING ENERGY CODE PART 2

Section 2(a), for heated and naturally-ventilated buildings, was published in 1981. Parts 2(b), for mechanically-ventilated buildings and 2(c), for air-conditioned buildings, are in preparation and 2(c) is now out for comment. The methods are theoretically-based, and intended largely for option evaluation at the design stage: no attempt has been made to calibrate them against existing buildings.

Some of Part 2(a)'s standard assumptions may need altering for energy-efficient designs. For example:

i Ventilation & infiltration rates.
ii The proportion of internal gains likely to offset heating needs.
iii Lighting, particularly with automatic controls.
iv Boiler and heating system efficiencies.

The standard calculation can easily accept such modifications.

D2 TANDEM

CIBSE Section 2(a), has been "stretched" to include mechanical ventilation and air-conditioning in the Tandem computer model under development at BRE. In its current form, Tandem gives the designer an energy performance rating (under 100 = pass, over 100 = fail), but no information on the predicted level of energy consumption or on the components of the final figure are yet provided.

D3 ESICHECK

Earlier in the project we approached the ESI to see if this powerful, empirically-calibrated model could be made available to us. Although encouraging noises were made, in the event this did not happen at the time it would have been most useful. However, it is now being used in BREEAM assessments and it may be worth developing and applying it more widely if it could be made fully available outside the ESI.

D4 PSA PERFORMANCE INDICATORS

The PSA used CIBSE Code 2(a) routinely to estimate the energy consumption of its designs. The results have allowed it to develop energy targets (Table D1) for new shallow-plan, single glazed naturally-lit and ventilated office designs. The areas stated are "treated": in the PSA's definition this includes plant rooms.

TABLE D1 PSA Energy Targets 1987

Typical average U-value	*(including windows)*	*1.6 W/m^2K*	
Lighting (to 350 lux)	*Installed load*	*9 W/m^2*	
	Annual electricity use	*17 kWh/m^2*	
Heating annual energy use (dependent on building floor area):	*5000 m^2 and up:*		*70 kWh/m^2*
	decreasing linearly to	*3000 m^2*	*75 kWh/m^2*
	and on to	*1000 m^2*	*80 kWh/m^2*
Below 1000 m^2, add 5 kWh/m^2 for each 100 m^2 decrease in floor area.			
Hence, heating energy target for		*500 m^2 is*	*105 kWh/m^2.*

Unfortunately, PSA seldom seem to have compared the measured energy consumption of their completed buildings directly with their CIBSE Energy Code 2(a) calculations. If they were, our own information suggests that the results would be likely to reveal a higher-than-estimated heating energy consumption (as occurred at the BRE Low Energy Office, even during its closely-monitored period) and quite possibly less systematic variation of heating energy consumption with building size.

APPENDIX E

Review of some existing practically-based office energy consumption ratings

E1 CIBSE ENERGY CODE PART 4

E1.1 Table E1 summarises CIBSE Energy Code Part 4 (1982) performance indicators (rounded and converted to kWh/ m^2 of treated floor area) for delivered energy consumption of offices in single-shift, 5-day week operation. The Code also includes rough correction factors (see table E2), though these are particularly uncertain as the weather and time-dependence of electricity and heating fuel use differs.

TABLE E1 CIBSE Energy Code overall performance indicators
(adjusted to kWh/m^2 of treated floor area)

GOOD	*SATISFACTORY*	*FAIR*	*POOR*	*VERY POOR*
< 195	*195-220*	*220-280*	*280-330*	*> 330.*

TABLE E2 CIBSE Energy Code performance indicator corrections

Continuous running	*1.4*	*7-day 1 shift*	*1.2*	*5-day 2-shift*	*1.3.*
Air conditioning	*1.4*	*Mechanical vent*	*1.3*	*Electric heating*	*0.8.*
Exposed sites	*1.1*	*South West England*	*0.9*		

(or use degree-days).

E1.2 Another table in CIBSE Energy Code Part 4 gives performance indicators, based on PSA measured data, for heating fuel (including HWS) and electricity for naturally-ventilated office buildings. The PSA usage pattern is probably not representative of commercial offices, where there are often more open-planned offices (where not only are illuminance levels higher - PSA tending to design to 350 lux, rather than CIBSE's 750 - but lights tend to remain on for longer) and the hours of occupancy are probably less rigid and more extended. The figures are given for lettable floor area: in Table E3 they have been converted to kWh/ m^2 of treated floor area (assuming, as stated in the Code, that nett lettable area is 80% of treated area), and rounded-off.

TABLE E3 PSA performance indicators for naturally ventilated offices
(adjusted to kWh/m^2 of treated floor area)

THERMAL	*GOOD*	*FAIR*	*POOR*	*VERY POOR*
up to 5000 m^2	*< 210*	*210-260*	*260-320*	*> 320*
up to 10000 m^2	*< 165*	*165-195*	*195-260*	*> 260*
over 10000 m^2	*< 145*	*145-180*	*180-260*	*> 260*

ELECTRICAL	*GOOD*	*FAIR*	*POOR*	*VERY POOR*
up to 5000 m^2	*< 20*	*20-30*	*30-40*	*> 40*
up to 10000 m^2	*< 25*	*25-30*	*30-40*	*> 40*
over 10000 m^2	*< 30*	*30-35*	*35-45*	*> 45*

E1.3 The electrical figures here are for total metered electricity to the building, not just for environmental services. They are based on survey information some 15 years old. Since then electricity consumption in most buildings has probably increased, with loads from extra electrical and electronic office equipment predominating over any reductions in lighting.

E2 DEPARTMENT OF ENERGY

E2.1 "Energy Efficiency in Buildings" (1985 - Reference 6) gives energy costs per square foot, though unfortunately whether this is a gross, treated or nett lettable area is not stated. By working back from the cost figures, we obtained the figures summarised in Table E4 below. The "naturally ventilated" figures bear a close resemblance to the PSA information in Table E3, suggesting that treated floor areas were used in the denominator.

Table E4 Performance indicators from "Energy Efficiency in Buildings"
(adjusted to kWh/m^2 of treated floor area)

THERMAL	*GOOD*	*OK*	*FAIR*	*POOR*	*VERY POOR*
Naturally ventilated	*< 180*	*180-195*	*195-265*	*265-325*	*>325*
Air conditioned	*< 145*	*145-170*	*170-205*	*205-370*	*>370*

ELECTRICAL	*GOOD*	*OK*	*FAIR*	*POOR*	*VERY POOR*
Naturally ventilated	*< 25*	*25-30*	*30-45*	*45-70*	*>70*
Air conditioned	*< 105*	*105-120*	*120-165*	*165-305*	*>305*

COMBINED	*GOOD*	*OK*	*FAIR*	*POOR*	*VERY POOR*
Naturally ventilated	*< 205*	*205-225*	*225-310*	*310-395*	*>395*
Air conditioned	*< 250*	*250-290*	*290-370*	*370-675*	*>675*

E3 INFORMATION FROM MAINTENANCE CONTRACTORS

E3.1 Information from maintenance contractors was been disappointing: they are normally only responsible for landlords' heating energy consumption, even in air-conditioned buildings where the electricity use by refrigeration, ventilation and lighting usually dominates annual energy costs. A general rule-of-thumb view seems to be that fossil fuel consumption in "good" buildings tends to be below about 200 kWh/m^2 and "poor" buildings above 300 kWh/m^2, and that air-conditioned buildings tend to use more heat than naturally-ventilated ones.

E4 THE AUDIT COMMISSION

E4.1 The Audit Commission's NPI yardsticks for local authority offices (reference 8) is 200 kWh/m^2 gross for offices under 2000 m^2 (2400 hours of use per year) and 230 kWh/m^2 for larger buildings (2600 hours per year). "Poor" offices have consumptions over 390 and 400 kWh/m^2 respectively. Unfortunately electricity and heating fuel use are added-together: a great pity. The Audit Commission suggest (although rather tentatively) that while "good" private sector and public sector buildings tend to have similar NPIs, "poor" examples in the public sector can be worse. Our own indications are that while this may be so, public sector offices tend to have lower electricity and higher space heating consumptions and hence lower total energy costs.

E5 BSRIA/EEO

E5.1 BSRIA have developed the Audit Commission's method for the 1988 revision of the EEO Publication - Energy Efficiency in Buildings: Offices (reference 16), but unfortunately they again add together delivered heating and electrical use, without any scaling. Normalised performance indices (NPIs) in table B5 of reference 16 are given in kWh/m^2 treated (they estimate nett lettable to be 80% of treated). The new information gives "good" levels which are similar to the earlier ones in Table E4, but the "fair" band has been widened and "very poor" abandoned.

Table E5 Performance yardsticks from "Energy Efficiency in Offices"

NPI (kWh/m^2 treated per year)	*GOOD*	*FAIR*	*POOR*	*Standard hrs/year*
A/C over 2000 sq m	*< 250*	*250-410*	*> 410*	*2600*
A/C under 2000 sq m	*< 220*	*220-310*	*> 310*	*2400*
A/C with computer suite	*< 340*	*340-480*	*> 480*	*8760*
N/V over 2000 sq m	*< 230*	*230-290*	*> 290*	*2600*
N/V under 2000 sq m	*< 200*	*200-250*	*> 250*	*2400*

E5.2 The NPIs are standardised to 2462 degree days for heating, normal exposure (sheltered x 1.1, severe x 0.9 for heating), and the given numbers of hours per year. Less intensive use means that the annual kWh/sq m is scaled-up to give NPI, with more intensive use it is scaled down.

E5.3 The data was obtained from self-completion questionnaires. There is some evidence that this can lead to "good" targets which are on the low side, as the buildings with the lower calculated NPIs can often have under-reported energy consumption and/or over-reported floor areas and hours of use.