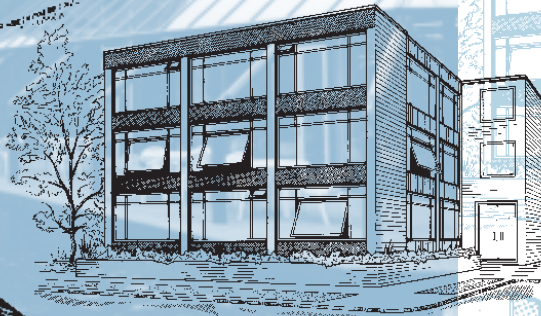


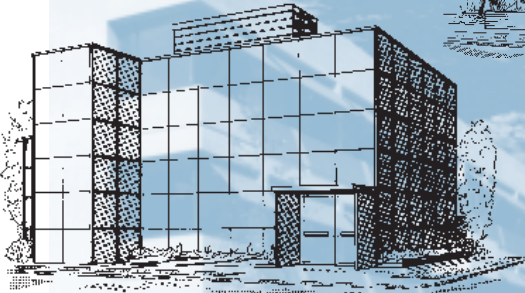
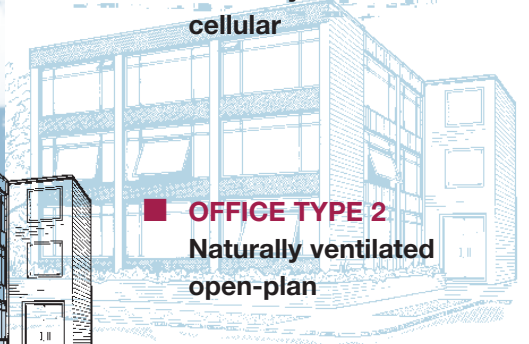
Energy use in offices



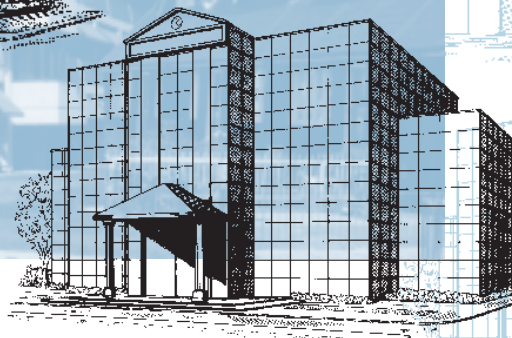
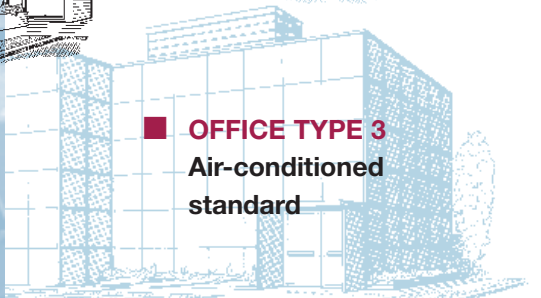
■ **OFFICE TYPE 1**
Naturally ventilated
cellular



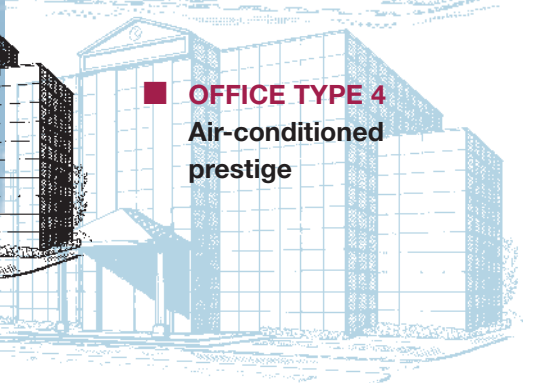
■ **OFFICE TYPE 2**
Naturally ventilated
open-plan



■ **OFFICE TYPE 3**
Air-conditioned
standard



■ **OFFICE TYPE 4**
Air-conditioned
prestige



ENERGY EFFICIENCY

**BEST PRACTICE
PROGRAMME**

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1 INTRODUCTION

This Guide is intended to raise awareness of the potential to improve the energy and environmental performance of offices, and to encourage positive management action. It describes four types of office buildings against which you can compare the performance of your own offices. It gives benchmarks for energy consumption, energy cost, and carbon dioxide (CO₂) emissions, which are quoted in kilograms of carbon (kgC) for comparability with other statistics. It outlines technical and management measures to help reduce energy consumption and costs. This edition builds on the content of previous Guides by providing additional detail to assist diagnosis, analysis, technical and managerial improvements.

STRUCTURE OF THE GUIDE

Although primarily written for technical consultants and facilities managers, the Guide should also be of interest to a range of building professionals, architects, owners and investors.

The Guide starts by looking at broader energy issues and moves into progressively increasing detail. Summary checklists for all readers are shown in section 7, and specialist terminology is explained in appendix B.

WHAT ARE BENCHMARKS?

Building energy benchmarks provide representative values for common building types, against which you can compare your building's actual performance. Comparison with simple benchmarks of annual energy use per square metre of floor area will permit the standard of energy efficiency to be assessed and enable remedial action to be taken. More detailed benchmarks can help pinpoint problem areas within a building.

Although rounded for clarity, the benchmark values presented in this Guide are derived from surveys of a large number of occupied buildings and include all energy uses, not just building services.

This Guide gives benchmarks for:

- **'Typical'** energy consumption patterns, which are consistent with median values of data collected in the mid-1990s for the Department of the Environment, Transport and the Regions (DETR) from a broad range of occupied office buildings.
- **'Good practice'** examples in which significantly lower energy consumption has been achieved using widely available and well-proven energy-efficient features and management practices. These examples fall within the lower quartile of the data collected.

New designs should aim to improve upon the *good practice* benchmarks.

Benchmarks are applied to:

- buildings as a whole
- environmental services, such as heating, lighting and air-conditioning, to typical comfort standards
- components of those services, particularly the efficiency of lighting and air handling systems
- office and computer equipment
- typical hours of use.

Special facilities are also covered, particularly catering kitchens and computer rooms. These vary greatly depending on their size, and intensity and efficiency of use. Sub-metering of gas and electricity to these areas is always desirable.

RELEVANCE TO DESIGN

The benchmarks given here will be higher than most design estimates, which often assume essentially perfect performance and operation, and ignore some end uses and practices. The component benchmarks (page 13-15) will help in setting appropriate power ratings, hours of use etc. System and component efficiency information may also be of interest to designers and those who are briefing them, and to prospective tenants when assessing buildings and systems.

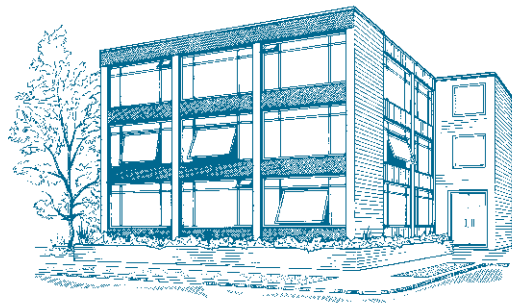
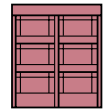
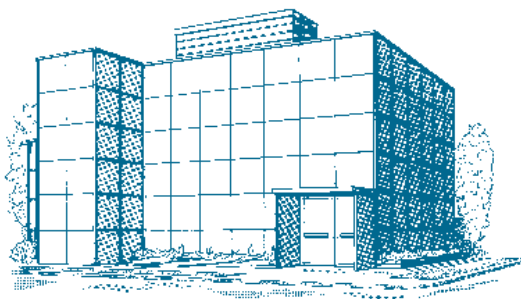
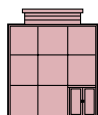
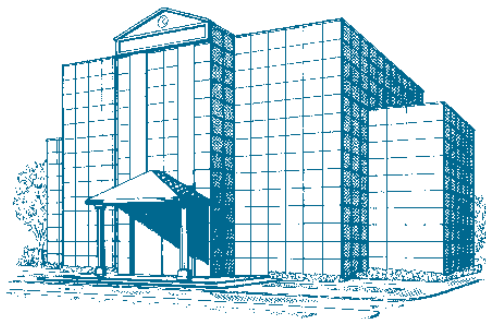
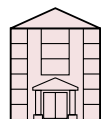
General Information Leaflet (GIL) 11 'Energy efficiency in offices. A review of 12 office case studies' reviews some good practice buildings from the 1980s. New designs will often be able to improve upon these, and should aim to do better than the good practice benchmarks given in this Guide.

INTRODUCTION

Using the benchmarks

Appendix A describes how to calculate the performance of your building. Energy use in offices depends on the type and size of the building. For example, a prestigious headquarters office is likely to consume more energy per square metre than a small, local office. For this reason, the benchmarks presented in this Guide refer to four generic office types (below).

The benchmarks are most appropriate for managed buildings with floor areas of 1500 m² or more. They allow for actual hours of use including cleaning, weekend work and so on, and the wastage and inefficiency that inevitably occurs to some degree, even in the best regulated environments.

1**naturally ventilated cellular****2****naturally ventilated open-plan****3****air-conditioned, standard****4****air-conditioned, prestige**

2 BACKGROUND

Energy use in offices has risen in recent years because of the growth in information technology, air-conditioning (sometimes specified when not required), and intensity of use. However, this trend is offset by considerable improvements in insulation, plant, lighting and controls. The energy use benchmarks presented in this Guide are based on data gathered in the 1990s and reflect both of these trends.

Despite perceptions to the contrary, energy-efficient offices are not expensive, difficult to manage or inflexible. Nor are they low on comfort and productivity. Energy-efficient techniques which work well tend to be reliable, straightforward, and compatible with management and user needs. Capital costs are often similar to those for normal offices, although budgets may be spent differently – for example, on measures to decrease cooling loads instead of on air-conditioning.

Further opportunities for improving energy efficiency should be sought when other changes occur, eg refurbishment, fit-out, alteration, and plant replacement. Here the best results ensue from a good brief, good design with attention to detail, sound construction and commissioning, and good control and management.

Low energy consumption is just one attribute of a carefully designed and well-managed building – comfort and productivity are others. Conversely, energy waste is an indicator of poor business management elsewhere.

Maintenance organisations need to be carefully briefed and supervised if they are to manage energy effectively. If this is not reflected in contract conditions, systems may be run wastefully.

3 CHARACTERISTICS AFFECTING ENERGY COSTS

Office fuel bills can range from about £4 to £30 per year per square metre of treated floor area (TFA), excluding VAT. Items under each of the four headings below can influence the outcome by a factor of two. Unit energy costs also vary. (Appendix B includes definitions of floor area, typical conversion factors, and typical energy costs.)

Key features:

- the standards to which the building and its services are designed
- the proportion of open-planned offices; these tend to use more energy, particularly for lighting
- the presence of air-conditioning.

Building quality:

- design which maximises the use of form and fabric to control the internal environment
- design which minimises the provision, capacity and use of building services
- the efficient design and effective, usable control of these services
- the quality of construction, installation and commissioning.

Occupancy and management:

- occupancy hours and, to a lesser extent, densities
- the amount of office and other equipment installed and its intensity of use
- matching standards and operating hours of services and equipment to usage
- effective maintenance
- unoccupied space.

Energy-intensive areas:

- mainframe computer rooms, communications rooms and extensive dealing rooms, and their air-conditioning.
- catering kitchens and sports and leisure facilities.

Other areas such as storage or car parking may have relatively low energy use.

It is rare to achieve excellence in all the above, so nearly all buildings – new and old – have significant opportunities for reduced energy costs.

CHARACTERISTICS AFFECTING ENERGY COSTS

OFFICE TYPES

The four generic types of office described below contain characteristic packages of the features on page 6 and provide reference points for benchmark comparisons.

1

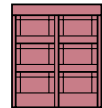
naturally ventilated cellular



- A simple building, often (but not always) relatively small and sometimes in converted residential accommodation.
 - Typical size ranges from 100 m² to 3000 m².
- The domestic approach, with individual windows, lower illuminance levels, local light switches and heating controls helps to match the operation with the needs of occupants and tends to reduce electricity consumption in particular. There also tend to be few common facilities. Catering often consists of the odd sink, refrigerator and kettle.

2

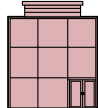
naturally ventilated open-plan



- Largely open-plan but with some cellular offices and special areas.
 - Typical size ranges from 500 m² to 4000 m².
- This type is often purpose built, sometimes in converted industrial space. Illuminance levels, lighting power densities and hours of use are often higher than in cellular offices. There is more office equipment, vending machines etc, and more routine use of this equipment. Lights and shared equipment tend to be switched in larger groups, and to stay on for longer because it is more difficult to match supply to demand.

3

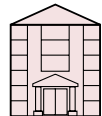
air-conditioned, standard



- Largely purpose-built and often speculatively developed.
 - Typical size ranges from 2000 m² to 8000 m².
- This type is similar in occupancy and planning to building type 2, but usually with a deeper floor plan, and tinted or shaded windows which reduce daylight still further. These buildings can often be more intensively used. The benchmarks are based on variable air volume (VAV) air-conditioning with air-cooled water chillers; other systems often have similar overall consumption but a different composition of end use. (See Good Practice Guide (GPG) 71 'Selecting air conditioning systems. A guide for building clients and their advisors'.)

4

air-conditioned, prestige



- A national or regional head office, or technical or administrative centre.
 - Typical size ranges from 4000 m² to 20 000 m².
- This type is purpose-built or refurbished to high standards. Plant running hours are often longer to suit the diverse occupancy. These buildings include catering kitchens (serving hot lunches for about half the staff); air-conditioned rooms for mainframe computers and communications equipment; and sometimes extensive storage, parking and leisure facilities. These facilities may be found in offices of other types, and, if so, should be allowed for.

MIXED-MODE OFFICES

Mixed-mode systems combine natural and mechanical ventilation and cooling in buildings which might otherwise have been fully air-conditioned.

Examples include naturally ventilated offices with background mechanical ventilation or with mechanical comfort cooling which is used only in hot weather. Some examples are given in General

Information Report (GIR) 15 'Technical review of office case studies and related information', and concepts, opportunities and pitfalls are discussed more fully in GIR 31 'Avoiding or minimising the use of air-conditioning'.

Choice of benchmarks for mixed-mode buildings is outlined in appendix A.

4 ARE YOUR ENERGY COSTS REASONABLE?

Energy costs are often much higher than they need to be, even in many new or refurbished offices. This needlessly increases the building's impact on the environment. The simple benchmarks given in table 1 will show if your annual energy costs are reasonable. The benchmarks in this Guide are shown per square

metre of 'treated floor area' (TFA) for the four types of office. (See appendix B for conversions from net lettable and gross area to treated floor area and table B5 for average energy costs.)

If your costs are higher than *typical*, you should investigate why, or seek assistance. If they are below *typical* – or even *good practice* – there will still often be scope for further cost-effective savings.

Fossil fuel – gas or oil – typically accounts for about £1.80/m² in all four types of office, while good practice examples use half as much or less. The remainder is electricity which, in air-conditioned offices, usually accounts for 80%-90% of total energy costs and CO₂ emissions.

The variation in energy use between office types can often provide an opportunity for significant savings during building procurement and design – see the checklist boxes below.




Office type	Good practice (£/m ² of treated floor area)	Typical (£/m ² of treated floor area)
1 	£3.50	£6
2 	£4.50	£7
3 	£8	£14
4 	£13	£20

Table 1 Annual cost showing benchmarks for different office types

OPPORTUNITIES FOR SAVING WHEN MOVING OFFICE

Make sure that energy and environmental issues are properly covered in the brief for design or property selection.

Include energy efficiency in briefs for alterations and fit-outs.

Ask energy specialists to review design specifications and performance.

Question requirement for air-conditioning when moving premises.

Be prepared to invest in measures that bring good returns. However, many measures will cost little or no more, and some will bring rapid savings.

Make sure that systems are readily controllable and properly commissioned.

OPPORTUNITIES FOR SAVING WHEN COMMISSIONING A NEW OFFICE

Ensure that energy performance is considered in the brief and detailed specification of buildings, services and controls for new construction, refurbishment and maintenance.

Consider whether air-conditioning is really required, and whether it is needed throughout the building.

Include power demand benchmarks for designers. Review them for appropriateness and compliance (see section 6).

Review effectiveness of system design and controls. Check for weak spots under various operating scenarios.

As a general rule, check that controls:

- are appropriate for the task and the management skills available
- allow systems to provide the required conditions and services efficiently and without waste
- respond clearly, quickly and effectively to management and occupant needs
- avoid systems defaulting to ON
- are properly commissioned.

ARE YOUR ENERGY COSTS REASONABLE?

Energy costs in tenanted buildings

Tenants who share buildings often pay for some of their energy via the landlord's service charge, and the rest via their own meters.

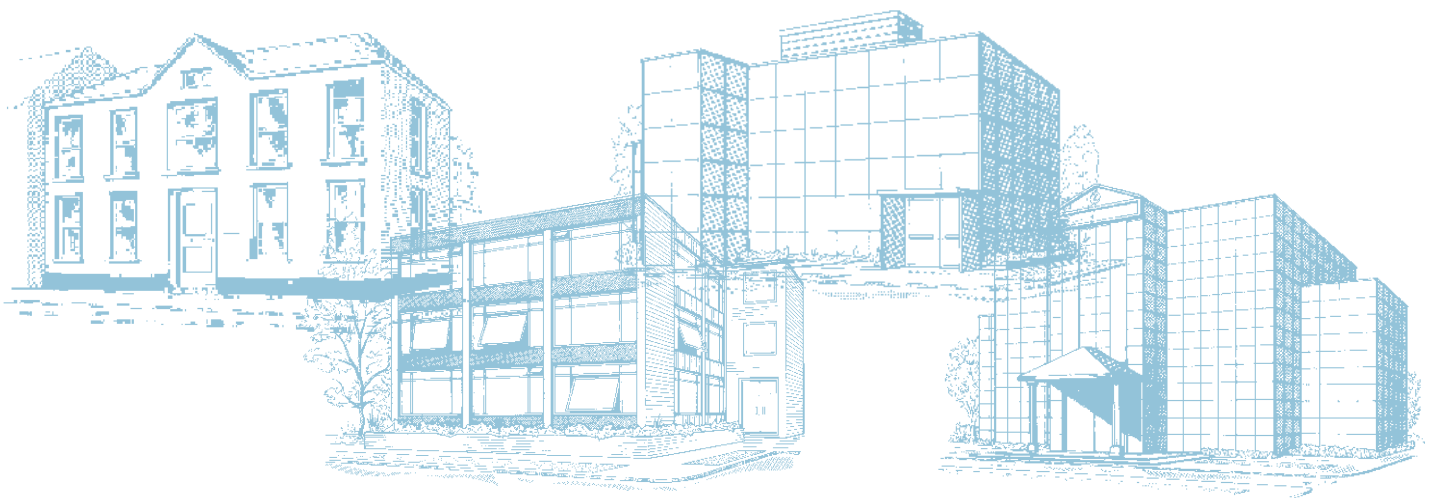
In small offices, energy within the service charge may be for staircase and outside lighting only, and perhaps a lift, security system and cleaner's hot water, costing say £1 per square metre of nett lettable office area per year. In many office buildings, however, landlord's services include central provision of heating, air-conditioning if installed (though systems for computer rooms, etc will usually be separately metered and charged), and often hot water excluding catering kitchens. These typically account for roughly half the building's total energy costs excluding those of special features such as computer rooms (see page 10).

Statistics from major landlords are published annually in the OSCAR report (see further reading on page 23). 1995/96 average energy charges are in the region of £5/m² of net lettable area (15% of the total service charge) in naturally ventilated offices and £11.50/m² (20% of the total) in air-conditioned offices. In *good practice* buildings, energy charges will be some two-thirds of these. (For floor area definitions and conversions to square feet see appendix B.)

The energy component of the annual service charge may already be stated in your bill. If not, your landlord should be able to tell you what it is. If it appears to be high, you should discuss why, and explore the scope for any cost-effective improvements to the systems, their operation, management and metering, or see if there is scope for more competitive purchasing.

In multi-tenanted buildings, energy use and costs can often be higher than where there is a single occupier. Frequently the landlord or the landlord's contractor runs systems liberally – for example with air-conditioning left on until late every evening because somebody holding a late meeting once complained. With better communication or improved control facilities, such waste can often be reduced. Installing sub-meters can lead to fairer allocation of energy charges.

Landlords will also have no incentive to invest to save energy if all the savings accrue to tenants who are obliged to pay the bills anyway. Similarly, tenants may not wish to spend money on things that belong to, or will revert to, the landlord, even if the investment would be amply repaid over their remaining tenancy. Thoughtful discussions can often resolve these difficulties, and lead to sensible actions with sharing of costs, risks and savings.



5 WHERE DOES THE ENERGY GO?

Figures 1 to 3 show annual energy use indices (EUIs), energy cost indices (ECIs) and CO₂ emission indices (CEIs). CEIs are quoted in terms of kilograms of carbon per square metre treated area (kgC/m²) emitted annually as CO₂. The data used to construct these graphs is in appendix B.

In figures 2 and 3 the segments of the graphs for heating and hot water are a smaller percentage of the whole than in figure 1, because a kWh unit of gas is less expensive and incurs fewer CO₂ emissions compared with a unit of electricity which would commonly be consumed for the other energy uses. This puts a strong emphasis on the need for electrically heated buildings to be particularly efficient. Such buildings should be compared with the CO₂ benchmarks rather than delivered energy.

It might be thought that the relative costs of gas and electricity are similar to the relative CO₂ emissions, and superficially figures 2 and 3 appear alike. However, larger buildings – particularly those with large computer rooms operating continuously – usually pay less per unit of electricity than smaller offices with low voltage supplies and less uniform load profiles. Consequently, the difference between large and small buildings is smaller in cost terms than it is in CO₂.

KEY

- Heating and hot water
- Cooling
- Fans, pumps, controls
- Humidification
- Lighting
- Office equipment
- Catering, gas
- ▨ Catering, electricity
- Other electricity
- Computer room (where appropriate)

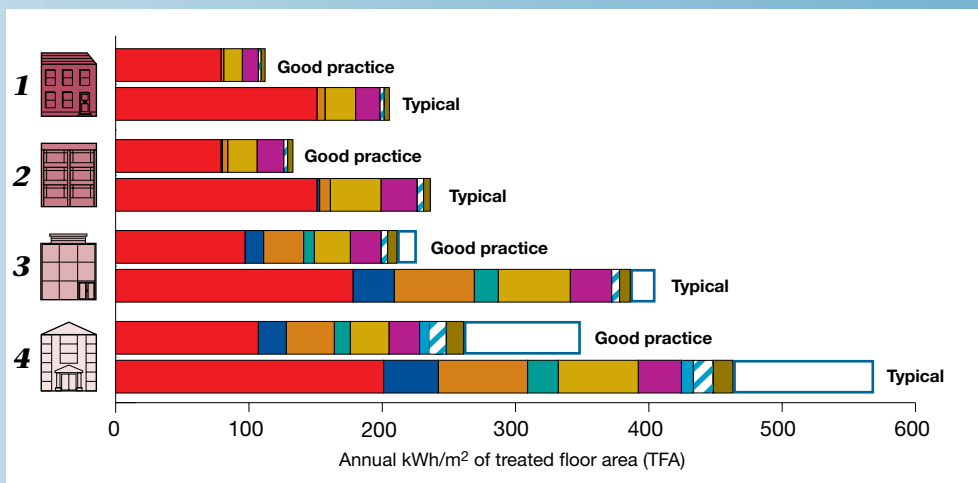


Figure 1 Energy use indices (EUIs) for good practice and typical examples of the four office types

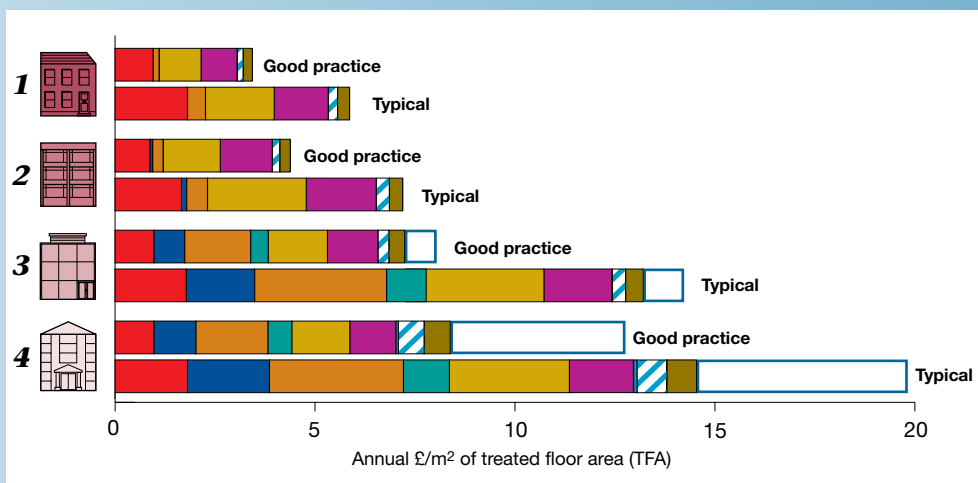


Figure 2 Energy cost indices (ECIs) for good practice and typical examples of the four office types

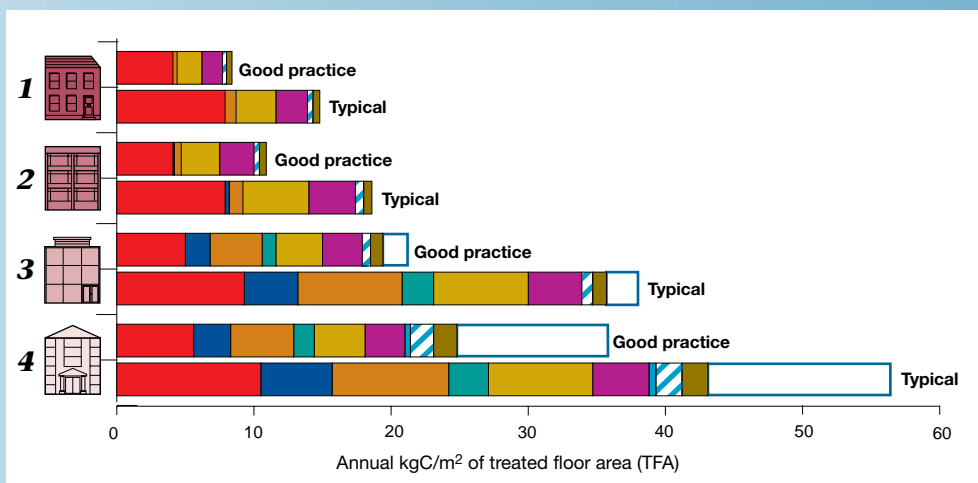


Figure 3 Carbon dioxide emission indices (CEIs) for good practice and typical examples of the four office types

WHERE DOES THE ENERGY GO?

Variation in energy use between building types and end-uses reflects:

- differing occupancy, servicing and equipment in each of the four types
- wide ranges in efficiency and utilisation for different systems.

There are nine principal end uses for energy in office buildings relating to building services or occupiers' equipment.

End uses (building services):

- **heating and hot water** – by gas or oil
- **cooling** – including chillers, packaged air-conditioning equipment, condensers and cooling towers
- **fans, pumps and controls**
- **humidification** – though rare, is spreading

in mechanically ventilated and air-conditioned buildings

- **lighting** of the treated area.

End uses (occupiers' equipment):

- **office equipment** – excluding vending machines, local kitchens or equipment in dedicated rooms (eg computer suites and print rooms)
- **catering** – including vending machines, kettles, dishwashers etc, and sometimes catering kitchens, shown in type 4 only
- **other electricity** – including lifts, print rooms, and energy use outside the measured treated area, for instance by plant room or exterior lighting
- **computer and communications rooms** – including air-conditioning of their dedicated suites. Energy use depends on the amount of equipment installed and can be substantial.

Subdivision of benchmarks

Factors that affect the components of the benchmarks can be grouped in terms of the energy source used for each end purpose. The text in the shaded areas that follow describes each

factor. Particular attention should be paid to reducing electricity consumption relative to the benchmarks, as it costs more and results in more CO₂ production than fossil fuel use.

FOSSIL FUEL CONSUMPTION

EUIs increase gradually with office type but ECIs are similar because the larger buildings tend to pay less per unit.

Heating

No offices of any age should really exceed *typical* levels. If they do, plant may be old, and control and management in need of attention. Heat energy use in air-conditioned buildings is particularly dependent upon maintenance, control and operation and it can often be reduced substantially.

For new offices, *good practice* EUIs should be seen as the upper limit. If your figure is higher, the building may not be airtight (even if 'sealed', prefabricated structures and curtain walling systems can be very leaky) or systems may be poorly controlled and managed.

In air-conditioned offices with 100% fresh air systems, excessive fresh air volumes should be avoided, and heat recovery and perimeter heating considered rather than using ventilation systems for preheating, etc.

Catering, gas

Catering kitchens are often wasteful. To control costs and encourage more efficient practices, their gas, electricity and water should be sub-metered and catering contractors re-charged.

Hot water

This is seldom easily measured. EUIs and CEIs related to treated floor area are shown in table 2, to allow hot water to be separated from heating. These figures are based on systems which are both matched to hot water need and sensibly controlled.

Although EUIs for electric water heating are lower, CO₂ emissions are usually higher. However, some systems using central heating boilers can be very wasteful in summer when main distribution pipework remains in operation to serve small loads. This can often be detected from monthly meter readings. Independent gas or electric water heating may then be preferable. Where electric water heating is to be substituted for fossil fuel fired water heating, the comparison should be made in terms of CO₂ emissions, taking account of the existing central heating boiler, distribution and circulation losses which may give greater energy consumptions than the typical figures in table 2.

Function	Energy source	kWh/m ² TFA		kgC/m ² TFA	
		Good practice	Typical	Good practice	Typical
Hand washing	Local electric	4	7	0.6	1.0
Hand washing	Central gas boiler	7	10	0.4	0.6
Hand washing and catering kitchen	Central gas boiler	12	20	0.7	1.1

Table 2 EUIs and CEIs for hot water

WHERE DOES THE ENERGY GO?

BUILDING SERVICES ELECTRICITY CONSUMPTION

Cooling

Electricity for mechanical cooling is significant, but seldom as much as that for the pumps and fans which distribute the cooling. Cooling plant and the associated pumps need to be carefully managed to run only when there is genuine demand, and small 24-hour loads should be independently cooled.

Fans, pumps and controls

These often constitute the highest energy cost category in air-conditioned offices. In all-air systems, fans account for at least two-thirds of the total. Attention to air volumes, operating pressures and hours of use can bring large savings.

In all buildings, pumps sometimes run for long hours or even continuously, simply to service

small loads on the system. These loads might be better serviced independently – see section 6.

Humidification

This is increasingly found in air-conditioned offices, particularly type 4. Systems are often wasteful, with unnecessarily high set points and needless operation in mild weather.

Lighting

This is another high end-use of electricity. Consumption depends on office type, utilisation of daylight, illuminance levels and hours of use. In open plan offices, where no individual has responsibility, efficient control of lighting is more difficult, and so lights usually stay on much longer than strictly necessary. Efficient installations and good, user-friendly controls should be the norm – see section 6.

OTHER ELECTRICITY CONSUMPTION

Office equipment

Most office workers have a personal computer with dedicated or shared peripherals, and networking. Leaving equipment on unnecessarily – particularly overnight – should be discouraged (see section 6).

Catering, electricity

It is worth reviewing power requirements of vending machines and considering whether they can be switched off when the office is empty. All-electric catering kitchens should be compared with the CO₂ benchmarks for catering electricity and gas combined, rather than the total delivered energy.

Other

Electricity use by lifts and ancillaries, such as car park lighting and security systems, tends to rise with the complexity and sophistication of the building as a whole.

Air-conditioned computer suites and communications rooms

The amount of equipment in the computer suite, and thus the energy consumption, can vary widely. A dedicated computer suite (or room) should be accounted for separately to avoid distorting the comparison with the benchmark. In all cases, these areas and their air-conditioning should be individually metered and checked to ensure that the air-conditioning is performing efficiently. Computer air-conditioning systems are sometimes very wasteful. Typically, they use as much electricity as the computer equipment. In *good practice* installations, consumption for air-conditioning can be reduced to about two-thirds of that used by the computers, and less if close humidity control is not required.

6 A CLOSER LOOK: SYSTEM AND COMPONENT BENCHMARKS

Comparing EUIs and other key indicators with benchmarks of various kinds can help you to assess the performance of individual systems. For example, data on installed power densities (IPDs) and hours of operation can provide useful insights into both efficiency and management, and point the way to improvement.

This section describes how energy consumption and performance indicators can be estimated for some key end uses, and gives benchmarks for the indicators.

When comparing values, it is important to check the areas concerned. For example, are office equipment load densities stated for the part of the office densely occupied by workstations, or for the treated floor area (TFA) of the whole building, including meeting rooms, corridors and so on?

LIGHTING

The annual EUI is the product of:

- a** the installed power density in W/m^2
- b** the hours of use of the lighting
- c** the percentage utilisation.

Benchmarks are given in table 3.

IPD is estimated by:

- adding up the wattage of all the lamps in an area
- adding control gear losses for discharge and fluorescent lighting (these typically add 20% to lamp rating, or 5% for high-frequency ballasts, but check manufacturer's data)
- dividing the total by the floor area.

For offices with a repeating luminaire ceiling pattern, only a representative ceiling module needs to be assessed.

The 'hours of use' is the annual period over which illumination (daylight or electric light) is needed in the offices, both for normal occupancy and for cleaning. Sometimes these are unnecessarily extended because lights are left on by, or for, the cleaners, who arrive much earlier or leave much later. Careful discipline and rearrangement of cleaning schedules can sometimes help. A lower illuminance level for cleaning will also reduce power consumption.

LIGHTING IT RIGHT

In open-plan offices, the most efficient lighting installations tend to have:

- well-designed lighting to suit the tasks and to make the space attractive
- high-efficiency lamps (often high-frequency fluorescent) in efficient luminaires that emit a high proportion of the light and control its distribution well
- good local, preferably individual, control – for example, using pull switches, hand-held infrared devices, or via the telephone – these can pay for themselves by simplifying wiring and minimising alterations when layouts and partitions are changed
- lights which can be switched on and off locally by occupants (see Information Paper IP6/96) and switched off automatically by occupancy sensors, or by a system which is properly programmed by a manager to take full account of occupiers' needs and opinions
- efficient circulation area lighting which is controlled separately, to prevent switching on more lights than necessary
- occupancy sensors in areas which are intermittently used, such as washrooms
- daylight sensors to switch off lights when they are not required.

LIGHTING BENCHMARKS





	1 		2 		3 		4 	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
a W/m^2	12	15	12	18	12	20	12	20
b hrs/yr	2500	2500	3000	3000	3200	3200	3500	3500
c percentage utilisation	45%	60%	60%	70%	70%	85%	70%	85%
EUI $kWh/m^2/yr$	14	23	22	38	27	54	29	60

Table 3 Lighting benchmarks

The 'percentage utilisation' is the time the electric lighting is on during those hours. It depends how much the lighting is off or dimmed, either by successful use of daylight, occupants selecting lower illuminance levels, or lights being off in unoccupied areas. The percentage tends to decrease with better manual and automatic controls.

As a general rule, automatic control works best to switch lights off or reduce their brightness when daylight is sufficient or people are absent. Provide occupants with the maximum amount of manual control appropriate, only automatically switching on where this is necessary for safety.

A CLOSER LOOK: SYSTEM AND COMPONENT BENCHMARKS

IPD can also be defined as the product of the desktop illuminance level (in lux) and the illumination efficiency in W/m² per 100 lux.

The good practice benchmark of 12 W/m² is based on a level of 350-400 lux (often a good compromise between screen and paper-based tasks) at an efficiency of 3 W/m² per 100 lux. This efficiency level is obtainable with good luminaires and high-frequency fluorescent lighting, with a small allowance for decorative lighting. For 500 lux or an uplighting installation to 300-350 lux, an IPD of 15 W/m² may be required. If your installation has an IPD well above 20 W/m², replacement will often be cost-effective, particularly with long hours of use.

FANS, PUMPS AND CONTROLS

Air handling is one of the largest energy users in an air-conditioned office. Its EUI is the product of:



- a** the amount of air handled – in litres/second per m² of TFA. This typically varies between about 1 and 8
- b** the average efficiency with which it is handled – called specific fan power (SFP) – in watts per litre/second (W per l/s)
- c** the annual hours run (hrs/yr).

For air-conditioning, SFP typically varies between 2 and 5 W per l/s. For energy-efficient systems a guideline of 1 W per l/s has been suggested, but this is difficult to attain except in simple systems or low speed operation.

While fans usually have to operate for normal occupancy periods, building operators should ensure that they do not run too liberally. Common reasons for extended operation are that parts of the building continue in use into the evening, or that the building takes a long time to heat up or cool down prior to occupation at the start of the day. This extended running can be alleviated by careful zoning so that the only fans to function are those which serve the parts of the building in use, and by selecting heating or cooling systems which can pre-condition all or part of the building without operating all the fans.

Air handling benchmarks are given in table 4 together with the benchmark including fans, pumps and controls (FPC). Chilled water pumps are usually the largest contributors to the difference between fan and FPC benchmarks.

Pump running hours can also show great variation. With good management, heating and cooling pumps operate for much less than normal occupancy hours – with heating ‘off’ in summer and cooling ‘off’ in winter and many mornings at other times. On the other hand, it is not uncommon to find chilled water pumps running continuously because some small 24-hour loads are connected to a central system. This can be very wasteful unless it is a variable capacity system, carefully designed for effective control and high efficiency at low load. In most cases, however, such loads are best given independent cooling systems.

	3 		4 	
	<i>Good practice</i>	<i>Typical</i>	<i>Good practice</i>	<i>Typical</i>
a l/s per m ²	4	4	4	4
b SFP W per l/s	2	3	2	3
c hrs/yr	2750	3500	3000	3700
Fan EUI kWh/m ² /yr	22	42	24	44
FPC EUI kWh/m ² /yr	30	60	36	67

The bottom line is the benchmark including pumps and controls; see appendix B.

Table 4 Air handling benchmarks

A CLOSER LOOK: SYSTEM AND COMPONENT BENCHMARKS

OFFICE EQUIPMENT

Typically, desktop and associated IT equipment such as computer, printers, modems and faxes average about 160 W per work location. A typical load density in an open plan office where nearly everyone has a computer is 15 W/m², though there can be pockets with more, with high occupation densities, multiple screens, or both. Do not over-estimate cooling loads and the need for air-conditioning: nameplate ratings can be misleading (see Energy Consumption Guide (ECON) 35 ‘Energy efficiency in offices – small power loads’).

The benchmarks in table 5 are the product of:

- a** the load density in W/m²
- b** the average hours per year (this includes for about 10% of the equipment being on permanently)
- c** the percentage of the floor area with IT equipment ie not including circulation space, meeting rooms, toilets, stores etc.

The benchmarks allow for more energy-efficient equipment selection and management in the *good practice* buildings (see GPG 118 ‘Managing energy use. Minimising running cost of office equipment and related air-conditioning’ and ECON 35). Avoiding unnecessary energy consumption is doubly important because it also reduces the heat

output of the equipment, and hence reduces overheating in naturally ventilated buildings and cooling loads in air-conditioned buildings.

Occupancy and equipment levels vary widely. Many small offices use less IT equipment less intensively, and their energy consumption will be lower. Some air-conditioned offices have high concentrations, though this is sometimes compensated for by liberal space standards in the building as a whole, particularly type 4.

NOTE: the benchmarks do not include dealing rooms, which are highly variable and should be assessed separately. Computer and communications rooms are also very variable and in a separate category. See section 5.





EQUIPMENT BENCHMARKS								
	1 		2 		3 		4 	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
a W/m ²	10	12	12	14	14	16	15	18
b hrs/yr	2000	2500	2500	3000	2750	3250	3000	3500
c percentage of treated floor area	60%	60%	65%	65%	60%	60%	50%	50%
EUI kWh/m ² /yr	12	18	20	27	23	31	23	32

Table 5 Equipment benchmarks

CHECKLIST FOR OFFICE EQUIPMENT

- Establish a purchasing policy to take account of energy requirements. Some brands and types of equipment use considerably less energy than others. Nameplate ratings can be unreliable and independent checks may be needed (see GPG 118).
- Standby modes are useful but not always energy efficient. Check what they do and that they are properly implemented. Encourage staff to turn idle systems off.
- Don't add to heat loads in the general office. Place equipment that doesn't need to be there in separate rooms, with local ventilation and cooling to suit.

7 SUMMARY CHECKLISTS

FOR SENIOR MANAGERS

People respond to leadership. State and demonstrate a commitment to the environment and to energy efficiency.

Make someone responsible for developing an energy policy (see GPG 186 'Developing an effective energy policy'). This will often be the facilities or technical services manager.

Ask them to review energy costs in relation to simple benchmarks, and to make recommendations. Include landlord's charges where appropriate.

Seek constant improvement. Review performance and agree standards, targets and actions at six-monthly intervals.

Give energy measures the same priority as other comparable investment and management decisions.

Good investment can save you money to devote to your main business.

Remember the hidden benefits. Well-designed energy-efficient solutions not only reduce costs and environmental impact, but can also improve occupant comfort, productivity, and the image of your organisation.

FOR FACILITIES MANAGERS

Obtain the support of senior management (see senior managers' checklist above).

State and demonstrate commitment to energy and environmental management (see GPG 200 'A strategic approach to energy and environmental management').

Consider appropriate benchmarks and review energy costs and service charges. See sections 3 and 4, and appendix A. Set up a monitoring and targeting system for continuous checks.

Understand your pattern of monthly energy use and how end-uses in your building relate to them. See other parts of this document and Fuel Efficiency Booklet (FEB) 7 'Degree days'.

Review opportunities for improvement and identify areas for action. This includes control and management, fuel purchasing, and technical measures.

Review occupancy, operating and cleaning hours. Seek opportunities for better control and management.

Assess end-use demands and identify improvement options. See sections 5 and 6.

Review time programmes and control settings to avoid waste. Common problems are excessive running hours of heating, ventilation and air-conditioning (HVAC) systems, particularly chilled water and humidification.

Make sure that small demands do not bring on large systems. For example security offices, control rooms and equipment rooms may need local heating or air-conditioning.

Consider technical surveys to identify waste and opportunities for savings. If necessary ask technical specialists for further review, explanation and recommendations.

Be sure that contracts for plant operation and maintenance include clauses on maintaining and improving energy efficiency. If not, don't be surprised if services are run liberally and wastefully, because this is the easiest way of minimising occupant complaints.

Set up appropriate sub-metering. This is particularly important for areas with large and uncertain electrical loads, and to aid space charging.

Include catering energy costs in any catering contracts.

Involve staff and report clearly to senior management. To maintain their confidence, they will need to understand and comment on what you are doing.

FOR TECHNICAL SPECIALISTS

Set up systems for energy management and tracking ongoing performance (see GPG 200).

Advise general and facilities management on the appropriate use of benchmarks (see sections 1, 4 and 5).

Explain performance of systems and identify opportunities for savings (see sections 5 and 6).

Assess energy end-uses in terms of level of service, efficiency of provision, loading, hours of need and efficiency of control and management; and provide custom benchmarks (see section 6 and Appendix A p19).

APPENDICES

APPENDIX A – CALCULATING AND USING INDICES

Appendix A illustrates the procedure required to calculate the Energy Cost Index (ECI). Energy use and CO₂ indices can be calculated and compared with benchmarks in a similar manner.

1 Determine building type

Choose the most appropriate category for your office from the four generic types described on page 7. (See page 19 if a single type is not applicable.)

2 Calculating the energy cost index

- A** From the bills you have paid find out the total annual costs and units consumed for each fossil fuel and for electricity. You may need to make adjustments for estimated bills, missing data or periods of more or less than a full year (see EEB 6 'Introduction to energy efficiency in offices').
- B** Find out your floor area. Treated floor area will have to be measured, or estimated (see appendix B).
- C** Divide each cost in A by B to obtain your ECIs in annual fuel costs per unit area per fuel.

3 Checking unit energy costs

- Obtain your annual cost and energy consumption of each fuel from A.
- If necessary, convert the annual units of each fuel consumed into kWh. Conversion factors can be found in appendix B.
- For each fuel, divide annual cost by annual consumption to get the average unit cost per kWh.

4 Unit cost assessment

If the costs are very different from the average energy costs quoted in table B5 of appendix B, then there is probably a mistake. If after checking they are still high, then you may be able to purchase fuel

more competitively unless your location or pattern of use is forcing up the unit rate (this should also be checked).

5 Choosing a benchmark

Choose *good practice* and *typical* ECI benchmarks for your office type from table 1 (page 8), or from table B2 (appendix B) if you require more detail or different units.

6 Making the comparison

Comparison can be illustrated by histograms, which place the ECI for your building between the chosen benchmarks, as illustrated in figure A1. If your unit costs for any fuel are particularly high or low, you may need to correct the benchmarks to the rates you actually pay.

An ECI above *typical* merits further investigation: for example, you may have justifiably extended occupancy hours, although often this also leads to wasteful operation. Between *typical* and *good practice* it is likely that worthwhile savings can still be made. ECIs below *good practice* are rare, but are potentially attainable in well-designed and well-managed buildings. Even with ECIs below *good practice*, scope for cost-effective savings can nearly always be found.

If your building has an ECI below *good practice*, BRECSU would be interested in collecting data on it. Please contact BRECSU at the address given on the back cover of this publication.

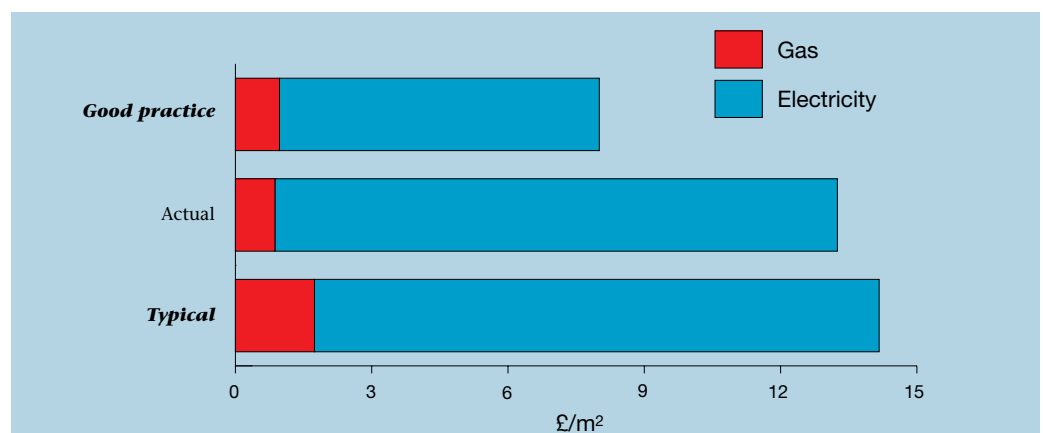


Figure A1 Annual energy costs in £/m² of treated floor area compared with good practice and typical benchmarks for a type 3 building

APPENDIX A – CALCULATING AND USING INDICES

A WORKED EXAMPLE

Building data:

- air-conditioned open plan
- gross internal floor area = 3390 m².

Annual energy consumption from bills:

- gas ■ 271 110 kWh ■ cost = £2657
- electricity ■ 686 250 kWh ■ cost = £37 774.

1 Determine building type:

- type classification (page 7)
- type 3 is appropriate



2 Calculating the energy cost index:

- A Collate data from bills (see above)

B Treated area estimate:

- from appendix B (table B4), treated area is typically 90% of gross
- $3390 \times 0.9 = 3051 \text{ m}^2$

C ECI calculation:

- gas $\text{£}2657/3051 = \text{£}0.87/\text{m}^2/\text{yr}$
- electricity $\text{£}37\,774/3051 = \text{£}12.38/\text{m}^2/\text{yr}$
- total $\text{£}13.25/\text{m}^2/\text{yr}$.

3 Checking unit energy costs:

- unit gas cost
 $\text{£}2657/271\,100 = 0.98 \text{ p/kWh}$
- unit electricity cost
 $\text{£}37\,774/686\,250 = 5.5 \text{ p/kWh}$.

4 Unit cost assessment:

- refer to appendix B (table B5)
- the calculated p/kWh figures above are close to typical for a type 3 office.

5 Choosing a benchmark:

- refer to table B2 (appendix B)
- tabulate cost benchmarks
- tabulate actual ECIs (2c above)

	Annual energy costs £/m ²		
	Gas	Electricity	Total
<i>Good practice</i>	0.97	7.04	8.01
Actual	0.87	12.38	13.25
<i>Typical</i>	1.78	12.43	14.21

6 Making the comparison:

Actual cost is close to *typical* for electricity and even lower than *good practice* for gas. There is likely to be good scope for savings in electricity consumption. Action needs to be taken to investigate this.

Display your benchmark data in tabular or histogram format (see figure A1)

Choosing benchmarks for other types of office

If a single type does not describe your office very well, compare each of your indices with an area-weighted benchmark compiled from the pair that are most similar. For example:

- for a naturally ventilated office with similar amounts of cellular and open-plan areas, your benchmark should be between types 1 and 2
- for an open-plan office with natural ventilation plus some mechanical ventilation and cooling, pro-rata your benchmark between types 2 and 3. Offices of this type will include mixed-mode designs, and ones with

comfort cooling provided by local packaged air-conditioning units

- for a head office without full air-conditioning, choose the components of the types 2 and 4 benchmarks which are most relevant.

Other systems

Offices with systems other than those covered by this Guide, including desiccant dehumidification, evaporative cooling, absorption refrigeration and combined heat and power, should be appraised in terms of their total CO₂ emissions.

APPENDIX B – REFERENCE DATA

Table B1, B2 and B3 present in tabular form the data shown in figures 1, 2 and 3 (page 10)





	1 		2 		3 		4 	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Heating and hot water – gas or oil	79	151	79	151	97	178	107	201
Cooling	0	0	1	2	14	31	21	41
Fans, pumps, controls	2	6	4	8	30	60	36	67
Humidification (where fitted)	0	0	0	0	8	18	12	23
Lighting	14	23	22	38	27	54	29	60
Office equipment	12	18	20	27	23	31	23	32
Catering, gas	0	0	0	0	0	0	7	9
Catering, electricity	2	3	3	5	5	6	13	15
Other electricity	3	4	4	5	7	8	13	15
Computer room (where appropriate)	0	0	0	0	14	18	87	105
Total gas or oil	79	151	79	151	97	178	114	210
Total electricity	33	54	54	85	128	226	234	358

Table B1 Annual delivered energy consumption (EUI) of good practice and typical offices for the four office types (kWh/m² treated floor area)





	1 		2 		3 		4 	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Heating and hot water – gas or oil	0.95	1.81	0.87	1.66	0.97	1.78	0.97	1.81
Cooling	0.00	0.00	0.07	0.13	0.77	1.71	1.05	2.05
Fans, pumps, controls	0.15	0.45	0.26	0.52	1.65	3.30	1.80	3.35
Humidification (where fitted)	0.00	0.00	0.00	0.00	0.44	0.99	0.60	1.15
Lighting	1.05	1.72	1.43	2.47	1.48	2.97	1.45	3.00
Office equipment	0.90	1.35	1.30	1.75	1.26	1.70	1.15	1.60
Catering, gas	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.08
Catering, electricity	0.15	0.23	0.19	0.33	0.28	0.33	0.65	0.75
Other electricity	0.23	0.30	0.26	0.33	0.39	0.44	0.65	0.75
Computer room (where appropriate)	0.00	0.00	0.00	0.00	0.77	0.99	4.35	5.25
Total gas or oil	0.95	1.81	0.87	1.66	0.97	1.78	1.03	1.89
Total electricity	2.48	4.05	3.51	5.53	7.04	12.43	11.70	17.90
Total energy cost	3.43	5.86	4.38	7.19	8.01	14.21	12.73	19.79
Unit costs:								
Gas (p/kWh)	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9
Electricity (p/kWh)	7.5	7.5	6.5	6.5	5.5	5.5	5.0	5.0

Table B2 Annual energy costs (ECI) (£/m² of treated floor area)

APPENDIX B – REFERENCE DATA





	1 		2 		3 		4 	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Heating and hot water – gas or oil	4.1	7.9	4.1	7.9	5.0	9.3	5.6	10.5
Cooling	0.0	0.0	0.1	0.3	1.8	3.9	2.7	5.2
Fans, pumps, controls	0.3	0.8	0.5	1.0	3.8	7.6	4.6	8.5
Humidification (where fitted)	0.0	0.0	0.0	0.0	1.0	2.3	1.5	2.9
Lighting	1.8	2.9	2.8	4.8	3.4	6.9	3.7	7.6
Office equipment	1.5	2.3	2.5	3.4	2.9	3.9	2.9	4.1
Catering, gas	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5
Catering, electricity	0.3	0.4	0.4	0.6	0.6	0.8	1.7	1.9
Other electricity	0.4	0.5	0.5	0.6	0.9	1.0	1.7	1.9
Computer room (where appropriate)	0.0	0.0	0.0	0.0	1.8	2.3	11.0	13.3
Total gas or oil	4.1	7.9	4.1	7.9	5.0	9.3	5.9	10.9
Total electricity	4.2	6.9	6.9	10.8	16.3	28.7	29.7	45.5
Total CO ₂ emissions (expressed as kgC/m ² of TFA)	8.3	14.8	11.0	18.7	21.3	38.0	35.6	56.4

Table B3 Annual emissions of CO₂ (CEI) (kgCarbon/m² of treated floor area) using CO₂ emission factors of 0.052 kgC/kWh for gas and 0.127 kgC/kWh for electricity

Delivered energy units

All energy units in this Guide are in kilowatt-hours (kWh), in which electricity and natural gas are usually billed.

1 kWh = 1000 Wh = 3.6 megajoules (MJ)
 1000 kWh = 3.6 gigajoules (GJ).

Conversion factors for oil are as follows:

- gas-oil 10.6 kWh/litre
- light fuel oil 11.2 kWh/litre
- heavy fuel oil 11.4 kWh/litre.

Older gas bills may be in therms.
 100 000 Btu = 1 therm = 29.31 kWh.

Floor area definitions

- **Gross internal area (GIA):** total building area measured inside external walls.
- **Treated floor area (TFA):** gross areas less plant rooms and other areas (eg stores, covered car parking, and roof spaces) not directly heated.
- **Nett lettable area (NLA):** GIA less common areas and ancillary spaces. Agent's lettable area.

NLA is often quoted in square feet.
 1 square metre is 10.76 square feet.

Estimating treated area

Treated floor area (TFA) is used as the denominator for energy indices in this Guide, because it is the area best related to energy consumption. It will often need to be estimated from NLA (available from agents' details) or GIA (from design data).

Area conversion factors vary from building to building depending on geometry, spatial efficiency, and areas devoted to plant rooms, unheated storage, etc. Rules of thumb based on case study data are shown in table B4.

Newer buildings often aim for higher ratios, for example by using efficient circulation, external escape stairs, and some roof-mounted plant.

These estimated values will be good enough for many purposes. If precise comparisons are required, measurement from scale plans may be necessary.





Type	Treated % of gross	Nett % of treated	Nett % of gross
1 	95	80	76
2 	95	80	76
3 	90	80	72
4 	85	80	68

Table B4 Area conversion factors

APPENDIX B – REFERENCE DATA

Heating energy correction

Benchmarks for heating energy are corrected to a country-wide average of 2462 degree days per year. (See Introduction to Energy Efficiency in Offices (EEB 6) appendix 1 for adjustment for other degree days, and FEB 7 for degree day figures for different regions.)

Energy indices

■ **Energy use index (EUI).** The annual delivered energy used by a building (or part of it) divided by a measure of its extent (usually the treated floor area). EUIs are normally split by fuel and frequently by end use. Ensure that the units of measurement for fuels, areas, and end uses are consistent with each other. EUIs in this Guide are expressed in kilowatt-hours per square metre kWh/m² of TFA, and all end uses are shown.

■ **Energy cost index (ECI).** As EUI but expressed in pounds and pence sterling per square metre of TFA.

■ **Carbon dioxide emission index (CEI).** As EUI, but expressed in kg of carbon/m² (kgC/m²). Conversion from delivered energy units to CO₂ emissions is discussed below.

Specific fan power (SFP)

The total power input to the fans in a system (supply and exhaust if present) divided by the airflow rate. The values are the same, whether

expressed as Watts per litre per second or kilowatts per cubic metre per second, and both reduce to Joules per litre (J/l).

Average energy unit costs

Fuel costs can vary widely with size and pattern of demand and with commercial factors. Table B5 shows the typical range of average unit costs at 1997 levels (total annual cost of the fuel concerned including standing charges but not VAT, divided by total annual consumption in kWh).

Organisations with large buildings or multi-site supply contracts may enjoy lower rates than these. Oil prices have tended to be similar to gas but fluctuate more. Unit electricity costs in the middle of the ranges below are used elsewhere in this Guide.





	ELECTRICITY	GAS
1 	7-8p	1.2p
2 	6-7p	1.1p
3 	5-6p	1.0p
4 	4-6p	0.9p

Table B5 Average total cost per unit excluding VAT

Carbon dioxide emissions

Each kWh of energy delivered to a building incurs atmospheric emissions of the major greenhouse gas CO₂ from the extraction, processing and delivery of each fuel and its consumption on site.

For the purpose of comparability with other statistics CO₂ emissions in this Guide are quoted as kg of carbon per kWh of delivered fuel (kgC/kWh). Conversion from CO₂ to carbon is the ratio of their respective atomic weights (44:12).

Quoted conversion factors vary according to the assumptions made. The table opposite shows the conversions used here, in carbon and carbon dioxide per kWh of delivered fuel.

Fuel	kgC/kWh	kgCO ₂ /kWh
gas	0.052	0.19
oil	0.069	0.25
coal	0.081	0.30
electricity average	0.127	0.46

'Derived from data for service sector buildings, Digest of UK Energy Statistics 1999'

The conversion factor for electricity varies with the primary fuel mix used to generate it. In the UK, it is currently falling owing to rising efficiency of generation and a move from coal to gas and some renewables.

FURTHER INFORMATION

General information

Office Service Charge Analysis Research (OSCAR), published annually by Jones Lang Wootton
22 Hanover Square, London W1A 2BN
Tel 020 7493 6040. Fax 020 7457 3956

The British Institute of Facilities Management

67 High Street, Saffron Walden, Essex CB10 1AA
Tel 01799 508608. Fax 01799 513237

British Council for Offices (BCO)

Shinfield Grange, Cutbush Lane, Shinfield
Reading RG2 9AF
Tel 0118 988 5505. Fax 0118 988 5495

BREEAM



The Building Research Establishment Environmental Assessment Method (BREEAM) is an independent, and authoritative scheme that provides an assessment of the overall environmental performance of both new and existing office buildings. New industrial, food retail and domestic buildings are also covered. It presents a means of measuring and making visible a building's environmental quality and provides a tool for optimising the performance of buildings throughout their life. Drawing on the latest scientific knowledge of the impacts of buildings on the environment, it provides a simple means of specifying and adopting current best environmental practice. For further information telephone 01923 664462.

FURTHER READING

BRE Information Paper 3/95 'Comfort, control and energy efficiency in offices'

BRE Information Paper 6/96 'People and lighting controls'

BRE/PA Office Toolkit

'Best Practice in the Specification of Offices'. BCO, May 1997

Energy Consumption Guide

35 Energy efficiency in offices – small power loads

Fuel Efficiency Booklet

7 Degree days

Good Practice Guides

- 16 Guide for installers of condensing boilers in commercial buildings
- 71 Selecting air conditioning systems. A guide for building clients and their advisors
- 118 Managing energy use. Minimising running costs of office equipment and related air-conditioning
- 160 Electric lighting controls – a guide for designers, installers and users
- 186 Developing an effective energy policy
- 200 A strategic approach to energy and environmental management

General Information Leaflets

- 10 All-electric office of simple design with low electricity consumption. Magnus House, Bridgwater
- 11 Energy efficiency in offices. Review of 12 office case studies
- 12 Energy efficiency in offices. Posford House, Peterborough
- 24 All-electric, air-conditioned office uses heat pump technology. Dirac House, St Johns Innovation Centre

General Information Report

- 15 Technical review of office case studies and related information
- 31 Avoiding or minimising the use of air-conditioning. A report from the EnREI programme

Introduction to Energy Efficiency

6 Offices

ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. There may be other relevant documents in preparation. Contact details are given on the back page.

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

Visit the website at www.energy-efficiency.gov.uk

For further information on:

Buildings-related projects contact:
Enquiries Bureau

BRECSU

BRE
Garston, Watford WD25 9XX
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

Industrial projects contact:
Energy Efficiency Enquiries Bureau

ETSU

Harwell, Oxfordshire
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy-efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting, etc.